FINANCIAL MODELING

An Introductory Guide to Excel and VBA Applications in Finance

JOACHIM HÄCKER
DIETMAR ERNST

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Joachim Häcker • Dietmar Ernst

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Preface

This book is structured around the instruments of modern Financial Management. Strategic decisions of corporations are increasingly supported by financial models. These are created by an expert, the financial modeler. In the context of financial modeling he creates applications based on financial knowledge in the context of modern standardized software – Excel in particular.

This textbook provides comprehensive training in the field of financial modeling for managers, financial experts, young professionals and students. These skills provide excellent career prospects. Quick and interactive learning is assured due to the structure as a training course which includes applied examples that are easy to follow. All applied examples contained in the book can be reproduced step by step with the help of the Excel files. These files are also available for download at www.certified-financial-modeler.de in addition to the web pages of the publisher provided on the first page. There you find additional files dealing with the topic of financial modeling. Best results will be obtained if you directly apply the theoretical contents and make use of the online-offering as you work your way through the text.

This textbook is suitable for teaching at the university and college level as well as for in house-training at corporations. It is also possible to study the material independently. Mastery of the subject matter can be demonstrated via the title “Certified Financial Modeler” which is awarded by the German Institute of Corporate Finance.

This book contains the following topics:

- Financial Modeling Standards
- Model Review
- Financial Modeling using Excel
- Financial Modeling using VBA
- Investment Appraisal and Financing
- Corporate Finance
- Portfolio Management
- Derivatives

We would like to thank the publishing house Macmillan Publishers and its employees for the always pleasant and constructive cooperation. A special thank you goes to Aimee Dibbens and Nicole Tovstiga from Macmillan Publishers for the ideas and support during the creation of this volume. We would also like to express our thanks to our sponsor, Volksbank Göppingen. Furthermore, we would also like to thank Lukas Breuer, Martin Geißler, Shushanik Hakobyan, Katharina Hirning, Timo Huguet, Nico Kletti, Finn Pilath, Marc Schurer, Julia Stange, Thorsten Steinhilber, Julian Wellge and Simon Zieglgruber for their support and contributions, which made the success of this book possible. We also thank the numerous readers for their contributions concerning the contents of the book.

We wish you enjoyable reading and success in financial modeling.
The editors Dietmar Ernst and Joachim Häcker with the authors

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List of Figures

List of abbreviations and symbols

A	=	Annuity
A_F	=	Financing annuity
A_I	=	Annuity for the investment
APV	=	Adjusted present value
B	=	Benchmark
B	=	Book value
C	=	Total cost
C	=	Coupon payment
C	=	Costs
CIF	=	Cash inflows
COF	=	Cash outflows
$Corr[r_(i,j)]$	=	Coefficient of correlation
COS	=	Cost of storage
$Cov[r_(i,j)]$	=	Covariance
c	=	Price of the call
c	=	Coupon rate (nominal interest rate)
C_{fix}	=	Fixed costs
c_v	=	Variable costs
CAPM	=	Capital Asset Pricing Model
$CFtE$	=	Cash flow to equity
d	=	Down-factor
d	=	Dividend payment
d	=	Market value of debt
d	=	Discount
d_M	=	Monthly down-factor

D = Duration
D_p = Portfolio duration
D_mod = Modified duration
D_t^+ = Positive difference between portfolio return and benchmark return
D_t^- = Negative difference between portfolio return and benchmark return
DCF = Discounted cash flow
e = Market value of equity
$E()$ = Expected value
$E(r_m)$ = Expected Value of the Return of the Market Portfolio
$EBIT$ = Earnings before Interest and Taxes
$EBITDA$ = Earnings before interest, taxes, depreciation and amortization
EBT = Earnings before taxes
EV = Enterprise value
f = Objective function
F_0 = Futures price
FV = Future value
g = Growth rate
h = Investment horizon
I_0 = Initial investment, investment outlay
i = discount rate
i = Discount rate
i_{eff} = Effective interest rate
i_{nom} = Nominal interest rate
IRR = Internal rate of return
L = Liquidation proceeds
L = Liability
ln = Natural logarithm
m = Length of the time interval
$max!$ = Maximizing
$min!$ = Minimizing
MEP = Maximum return portfolio
MRP = Market risk premium
MVP = Minimum variance portfolio
N = Cumulative standard normal distribution
NCF = Net cash flow
NPV = Net present value
n = Number of periods, (remaining) time to maturity

$NOPLAT$ = Net operating profit less adjusted taxes
NPV = *Net present value*
$oFCF$ = Operating free cash flow
P = Present value (price) of the bond
P = Profit
P_0 = Capital invested at time 0
P_t = Portfolio value at time t
P_{clean} = Clean price of a bond
P_{dirty} = Dirty price of a bond
PV = Present value
p = Price of the put
p = price, revenue per unit
P = Price
P_0 = Capital invested at time 0
P_t = Portfolio value at time t
q = Probability and pseudo-probability
q_t = Log-return of period t
= Mean log-return in period$t$
$\overline{q_t}$ = Average return during the interval
r = Return, Market return p.a.
r_e = Return on equity, cost on equity
$r_i^{<m}$ = Returns that are lower than the mean
r_m = Return on market portfolio
r' = Excess return
r^a = Arithmetic average return
r^c = Continuous return
r^d = Discrete return
r_d = Return on debt, cost on debt
r_f = Risk-free rate of return
r_{fM} = Monthly risk-free rate of return
r_i = Return of asset i
r^m = Money-weighted return
r_P = Portfolio return
r_req = Required return
r^s = Simple return
r_t = Return in period $t$resp. return for a period less than one year
r^{twr} = Time-weighted return resp. geometric average return
$r_{annualized}$ = Annual return respectively annualized return
RP = Risk premium

s = Estimate for volatility
$S[.]$ = Standard deviation of return
S_0 = Starting price (underlying)
$SemiVar[r]$ = Semi-variance of the return
$SemiS[r]$ = Semi-standard deviation of the return
SIM = Single-index model
SR = Sharpe ratio
t = Time period
t = Corporate tax rate
T = Term to maturity
T = End of the time period
$T - t$ = Remaining term to maturity
TE = Tracking error
TEV = Tracking error variance
TV = Terminal Value
TP = Tangency portfolio
u = Up-factor
U = Utility
u_M = Monthly up-factor
V = Variance-covariance matrix
V' = Variance-covariance matrix of the excess returns of the individual assets
VaR = Value at risk
$Var[.]$ = Variance of return
w = Weights of the assets
w_i = Weight of asset i in the portfolio
$WACC$ = Weighted average cost of capital
X = Exercise price of the option
y = Convenience yield
α = Alpha
β = Beta factor, Beta
$(1 - \alpha)$ = Confidence level
β = *(Company-specific) Beta Factor*
β^u = Unlevered Beta Factor
β^l = Levered Beta
β_d = Debt Beta
Γ = Gamma
Δ = Delta
ε_t = Random forecast error in period t resp. random residual

T	=	Theta
K	=	Vega (Kappa)
λ	=	Lambda: parameter of risk aversion
P	=	Rho
μ	=	Expected value of the return
$\rho_{i,m}$	=	Coefficient of correlation
σ	=	Standard deviation of return
σ_t	=	Standard deviation for a period of less than one year
σ^2	=	Variance
$\sigma_{annualized}$	=	Annualized standard deviation of return
$\sigma^2_{annualized}$	=	Annualized return variance
$\sigma_{i,j}$	=	Covariance
σ^2_t	=	Return variance for a period of less than one year
τ	=	Period from the purchase date to the next coupon payment date
μ	=	Mean value
Ω	=	Omega

List of Synonyms

Since many terms in the field of derivatives have a synonym, we have collected a list of the key terms:

Terminology used	Synonym	Synonym
At expiration	Last day of trading	
Bond futures	Interest rate futures	
Cost-of-carry	Basis	
Exercise price	Strike price	
Long	Buyer	
Selling (an option)	Writing (an option)	
Short	Seller	
Term	Term to maturity	Life
Option premium	Option price	

1
Introduction

Financial modeling can best be structured around ten questions. These questions are answered in the two workshops on Excel and VBA as well as in the chapters on Financial Modeling Standards, Model Review, Investment and Financing, Corporate Finance, Portfolio Management and Derivatives – these are the prerequisites for successfully completing the degree of Certified Financial Modeler.

1 How Can Managers Assure that the Decision Papers which They Receive Are Not Already Flawed and Faulty Decisions Are Reached as a Consequence?

The book combines professional knowledge in the most important fields of finance with thorough programming knowledge in Microsoft Excel and Microsoft Visual Basics for Applications (VBA). This allows the targeted use of financial theory to solve clearly specified problems while minimizing errors. Thus the users can systematically develop Excel solutions for all issues which are relevant for them.

2 How Can Applied Tasks Be Modeled Clearly and in a Structured Manner?

With the financial modeling standards we provide you with the foundations of financial modeling. Financial modeling is based on a set of

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principles which will fundamentally change the way you will work in the future. You can structure all models in a way that will facilitate your daily work by greatly increasing efficiency and transparency. Since financial modeling also means constant application and improvement, we begin with a workshop that demonstrates the fundamental methods of financial modeling with reference to an investment decision using MS Excel. Financial modelers aim at the highest possible quality of a financial model. We show you how the model review process can be used to assess the model and assure its high quality.

3 How Can Macros Be Used in the Modeling Process?

The VBA programming workshop provides a first introduction to the programming of macros. They can be utilized to greatly enhance the efficiency of all office applications. It is possible to standardize routines that are very hard to standardize with the basic Microsoft programs. It is impossible to deepen the knowledge about VBA on a purely theoretical level. Required is the constant work with VBA, experimentation and improvement based on the premise of learning by doing. Financial modeling experts always have solid knowledge of VBA and are able to independently develop new programs. Is the knowledge of VBA absolutely essential for financial modeling? We do not think so, since Microsoft Excel offers solutions for almost all types of questions. But knowledge of VBA can help to significantly facilitate the workflow, especially with regard to individualized surfaces and efficient approaches. But it also needs to be pointed out that the use of VBA involves black box solutions, in other words models that are hard to trace, especially for third parties that lack the necessary VBA knowledge. Should those models contain programming errors, it is extremely difficult to identify and remedy them.

4 How Can Financial Modeling Be Used in Applied Work in Finance?

The foundations of financial modeling are applied in the chapters to the core fields of modern finance, namely

- Investment and Financing,
- Corporate Finance,
- Portfolio Management and
- Derivatives.

The focus is not on basic textbook knowledge, but rather on techniques and approaches used by professionals in applied work in their respective fields. The combination of thorough knowledge in Excel and VBA with professional knowledge in finance defines our understanding of financial modeling. Combining scientific approaches with applied work is our motto. Consequently the team of authors is made up of practitioners in the fields of financial management, corporate finance, portfolio management and derivatives as well as academics with a specialization in these fields.

5 How to Create Financial Models for Investment and Financing?

Fundamental models of investment and financing are presented in this chapter. They serve as the foundation for the following finance topics of corporate finance, portfolio management and derivatives. The net present value method was already presented in the Excel workshop in order to show some of the possibilities for financial modeling. In this chapter, additional methods of investment analysis, both dynamic and static, are presented.

Solid financing decisions initially require an analysis of the profit and loss statement, the balance sheet and the cash flow statement. This is done in the context of an analysis of key figures. Concerning financing decisions, instruments of internal and external financing are distinguished. The main element of internal financing is financing out of the free cash flow. With regard to external financing, a distinction is made between the instruments of equity financing and debt financing.

6 How to Create Financial Models for Corporate Finance?

In the chapter on corporate finance, we focus on issues of corporate planning and valuation, which are at the core of every corporate finance transaction. Since corporate valuation is a central topic in the field of investment theory, this chapter, the Excel workshop, the VBA workshop and the chapter on investment and financing are tightly linked.

The implementation of knowledge in corporate valuation in financial modeling offers the big advantage of systematically capturing and understanding the complex linkages between planning, determination of cash flows and cost of capital and the final valuation. The determination of the cost of capital in corporate valuation is based on modern portfolio theory. In this way, a link is established with the chapter on portfolio management.

7 How to Create Financial Models for Portfolio Management?

Portfolio management deals with the allocation of wealth. Central aspects for the asset manager are the tradeoff between return and risk of the portfolio and the measurement of these variables. It is also demonstrated how portfolios can be optimized in the context of active and passive portfolio management. This is done with reference to the capital market models that are generally accepted by practitioners.

8 How to Create Financial Models in the Field of Derivatives?

The valuation of options and futures is explained in the chapter on derivatives. Derivatives remain mysterious for many students and practitioners in the field of finance and are thus frequently reserved for a small group of experts. In our opinion, this is due to the fact that the knowledge about derivatives is not taught in a transparent manner. In financial modeling it is demonstrated how the valuation of options and futures is conducted, which input factors are required and what type of algorithm is behind the calculations. Once the valuation of derivatives in financial modeling has been understood, it becomes clear that the process resembles the valuation of a company and that questions of risks are treated in a manner that is familiar from portfolio management.

9 Who Needs a Deep Understanding of Financial Modeling?

All graduates and practitioners in the field of finance should possess a thorough knowledge of financial modeling. But experience shows that many financial experts have no or only rudimentary financial modeling skills.

At the same time, banks, financial service providers and other companies for their finance and controlling departments are urgently looking for people with thorough knowledge in Excel and VBA, who are able to develop models that address concrete applied issues. In that sense, financial modeling skills are competencies that offer outstanding opportunities for beginning or advancing a career in finance.

10 How Can I Demonstrate My Financial Modeling Skills?

Everybody who has worked through this book and digested its contents possesses outstanding skills in the field of financial modeling. In order to give you an opportunity to showcase your qualifications, we offer an examination which, upon successful completion, grants the title of "Certified Financial Modeler." This book defines the contents of the certification course for the "Certified Financial Modeler." Participants in the certification course "Certified Financial Modeler" are provided with practice questions and sample solutions, which are structured in the same way as this book and which clarify in a concise manner the linkages among the individual aspects contained in all eight parts.

The examination to obtain the title of "Certified Financial Modeler" is offered and administered by the German Institute of Corporate Finance. Additional information about the "Certified Financial Modeler" including the registration forms can be found at www.certified-financial-modeler.de. We wish you gainful reading and look forward to your suggestions and comments at info@gicf.de.

2
Financial Modeling Standards

1 Executive Summary

In the chapter “Financial Modeling Standards” 5 process steps and 20 milestones of financial modeling are presented and 150 recommendations for action are listed. The aim is to provide the financial modeler with standards for constructing his model. Why does a financial modeler need such standards?

According to ICAEW (Institute of Chartered Accountants in England and Wales) “approximately 90% of all Excel spreadsheets contain errors!” [. . .] and about 65% of all Excel spreadsheets have been created without applying formal methods!”[1] But errors in Excel are not the same thing as typos in PowerPoint. They can induce strategic mistakes that destroy value and have major implications. In the case of an acquisition, for example, the buyer could pay too much and therefore face a lawsuit from his shareholders. How can such a scenario be avoided?

The financial modeler takes the standards into consideration when he develops a financial model in Excel. In the process, he will make use of current finance knowledge, which should be of high academic quality and at the same time applicable to the transaction. During the model review, the financial model will be scrutinized carefully. Such an approach will move the financial modeler close to his goal of developing an Excel workbook with zero errors. Every company, every bank, every auditing firm or consultancy should provide their modeling experts with clear standards that serve as the equivalent of guardrails.

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This is the only way to work successfully across departments, across industries and especially internationally. In addition to concerns about quality, legal aspects such as liability and corporate governance are also important. In current business practice, however, the picture is very different. And the academic community has also contributed little to support practitioners with clearly implementable standards. It is the aim of this book to make a contribution toward improving the quality in the field of financial modeling with the proposed standards.

2 Introduction, Structure, Learning Outcomes and Case Study

Structure

This chapter serves as an introduction to the financial modeling standards and answers the following questions:

- What does financial modeling mean?
- What are models?
- What are the concrete aims of the model?
- What is required of a financial model?
- How is the model used and who is the user?
- Which resources are available with respect to time, personnel and money?
- How can a task list be defined?
- How can financial models be structured in a modular fashion?
- Which are the most important textbooks in the English language on the topic of financial modeling?
- Which "Best Practice Financial Standards" exist for financial modeling?
- Which outstanding modeling approaches exist in the English language and which financial modeling approach are they based on?
- What is the structure of the "House of Financial Modeling?"
- What are possible career paths toward expertise in financial modeling?
- Which are the top-10 financial modeling standards?
- How can the top-10 financial modeling standards be implemented?

- Which are the 5 process steps of financial modeling?
- Which 20 milestones of financial modeling exist and how are they structured?
- What do the 150 suggestions for action in financial modeling state?

Learning Outcomes

The practical implementation of the financial modeling standards is taught with a case study. The financial modeler

- Can comprehend and put into perspective the model in the Excel workbook as a representation of reality,
- Can reproduce and critically discuss the basic ideas of the financial modeling standards,
- Will learn the tools necessary to apply the financial modeling standards to topics in finance from his specific area of work,
- Can structure an Excel workbook in such a way that he can independently conduct a corporate valuation and critically reflect on the results,
- Is able to solve specific problems in finance (here especially in the areas of investment and financing, corporate finance, portfolio management and derivatives).
- Can reproduce and critically discuss the different strands of the literature on financial modeling. He is also able to put the approach presented in this text in the wider context of the available literature.

Definition

> In financial modeling, the key issues in the field of finance are mapped and solved holistically with the help of a computer-based analysis.

Case Study

The top-10 standards are derived from the standards presented in this chapter. Those are discussed in detail with reference to a case study – the Pharma Group. The chapters “Corporate Finance Part I and Part II” and “Model Review” also utilize this case study. The chapters "Financial Modeling Standards", "Model Review" and "Corporate Finance Part I and Part II" are very closely linked. For specialists in corporate finance, these three parts constitute the main tools for their work in companies, banks or investment banks, auditing firms or boutiques.

3 Foundations of Financial Modeling

3.1 What Are Models and What Is Financial Modeling?

Models are everywhere in our daily life. We use them all the time without being fully aware of that fact. Every map is a model of the landscape. Weather forecasts are based on models. Children imitate the world of grownups with toys – also miniature replicas of reality. Buildings, machines, ships are initially built as small models and tested, before they are constructed in their original size. The computer used to write this book was assembled on the basis of a circuit diagram (see Fig. 2.1).

Models (Latin *modulus*: pattern, form) are simplified descriptions of reality. With the abstract representation of complex objects, processes or structures, relevant interrelations and characteristics can be identified and complexity can be reduced. Models facilitate assessment and research or put us in the position to undertake these activities. The result can be an insight, a forecast or a decision.

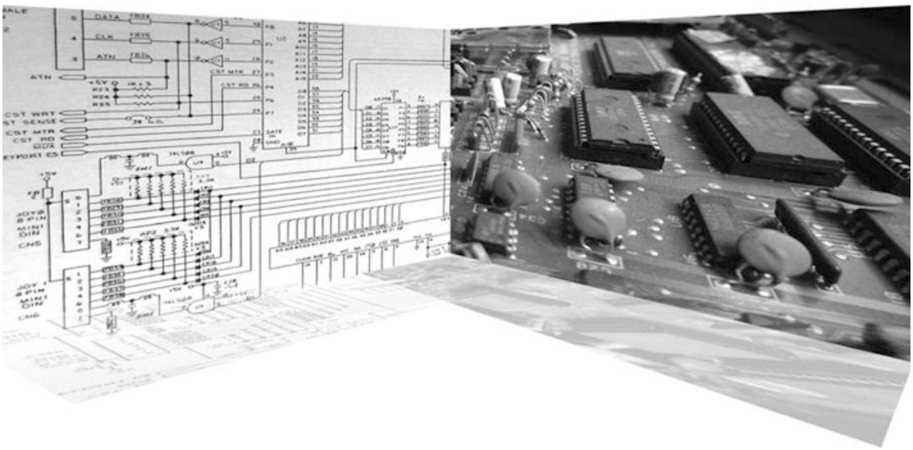


Fig. 2.1 Models and reality

Models should not be confused with the real world. They only serve as a substitute for a given task and for a limited period of time – thus they only express subjective awareness and not reality itself. It must be constantly kept in mind that models are built to provide interpretations. This leads to the fundamental questions: for whom, why and for which purpose is the model constructed?

Models offer significant advantages over the use of real objects:

Efficiency: The costs of model development and application are significantly lower compared to similarly comprehensive analyses on the real object. (Example: when constructing airplanes or automobiles, the aerodynamic behavior is tested with the help of miniature plastic models in the wind tunnel.)

Time savings: Models generate information much quicker. With a model it is possible to simulate a multitude of combinations, an activity that would require many years in the real world. (New additives for concrete, for example, are tested with models for their physical and chemical attributes before being used in buildings.)

Implementation and decision support: Models can be used for tasks and inquiries which could not be conducted in other ways. Decisions about corporate mergers are reached with the help of models. These models work with assumptions which aim at assessing the future development perspectives and to reduce inherent uncertainty.

Reduced risk: Especially computer models do not have physical or economic consequences. For this reason, expensive crash tests of ships and trains are replaced as much as possible with computer simulations.

Insights: Behavior or chains of events can be localized under given conditions (laboratory conditions), possible interventions and their effects can be determined and possible alternative developments can be detected in a timely manner. In the natural sciences such as physics, chemistry and pharmacy, laboratories are fundamental research instruments.

Knowledge transfer: With models it is possible to train and simulate capabilities which help to master the actual task (such as flight simulators when training pilots or business simulations in academic training).

The advantages of models are the reason why they are of paramount importance in all academic disciplines. In modern business management and in daily business they are also indispensable tools which help to explain and manage complex relationships. The term financial modeling combines questions from finance with techniques for constructing models that are analyzed and solved holistically with the help of computers.

3.2 Analyzing the Model Requirements and Defining a Task List

As complexity increases and transparency of a task is reduced, it becomes increasingly important for the financial modeler to get clarity about the question at hand and the aim of the financial model as well as the related goals. Answers are required to the following questions (see Fig. 2.2):

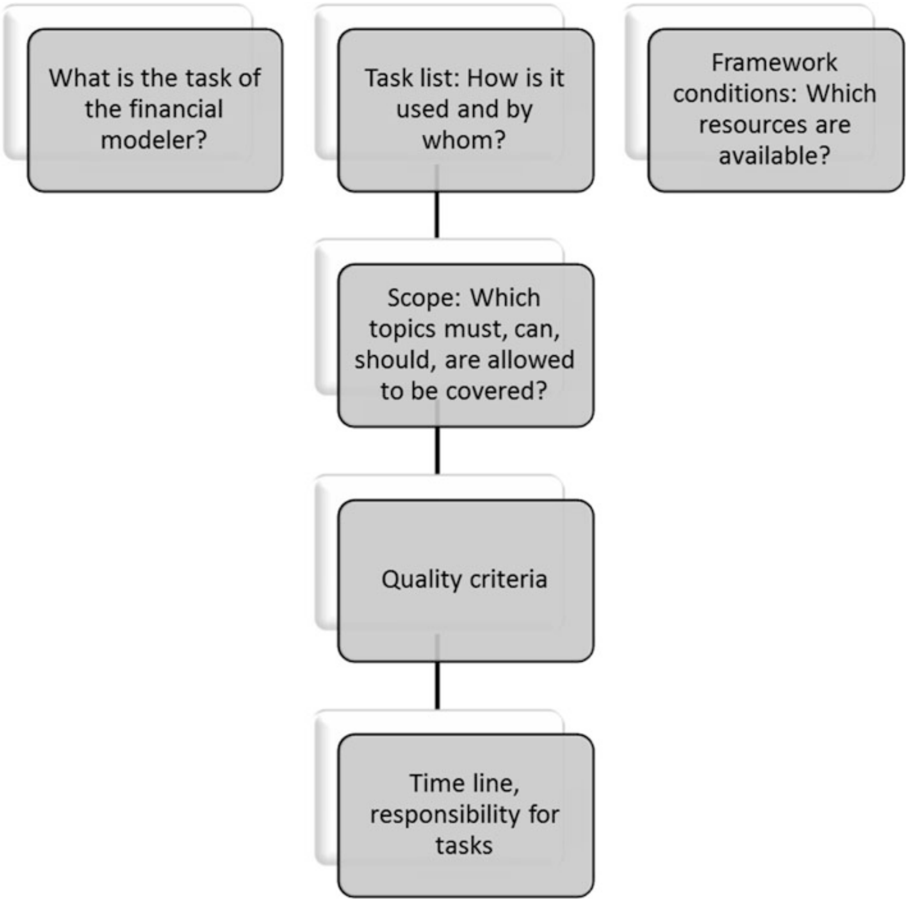


Fig. 2.2 Main themes for the task list – toward the financial model

- What concretely must be accomplished?
- What is required of the financial model?
- How is it used and by whom?
- Which resources with respect to time, personnel and finances are available?

The resulting profile of requirements and the task determine contents, type of solution and path toward the solution. Each financial model should only be used for the specified purpose – in our case only to reach investment decisions. A generally valid broad model that covers all aspects is inefficient, since any increase in complexity will also imply an increase in the potential for errors and lead to a decline in the reliability of the conclusions reached. A financial model to calculate the profitability of an investment (see Chapters 12 and 13) requires assumptions about the future development of the sales market as the basis for assessing the profitability. However, a forecast of growth prospects of the global economy is not needed in this case and will not help to answer the question at hand.

All interested parties should be involved from the very beginning in order to determine the goals and features of the model. Different opinions, expectations and possible conflicts need to be solved at the beginning. The goals should be independent of the solution and formulated in line with the purpose of the model. The perspective of the user and not technical feasibility is the decisive factor.

It is true for every financial model that the product must be accepted by the people who use it and who reach decisions based on its results.

The aim of the financial model and the concrete implementation should therefore always be defined in the very beginning. Recommended is a binding and written agreement. The contents of such a task list offers orientation during the development phase and allows tracking the progress of the work flow. Such a specification also facilitates testing of the financial model. The definitions can serve as criteria for assessing the quality of the financial model. In addition, the descriptions in the task list serve as important preliminary input for a user guide and the documentation of the financial model. This saves time.

The necessary scope and the degree of detail which is found in the task list depend on the financial model: The simpler it is, the shorter the compilation. Only the expectations concerning the sophisticated and substantial parts of the model are specified in detail, while strongly simplified information is sufficient for less complex elements.

At a minimum, a task list should contain the following items (see Fig. 2.2):

- **Functional coverage:** What needs to be accomplished at a minimum and what are the consequences if this target is missed? Which tasks are not included?
- **Requirements:** What needs to be in place so that the aims can be reached? This includes all types of resources such as personnel, materials, time, budget, technical infrastructure and management support.
- **Quality criteria and documentation:** How should the quality of the financial model be assessed? Who assesses the results?
- **Timeline:** What are the priorities and during which time period should the financial model be implemented? Which intermediary results need to be presented when?

3.3 Structuring Financial Models in Modules

Financial modeling deals with complex and unstructured tasks. Not all possible problems are known in advance and the answers require originality and creativity. Model development is not a routine task. A successful and efficient method to solve complex tasks is the use of modules. This means that the complete task is broken down into smaller and autonomous parts (see Fig. 2.3).

> The use of modules is a method where complex tasks are broken down into smaller, simpler and independent components. The solution moves from total to specific, from abstract to concrete.

Figuratively, modules are like building blocks from a child's toy box. They can be put together in numerous variations to arrive at different objects (house, castle, ship and so forth). For the financial modeler, the building blocks are areas in the Excel worksheets that are filled with formulas and data in order to fulfill different tasks: input area

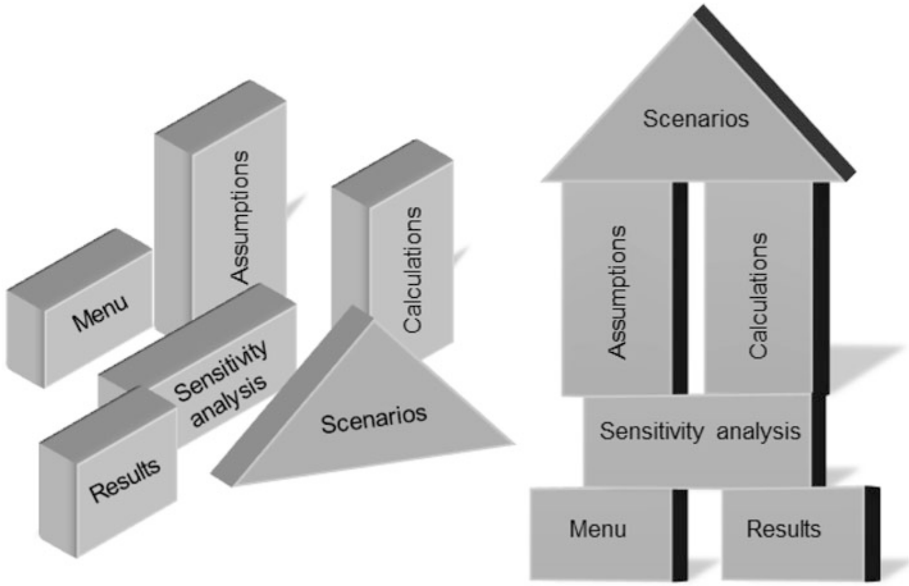


Fig. 2.3 Modules are like building blocks from the toy box

(assumptions), results, calculations, sensitivity analysis, scenarios, data imports, simulations, documentation, notices and disclaimers, menu and so forth.

Modules offer several advantages:

- Due to their size, they are more transparent, more clearly structured and therefore more easily understood than the complete complex model.
- Calculations can be done more easily. The compact modules can be changed more easily and calculation can be done better. In a large model, it can happen easily that information, assumptions and calculations are in different locations. Redundancies and mistakes are thus inherent in the system.
- A financial model can be enhanced and extended more easily. This simply means adding another module.
- Teamwork is facilitated, since delegation is possible.
- If the timeline is at risk, module with lower priority can be pushed back.
- Modules can be used as blueprints for additional tasks.

Modules must be compatible with each other.

The individual and isolated modules only have value when integrated into the overarching model and linked with each other. The quality of the financial model is revealed among other things by the ease of adding additional modules. The specific challenges for the financial modeling with modules are:

- Correct and clear boundaries between the modules need to be drawn.
- It is important to check carefully whether the module leads to errors in the overall model.
- A methodical approach is recommended, so that the individual components can be combined into a complete and functioning financial model.

4 Current State of Financial Modeling in Theory and Applied Work

4.1 Literature on Financial Modeling

Financial modeling is a fairly recent addition to the business management literature. Three different categories of financial modeling literature can be distinguished:

1. Textbooks on the topic of "financial modeling";
2. "Best practice financial standards" for financial modeling;
3. Specialized IT literature.[2]

Textbooks on the topic of "financial modeling" deal primarily with financial modeling approaches and techniques and frequently offer additional Excel-based case studies. Best practice financial standards for financial modeling are focused primarily on techniques of modeling and the modeling process. Specialized IT literature provides the reader with detailed information about Excel functions and formulas or alternative financial modeling software.

Textbooks on the topic of "financial modeling":
This book belongs to the category of "textbooks on the topic of financial modeling." The aim is to satisfy high academic standards while at the same time being highly relevant for applied work.

When analyzing the market for financial modeling books, we specifically looked at the following textbooks, which are outstanding in our opinion (in alphabetical order) and focus on general topics of financial modeling:

✓ Barlow (2005) *Excel Models for Business and Operations Management*

✓ Benninga (2014) *Financial Modeling*

✓ Day (2012) *Mastering Financial Modelling in Microsoft Excel: A Practitioner's Guide to applied Corporate Finance*

✓ Powell/Baker (2009) *Management Science: The Art of Modelling with Spreadsheets*

✓ Powell/Batt (2008) *Modeling for Insight: A Master Class for Business Analysts*

✓ Read/Batson (1999) *Spreadsheet Modelling Best Practice*

✓ Rees (2008) *Financial Modelling in Practice: A Concise Guide for Intermediate and Advanced Level*

✓ Sengupta (2010) *Financial Analysis and Modeling Using Excel and VBA*

✓ Swan (2008) *Practical Financial Modelling: A Guidance to Current Practice*

✓ Tjia (2009) *Building Financial Models: The Complete Guide to Designing, Building and Applying Projection Models*

Best practice financial standards for financial modeling:
Best practice financial standards are recommendations which allow efficient and prudent work practices in financial modeling. Best practice financial standards for financial modeling can be established via benchmarking and the continuous comparison of the products, methods, results or processes of competing approaches. Benchmarking is particularly challenging in the case of financial modeling, since financial models or the process of creating these models are frequently not made public due to their confidentiality. As many different applications for financial models exist, it is doubtful whether best practice

can be established. Nevertheless, best practice for financial modeling is discussed in the literature and initiated by organizations.

The Spreadsheet Standards Review Board (SSRB), a nonprofit organization founded by BPM Analytical Empowerment Pty Ltd, publishes a number of best practice spreadsheet modeling standards (URL: http://www.ssrb.org/; URL: http://www.bestpracticemodelling.com). These spreadsheet modeling standards are updated regularly. Recommendations for changes, improvements or deletions of standards are taken into considerations. The version 7.0 of the best practice spreadsheet modeling standards was published in June 2013 and consists of 68 standards as well as 72 conventions, which are assigned to 16 different areas of spreadsheet modeling. Identification and improvement of best practice standards are advanced by the SSRB.

An additional nonprofit organization that participates in the discussion about risks, methods and evaluation of financial modeling is the "European Spreadsheet Interest Group" (EuSpRiG). The organization was founded in 1999 by academics from different universities and has advanced research in the field of spreadsheet applications and discusses current issues at annual conferences.

FAST Standard Organisation Limited was founded in the year 2011 (URL: http//www.fast-standard.org). The four letters stand for Flexible, Appropriate, Structured and Transparent. FAST was established with the aim of establishing a continuously updated and refined guide for the construction of financial models. It is backed by the philosophy that models need to be flexible, appropriate, structured and transparent.

4.2 Different Approaches – Identical Aims

Knowledge of finance and Excel do not automatically imply the ability to produce outstanding financial models that are based on standards.[3] Research has shown the necessity of following a structured financial modeling approach in order to arrive at best practice financial models. However, the approaches discussed in the literature differ with regard to structure, scope and focus. Some concepts focus on a modeling methodology,[4] while others are most concerned with the technical implementation.[5] We want to list the most important books in the

English language on the topic of financial modeling.[6] Figure 2.4 summarizes eleven selected modeling approaches in alphabetical order. An overview is provided concerning the underlying financial modeling approach and the main fields of application.

#	Author	Financial modeling approach and main fields of application
1	Barlow (2005)	**Three main steps** Formulating the problem, derivation of mathematical formulas and setting up of "business models" (for example cost accounting and marketing) and "models for operations management" (for example production and project management).
2	Benninga (2014)	**Focus on subject-specific topics** The main focus is on the technical and mathematical implementation of different tasks in financial management in the fields of corporate finance and valuation, portfolio management, options, bonds, Monte Carlo simulation, Excel techniques and VBA.
3	Day (2012)	**15 steps:** Definition of aim, user requirements and user surface, key variables and rules, breakdown of the calculations, individual modules, menu structure, management reports and summaries, sensitivity analysis, backup, documentation as well as peer group comments. The models are presented for various uses, such as analysis of variances, risk analysis, leasing, corporate valuation, bonds, decision tree method and so forth.
4	Powell/Baker (2009)	**The tools of modeling:** Simplification of the problem, structuring of the problem in modules, development of a prototype and improvements, design of graphics to illustrate the key linkages, identification of parameters and conducting of sensitivity analysis, separation of development of ideas and evaluation, working backwards from the answer to the approach, focus on model structure and not on data input. The models are shown for methods such as regression analysis, linear and nonlinear optimization, network models, decision tree analysis and Monte Carlo simulation.
5	Powell/Batt (2008)	**Four stage process:** Problem identification, problem presentation, model construction and assessment of results. The method is applied to numerous cases, including pharma and leasing companies.
6	Read/Batson (1999)	**Six steps:** Scope, specification, design, modeling, test and use. The steps are explained with reference to a number of small cases.

Fig. 2.4 Major financial modeling approaches in the literature

7	Rees (2008)	**Principles of modeling:** Model design, model structure and planning, model development, presentation of results, sensitivity analysis as well as model testing. The principles are used in the fields of corporate valuation, risk modeling, options and real options models as well as VBA.
8	Sengupta (2010)	**Ten steps of financial modeling in Excel:** Definition of the problem structure, definition of inputs and outputs, identification of users, understanding of financial theory and mathematics relevant for the models, model design, construction of the spreadsheet, protection of the model, documentation and – if necessary - updates. This approach is used for the following areas: financial statements, time value of money, financial planning, bonds, simulation of share prices and options. A specific focus is on VBA.
9	Spreadsheet Standards Review Board (2013)	**16 fields of spreadsheet modeling:** The 16 fields of modeling are described with reference to 68 standards and 72 conventions, which lead to a best practice model. No focus on a specific field of application.
10	Swan (2008)	**Top-down approach:** Model structure, quality control, formulas and functions, model use, sensitivity and scenario analysis as well as automation. No focus on a specific field of application.
11	Tjia (2009)	**Model development in the form of best practice** Top-down view of the model development stage in the field of corporate finance and corporate valuation.

Fig. 2.4 (Continued)

The different approaches range from models with three phases to models in 15 detailed steps.[7] All concepts share the idea that financial modeling is a top-down process, beginning with the identification of the purpose of the model and its aims. Next are definitions of inputs, calculations and outputs and finally the construction of the model. Another aspect that is frequently discussed is the standardization in financial modeling. A summary of the aims of the standardization of financial modeling is provided by the Spreadsheet Standards Review Board[8]:

- ✓ "Enhanced quality and transparency,
- ✓ Reduced development times and costs,
- ✓ Minimizing the risk of errors,
- ✓ Simplifying the efficient exchange of methods of model development,

✓ Avoiding redundancies as well as
✓ Harmonizing the requirements of developers and the demands of users."

A large part of the literature contains explanations and suggestions for the technical implementation of Excel functions and formulas. This part is usually described separately from the modeling methodology and is considered to describe the financial modeling tools.[9] The extensive range of Excel functions justifies this separation between modeling tools and modeling methodology. Several authors[10] present the previously described methods with the help of detailed cases. This approach is a very suitable teaching tool to illustrate the building of financial models and can be used rather well for courses on financial modeling or for independent study.

How does this textbook "Financial Modeling" add to the already existing literature?

The methods to develop models which were presented above are solid, but in some cases they do not offer a stringent structure for model development with regard to problem identification, model structure and planning, model setup, quality assurance and model presentation. Since linkages among the individual process steps do exist, the financial model should also be based on clearly structured development stages. These linkages are presented in chronological order as instructions for modeling in the following section.

The existing financial modeling literature contains comprehensive knowledge. However, this knowledge has not yet been presented in a way that is structured and suitable for applied work/concrete applications and can serve as a guide for financial modeling.

The demand of GROSSMANN/ÖZLÜCK supports this: "What is needed is a "spreadsheet engineering methodology" [. . .] that applies to a particular well-defined problem domain, and provides detailed, integrated guidance on design, construction, and documentation of spreadsheet software."[11] In our book, we want to follow up on this demand. It is our aim to derive a general "Spreadsheet Engineering Methodology," which can be applied to a clearly defined and specific problem and provides detailed and integrated guidance on design, construction, and documentation of spreadsheet software.

In the following, a methodological framework for financial modeling is developed: The so-called "Financial Modeling Standards." In the later sections, these financial modeling standards together with the

Excel and VBA tools covered in the book are applied and explained in detail on the basis of concrete cases. This provides the future financial modeler with an integrated view of financial modeling which covers all necessary steps. It begins with the financial modeling standards (Module 1), discusses the tools of financial modeling (Module 2) and includes the practical implementation (Module 3). Following the study of all chapters, the user is in a position to develop professional financial models. Our "House of Financial Modeling" thus rests on three modules (see Fig. 2.5).

Figure 2.5 clarifies the structure of the "House of Financial Modeling." The steps required to become a professional financial modeler are displayed in Fig. 2.6. The process extends over three modules. Module 1 includes the first two columns of the "House of Financial

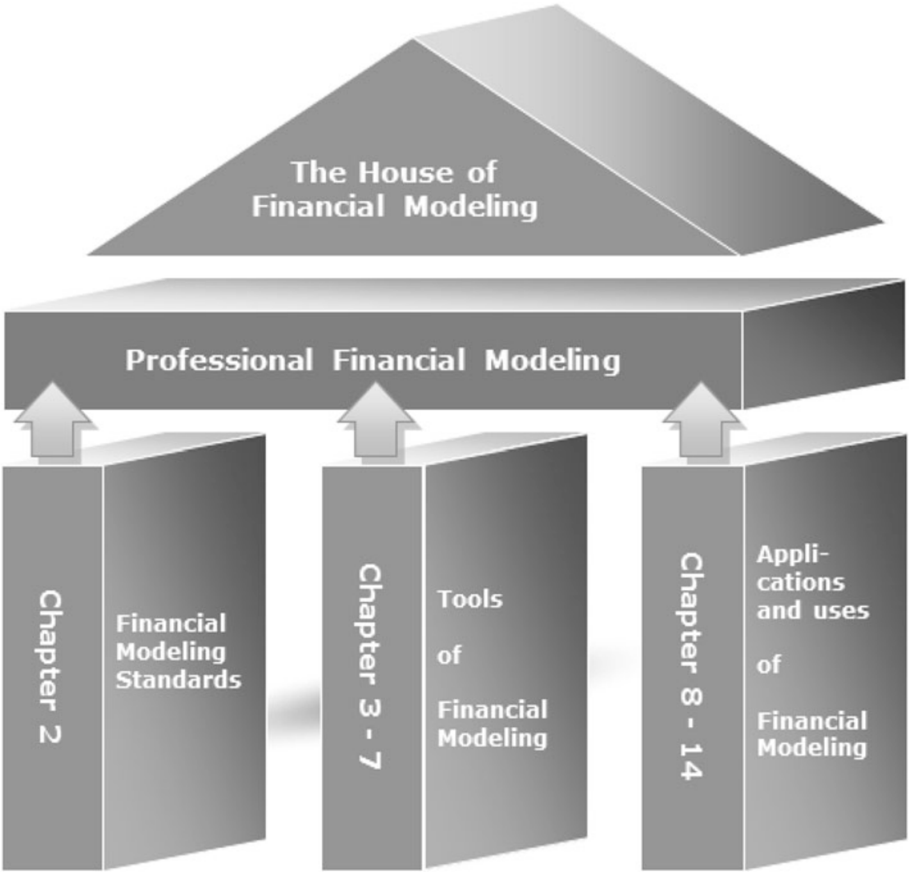


Fig. 2.5 The "House of Financial Modeling"

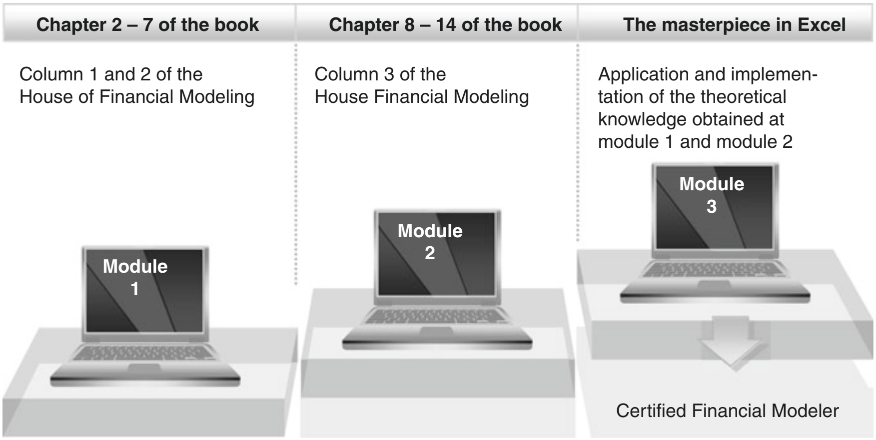


Fig. 2.6 Becoming a financial modeling professional

Modeling" (Chapters 2–7 of the book). Module 2 covers the third column of the "House of Financial Modeling" (Chapters 8–14 of the book (including electives)). In module 3 the financial modeler has mastered the necessary prerequisites for professional financial modeling and the knowledge is now applied. The financial modeler constructs a financial model of high quality – he presents his masterpiece. Once he passes all three modules, his accomplishments are formally acknowledged. He has earned the designation of Certified Financial Modeler.

5 Financial Modeling Standards

The authors have critically assessed the literature listed above. Based on their personal experience in academia and in applied work, a modeling framework with a holistic character was developed. It is expected to provide the financial modeler with a set of standards that allows him to develop a financial model of high quality for each individual issue that may arise in his field of work.

5.1 Top-10 Financial Modeling Standards

Type and extent of a financial model are shaped by numerous factors. Financial models are used in many different departments of a company and frequently serve as the basis for decisions. Despite the multitude of models, a number of principles exist, which apply to all types of models. We call them financial modeling standards. The aim of our financial modeling standards is to increase the quality of the model and with it the reliability of the results. Figure 2.8 contains 150 standards that are based on best practice respectively recommendations that show how financial models can be developed efficiently. The standards are independent of the contents of the models. While these standards can and should be applied to every financial model, there will still be cases where not all standards are relevant or where adherence to the standards is impossible or not advisable.

Among our 150 standards we have identified the top-10 financial modeling standards. They are presented in Fig. 2.7:

The Top-10 Financial Modeling Standards		
1.	Define the modeling purpose	✓
2.	Separate the problem into independent subunits (modules)	✓
3.	Provide a graph of the flow of data and the model structure	✓
4.	Separate inputs from outputs	✓
5.	Choose a unified layout for the worksheets	✓
6.	Use unified formatting	✓
7.	Avoid complex formulas and use only one type of formula	✓
8.	Avoid circular references	✓
9.	Work with control functions	✓
10.	Present the results professionally	✓

Fig. 2.7 The top-10 financial modeling standards

5.2 150 Financial Modeling Standards

We distinguish the following five steps in the financial modeling process:

1. **Problem analysis:** Planning of the work flow, determination of the purpose of the model and the needed input data. Excel is not used in this process step.
2. **Model structure and planning:** Determination of the formatting and the labeling system as well as the structure of the work file.
3. **Model setup:** Excel implementation of the planned structure.
4. **Quality control:** Control functions to minimize errors are integrated and the entire model is checked by a third party.
5. **Model presentation:** Presentation of the results.

These five process steps of financial modeling can again be broken down into the 20 milestones which are listed below the process steps (see Fig. 2.8).

The 5 **process steps of financial modeling** (first hierarchy level) serve as guidance for the process of financial modeling and lead us step by step toward our goal while employing the 20 **milestones** (second hierarchy level) – from the definition of the task all the way to the presentation of the model in front of clients or management. Listed below the milestones are a total of 150 **recommendations for action** (third hierarchy level). The structure of Fig. 2.8 is also reproduced in the accompanying Excel work file. The Excel work file provides a list of the recommended standards and can be used by the

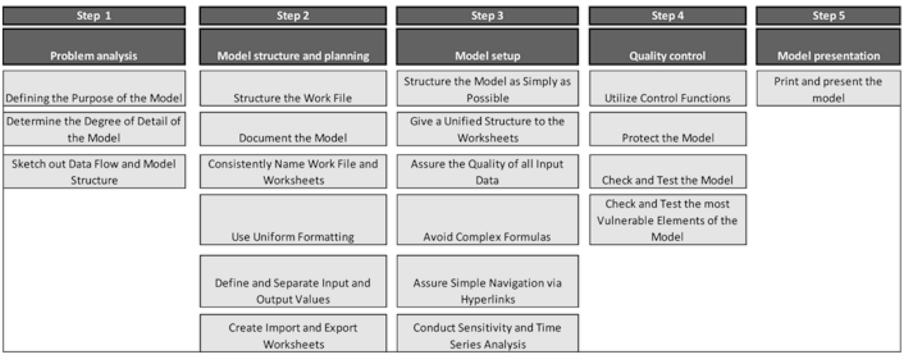


Fig. 2.8 The five process steps of financial modeling and the 20 milestones

financial modeler as a check list. This assures that the financial modeler actually adheres to all standards during the development process.

For every recommendation for action, three fields are provided in the work file:

- Yes,
- No,
- n.a. (not applicable).

Once the recommendation for action has been implemented, the field "yes" is checked in the work file. If the recommendation for action was not used, the field "No" is selected. In the notes it is briefly explained why the recommendation for action was not implemented. The field "n.a." means that the recommendation for action is not relevant for the model or that the implementation is not possible or practical. If a specific milestone is not relevant, the financial modeler can mark it with "n.a." In this case, all recommendations for action below that milestone are folded in. The milestone, however, will remain in the overview (see Fig. 2.9).

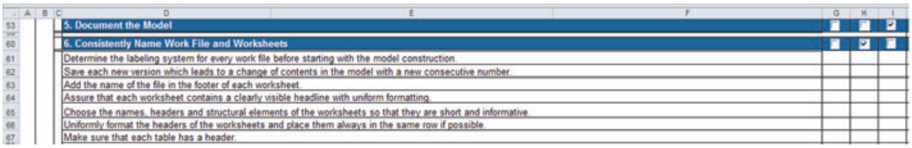


Fig. 2.9 How the Excel work file works – with reference to the example of the milestone "Documentation of the model"

In the following sections, the process steps, milestones as well as the corresponding recommendations for action are described.[12]

5.2.1 Definition of the Problem

Defining the Purpose of the Model

1. Analyze and identify the problem. Understand the task you are given.
2. Assure that a solution to the problem can be provided with the help of financial modeling.
3. Consider all information necessary for the process of modeling and determine how it can be obtained.

4. Make sure that the purpose of the model and the modeling process are coordinated with the user of the model.
5. Put the aims and the implementation plan in writing and determine the range of application of the model.
6. Make sure that your model is compatible with the Excel version of the model user.
7. Set up a project plan and timeline with clear deadlines and expected results.
8. Get agreement on the budget and the number of man-days available for the modeling process.
9. Get an understanding of the technical knowledge and skills of the final user of the model.

Determine the Degree of Detail of the Model

10. Determine the degree of detail of the model. Should the model provide a quick answer to a finance question or pursue an extensive solution path?
11. Build the model in a simple and structured fashion.
12. Determine the most important input and output variables and make use of all of them in the model. Avoid irrelevant data or calculations in the model.
13. Utilize a top down – bottom up approach. Initially determine the required output variables top-down and define the needed inputs. Construct the model bottom up from the inputs to the outputs.
14. Separate the problem into independent and less complex parts (modules). Again separate the modules into less complex submodules.
15. Continue the process of creating submodules until you have arrived at simple tasks.

Sketch out Data Flow and Model Structure

16. Generate influence diagrams. The aim of these diagrams is to visualize the relationship between inputs and outputs.
17. In the influence diagram, each variable should be used only once.

18. Demonstrate the logical links between the worksheets of the model.
19. Sketch the structure of each worksheet graphically.
20. Develop a prototype of the model.

5.2.2 Model Structure and Planning

Structure the Work File

21. Structure the work file in a way that it contains at a minimum the sections cover sheet, table of contents, management summary, assumptions and output.
22. If necessary, add the sections model documentation and diagrams to the work file.
23. Present all parts of the work file that belong together as closely linked as possible.
24. Use color coding to make it clear which worksheets share the same contents and therefore belong together.
25. List the table of contents as the second worksheet following the cover sheet in the work file.
26. Give a name to each section and each worksheet both on the tab and in the table of contents.
27. Separate inputs (assumptions) and outputs (calculations and links).

Document the Model

28. Document all types of formatting and styles of the cells used in the work file in the legend.
29. Add the following data to the cover sheet of the work file: the name of the model, the date of creation or the date of the last update, the name of the developer of the model as well as additional comments.
30. Make sure that the notes in the work file contain the following information:
    - Task and aim,
    - Current version of the model,

- Information about links to external work files,
- Description of the contents of the work file,
- Activation of functions (such as macros, iteration),
- Operating instructions.

31. Document the process of modeling with commentaries and update all commentaries regularly. Use text fields for comprehensive texts.
32. If the model has not yet been tested, clarify this in the header or footer.

Consistently Name Work File and Worksheets

33. Determine the labeling system for every work file before starting with the model construction.
34. Save each new version which leads to a change of contents in the model with a new consecutive number.
35. Add the name of the file in the footer of each worksheet.
36. Assure that each worksheet contains a clearly visible headline with uniform formatting.
37. Choose the names, headers and structural elements of the worksheets so that they are short and informative.
38. Uniformly format the headers of the worksheets and place them always in the same row if possible.
39. Make sure that each table has a header.

Use Uniform Formatting

40. Use unified formats for headings, tables and so forth in the entire work file.
41. Set up templates for the formats used.
42. Individual modules, unless they are spread out over different worksheets, are best encircled by a solid frame line. It should be thicker than the inside lines.

43. For ranges that should be separated in a table, black frame lines work well (for example, to separate subtotals and totals).
44. It is recommended to only work with thin lines between the columns. Separating lines between the columns is not absolutely necessary. Dotted lines are pleasing to the eye.
45. If columns are separated by lines, it is better for the reading flow not to use additional lines for the rows.
46. A possible variation is to use shading for every other row (such as a shade of grey) or to work with dotted lines.
47. Numbers of the same type should be formatted uniformly and separators for thousands should be used.
48. Format the numbers according to the country-specific norms. For example, negative numbers should be put in brackets in Anglo-American countries while they have a minus sign in Continental Europe.
49. As a general rule, work with two decimal places.
50. Format the cells that contain percentages using percent.
51. Select a manageable number of colors and use them consistently in the entire work file.
52. Choose a white background color for the output worksheets.
53. Use identical colors for the tab of worksheets that belong to the same section. List the colors in the table of contents.
54. For input cells that require a fixed numerical value, use, for example, orange as background color.
55. For output cells which are used for calculations or which are linked, use, for example, gray as background color.
56. Use the light yellow background color for all cells that are still being worked on. Change the color once the work has been completed.
57. Use the black font color for formulas and fixed numerical values.
58. Use the green font color for mixed contents (combination of fixed numerical values and formulas).
59. Use the green/red font color and background color for controls.

60. Format all hyperlinks of the worksheet in bold, underlined and in the color blue or format the hyperlink as a button.

Define and Separate Input and Output Values

61. Classify the worksheet either as an input worksheet or as an output worksheet, depending on its function.
62. Enter all assumptions in the assumptions worksheet.
63. Show all output in output worksheets.
64. Make sure that the worksheet for the assumptions only contains assumptions or – where it serves to support a structured presentation – simple calculations with the underlying assumptions.
65. Assure that no input data is entered into the output worksheets.
66. Assure that the input values are only entered into the worksheet that contains the assumptions.
67. Assure that input and output cells are clearly distinguished.
68. Assure that the input cells only contain fixed numerical values and no formulas.

Create Import and Export Worksheets

69. If possible avoid linking to another work file.
70. Create a diagram which displays the links between work files, if one work file is linked with more than one other work file.
71. All imported data which is linked to an external work file must be presented in a separate import worksheet.
72. All exported data which is linked to an external work file must be presented in a separate export worksheet.
73. Each import or export worksheet should only contain data from only one work file.
74. Changes in the export worksheet should only be implemented if the work file that is linked to the import worksheet is opened.
75. The import worksheet of a work file should be structured in the same manner as the corresponding export worksheet of the relevant work file.

5.2.3 Model Setup

Structure the Model as Simply as Possible

76. Initially construct individual modules. Assure that these are free of errors. Complete the model step by step.
77. Develop the work file and the worksheets according to the blueprint.
78. Activate the auto save function.
79. The work file should be set in such a way that calculations are done automatically.
80. Avoid circular references.
81. Always build every model from left to right and from top to bottom.

Give a Unified Structure to the Worksheets

82. Structuring and formatting of all output worksheets of the same type should be uniform.
83. Place similar data and information for different worksheets in the same cells.
84. Assure that each worksheet contains a header and a hyperlink to the table of contents.
85. Leave the first column and row of each worksheet blank.
86. If it helps to improve the structure, group the columns respectively rows with the Excel function *Group* in order to shorten the length of the worksheet.
87. Use the Excel function *Group* and never the Excel function *Hide*.
88. Combine the information in topical blocks if a larger number of rows on a worksheet are unavoidable. This guarantees a better overview.
89. Whenever possible, use the Excel function *Freeze Rows* in order to assure that all important information is always visible.
90. Structure the worksheet in such a way that the formulas only reference the cells above or to the left.
91. Use the same cells in different worksheets for the same purpose.

92. Do not use gridlines.
93. Make sure that the complete text is visible in one row.
94. Provide units for all numbers.
95. Design each cell in such a way that it can be determined at all times whether it is an assumption or an output.
96. Design each cell in such a way that it is always apparent whether it contains a formula, a combination of fixed values and formulas or a fixed value.
97. Protect all cells that are not allowed to be overwritten.
98. Highlight important output and summarize the most important output in the *Management Summary*.

Assure the Quality of all Input Data

99. Document the source and the type of all input data.
100. Add each individual assumption to the assumptions worksheet only once.
101. Each input cell should have a link to an output worksheet. As a general principle, assure that no input or output data is included in the work file that is irrelevant for the calculation.
102. Do not use the function *Protect Cells* for the input cells in the worksheet Assumptions.

Avoid Complex Formulas

103. Avoid complex formulas and only use one type of formula per row or column.
104. Break down complex formulas into simpler ones. Explain, where necessary, complex formulas including their interdependencies with the help of handwritten diagrams.
105. Enter every formula only once. Copy it to other cells if needed.
106. Make sure that no manual input of numerical values in formula cells takes place.
107. Adjust the affected formulas when adding new rows or columns.

Assure Simple Navigation via Hyperlinks

108. Use hyperlinks for simple navigation through the work file.
109. Always use hyperlinks if the next step of the developer of the model can be foreseen and is clearly transparent.
110. Format the hyperlinks in a way that differentiates them from the other data and can be clearly recognized in the work file.
111. Choose a text for the hyperlinks that is as short and concise as possible and reflects their purpose.
112. Assure that it is possible to jump from the worksheet *Table of Contents* to all other worksheets with the help of hyperlinks.
113. Assure that the hyperlinks are clearly visible and positioned prominently on the respective worksheet.

Conduct Sensitivity and Time Series Analysis

114. Present all assumptions for the sensitivity analysis in a worksheet called "Assumptions."
115. If possible, structure the worksheet with the assumptions for the sensitivity analysis in the same way as the corresponding worksheet with the main assumptions.
116. Display the time axis horizontally and not vertically.
117. Assure that the dates for each time series are clearly identifiable and visible.
118. Place the first period of each time series in the same column.

5.2.4 Quality Control

Utilize Control Functions

119. Conduct error controls already during the development stage and not only at the end of the modeling process.
120. Include control calculations. In the case of several control calculations, group them.
121. Place the calculations for the controls on the relevant worksheet.

122. Use control functions, checks for the validity of data, error checking, conditional formatting and protection of the worksheet to avoid the input of invalid assumptions.
123. Classify the controls either as control calculations that show the concrete numerical deviation or as binary control calculations.
124. Present the results for the various controls in a separate worksheet reserved for that purpose.

Protect the Model

125. Protect cells that are not to be changed.
126. If necessary, limit the input options for the cells.
127. Protect the work file with a password, which consists, for example, of the beginning letters of a sentence and a number.

Check and Test the Model

128. Have the model checked by a third, independent person.
129. Set up a plan for testing. What is tested and how is it tested?
130. Document the process of testing (such as errors found, final results).
131. Test a copy of the model and not the original.
132. Before you begin testing, you should develop a clear understanding of the precise working of the entire model.
133. Make sure that the model also runs on other personal computers.
134. As a reviewer, do not make any changes to the model.

Check and Test the Most Vulnerable Elements of the Model

135. Mark the cells that need to be checked again.
136. Assure that the macros run without errors.
137. Check all formulas, especially the longer and more complicated ones.
138. Find the cells that contain links to other work files.
139. Find the cells that contain formulas with mixed contents.

140. Find the cells that contain conditional formatting.
141. Find the cells that contain data checks.
142. Check that all cells are linked correctly.
143. Check the correctness of the outputs by using simple input values.
144. Check the formulas for plausibility using a calculator, your own assessment and extreme input values.

5.2.5 Model Presentation

145. As in the case of some output worksheets, you can deviate from the financial modeling standards for the worksheets that contain the presentation, if it serves to better structure the material. However, you should document all deviations.
146. If possible, use the same print scale for each printed page. Legibility of the tables including the contents should be optimal (print scale 100%).
147. Assure that the margins are identical for all worksheets (breadth and height of the margins are identical for all worksheets).
148. Print out the work file with headers and footers.
149. Make sure that the footer of each printed page contains the name of the work file, the name of the worksheet, the page number and the print date.
150. Make sure that the start of the individual worksheets (upper left) is visible on the screen when opening the worksheet.

6 Implementing the Top-10 Financial Modeling Standards with Reference to an Example

Module 2 of our book contains the following chapters: Chapter 8: Investment Appraisal; Chapter 9: Financing; Chapter 10: Corporate Finance Part I; Chapter 11: Corporate Finance Part II; Chapter 12: Portfolio Management Part I; Chapter 13: Portfolio Management Part II; and Chapter 14: Derivatives. Key element of each of these chapters is a comprehensive Excel work file, which is compiled on the basis of the financial modeling standards.

On the following pages, an applied example is used to illustrate and briefly explain the implementation of the Top-10 financial modeling standards listed in Figure 2.7. The applied example used here is based on Chapters 10 and 11 (Corporate Finance Part I and Part II) and the financial model in Excel covering Pharma Group. In the same fashion, it is also possible to derive applied examples for the 5 process steps of financial modeling, the 20 milestones as well as the 150 recommendations for action. To improve the flow of the presentation, we have limited ourselves to the top-10 financial modeling standards.

6.1 Define the Modeling Purpose

At the start of the model development process, the financial modeler is concerned about the milestone *Identification of the modeling purpose* in the context of the first process step *Problem Identification*. The analysis of the problem and the task requires substantial knowledge of finance, but not yet any specific modeling abilities. The *Identification of the modeling purpose* is of major importance for the modeling process and the final results of the financial model. Especially in the case of poorly structured problems, it is important to analyze the requirements of the model user and to get clarity about the purpose of the model. The modeling purpose should be clearly defined and determined. In order to avoid any misunderstanding, it is recommended to coordinate the aims and the details of the modeling process with the end user or the client and to put the implementation plan in writing. In our example, this is the following clearly defined modeling purpose:

In the context of an M&A project, the financial modeler received the mandate from a potential buyer of Pharma Group to conduct a corporate valuation. The potential buyer wants to acquire 100% of the publicly listed shares of Pharma Group and is interested to minimize the premium which he has to pay in addition to the current share price. The seller conducts a "controlled competitive auction"[13] and five other potential buyers are also still involved. Due diligence[14] has been conducted and the client of the financial modelers now wants to submit a binding offer. For this he needs an assessment of the corporate value from the financial modeler. Should the financial modeler arrive at a valuation range that is below the current market capitalization with his valuation exercise, his client would not submit a binding offer. But since the financial modeler presents a valuation range from €84 billion to €90 billion as the result (see Chapter 11: Corporate Finance Part II), it can be assumed that the client will submit a binding offer. In summary, the modeling purpose can be defined as the request of the client to obtain a valuation assessment from the financial modeler.

6.2 Separate the Problem into independent Subsections (Modules)

The task given to the financial modeler is the derivation of a valuation range for Pharma Group. He only has one week to complete this assignment and is under pressure. This situation is comparable to that of a mountaineer who faces the challenges of climbing a very steep mountain. An old rule of mountaineering says: "Do not look up to the summit, but instead break down the journey into smaller stages and only think from one stage to the next." As displayed in Fig. 2.10, the financial modeler, who is at the starting point and faces the mountain, will not look up to the summit and into the sky. The challenge would lack structure and appear overwhelming. Instead, he will break down the journey into smaller stages. He will set up a basecamp and define significant points as milestones.

This important insight will also be utilized in financial modeling. The process of obtaining a valuation range will be separated into important modules. In our case, the valuation methods are defined as a first step:

1. Discounted cash flow method
2. Market capitalization and book value
3. Trading multiples
4. Transaction multiples

This structure is still very rough. The discounted cash flow method can be broken down further and the sub-modules planning, cash flow calculation, calculation of the cost of capital and valuation with the WACC approach, APV approach and equity approach can be defined. The calculation of the cost of capital, for example, can again be broken down into further sub-modules

Fig. 2.10 Modules help you to get to the top[15]

such as cost of equity, cost of debt capital and capital structure. The cost of equity capital can be compartmentalized further in riskless rate of interest and risk premium. The individual modules are broken down into additional sub-modules until the entire complex problem has been turned into a series of simpler issues that can no longer be reduced. The solutions to these sub-modules are again aggregated in order to solve the entire complex problem.

Each module may extent over several worksheets, which can contain additional sub-modules. For the corporate finance chapter, the work file has the following structure (see Fig. 2.11):

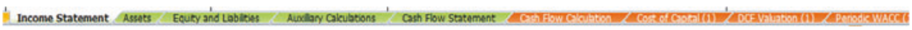
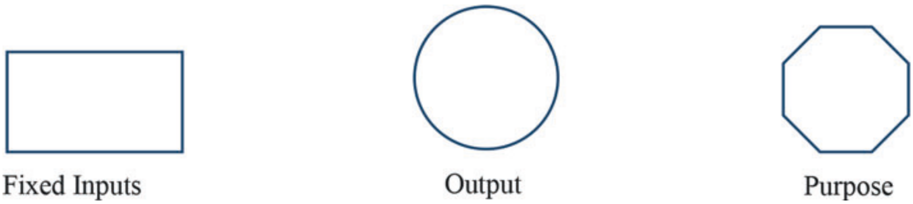


Fig. 2.11 The structure of the work file in the corporate finance chapter using the example of the valuation method "DCF period-specific WACC approach"

6.3 Provide a Graph of the Flow of Data and the Model Structure

Flow of data:
Particularly complex and unstructured tasks make it more difficult to recognize the relationships between inputs and outputs. An influence diagram serves to visualize the linkages and to demonstrate how the input factors affect the results. Even though the influence diagrams do not provide a solution for the problem, they help to clarify the structure and the task. They are employed at the beginning of the modeling process, before Excel has even been opened.[16]

The starting point of the influence diagram is the output value. This means that each output is broken down into independent components which have a direct influence on it. These components can also be output variables from other parts of the model. The presentation of the individual components using different symbols helps to illustrate the model structure. Powell/Batt, for example, use the following symbols which will also be employed by us[17]:



The setup of influence diagrams is presented in the context of the deviation of the weighted average cost of capital (WACC). Figure 2.12 shows the input values which influence the weighted average cost of capital.

The WACC, which is the output variable, consists of four elements: cost of equity and cost of debt after taxes, percentages of equity capital and debt capital. The cost of equity is directly influenced by the business risk and the riskless rate of interest. The riskless rate of interest is a fixed input value which is an assumption in the model. The business risk is determined by two inputs and is thus an output represented by an oval. Both the percentage of equity capital and the total capital depend on equity capital. The equity capital is only included once in the diagram and is also a fixed input value.

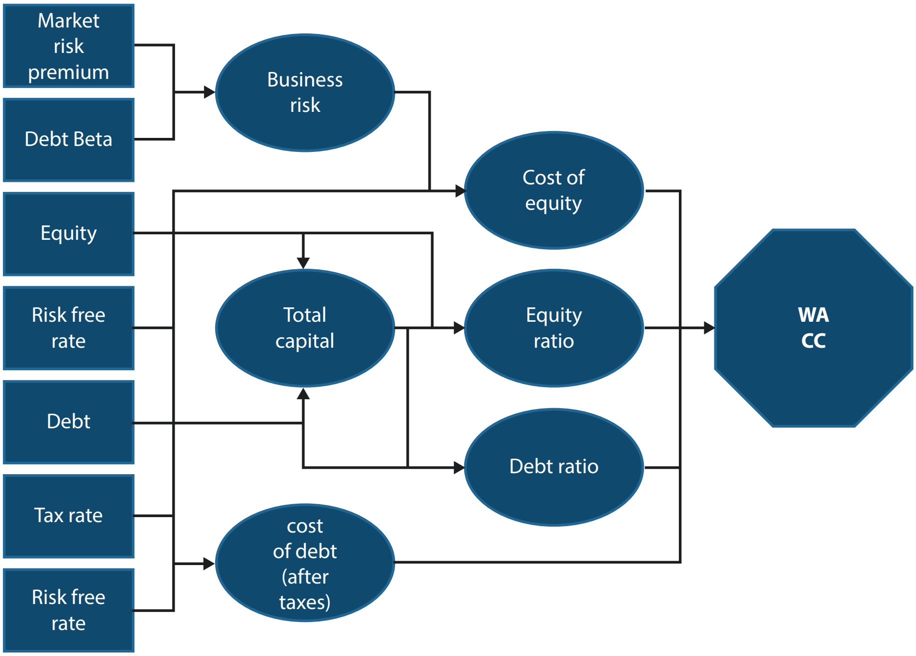


Fig. 2.12 The influence diagram for the determination of the weighted average cost of capital (WACC)

The diagram focuses on the relationship between variables and not on their contents. It helps to identify relevant parameters and allows the immediate elimination of irrelevant parameters from the model.

Model structure:
Now that the flow of data has been mapped, the financial modeler will establish the model structure. Major problems will arise if a model is implemented incorrectly in Excel by the financial modeler. This type of error is almost impossible to detect or to correct after the fact. Therefore it is recommended to initially structure the task with pencil and paper (the same also holds for the influence diagrams in the case of more complex financial models). We use the example of the link of the integrated profit and loss statement with the assets and liabilities in the balance sheet of Pharma Group. The financial modeler provides a handwritten overview of the structure which looks as follows (see Fig. 2.13):

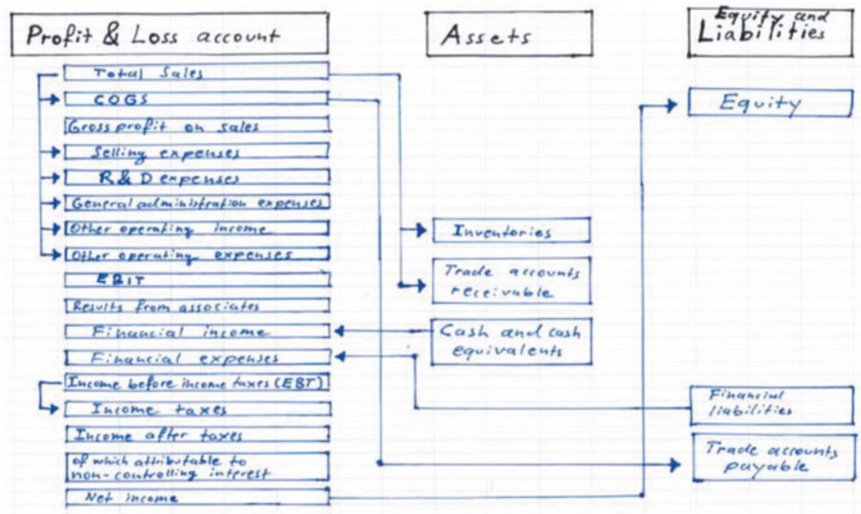


Fig. 2.13 Central links of the profit and loss statement with assets and liabilities on the balance sheet of Pharma Group (handwritten)

Figure 2.13 makes it clear that interest bearing liabilities (cash and cash equivalents) serve as the basis for interest expense (interest income). The liabilities from trade accounts payable depend on the cost of goods sold. A positive result of the group can – depending on the policy for retaining earnings – increase the equity capital. The two items in current assets, namely "inventories" and "trade accounts receivable" again depend on sales. Numerous items in the profit and loss statements are in turn linked to sales: cost of goods sold, selling expenses, research and development expenses, general administration expenses, other operating expenses as well as other operating income. Earnings before taxes (EBT) serve as the base for assessing income taxes.

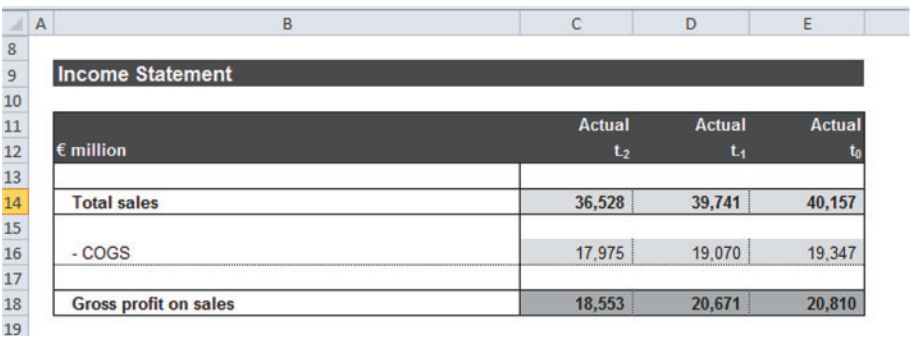
It also becomes clear that the financial modeler uses exactly the same terminology as in the case of Pharma Group. He talks about net income and not about the net result. The handwritten overview of all linkages between the profit and loss statement and assets and liabilities on the balance sheet of Pharma Group will be transferred by the financial modeler to Excel at a later point in time. The concrete modeling steps in Excel will be shown in Chapters 10 and 11 (Corporate Finance Part I and Part II).

6.4 Separate Inputs from Outputs

The separation of inputs and outputs is of primary importance among the top-10 financial modeling standards. Anybody who ever worked with a financial model where this standard was ignored will easily understand this. An Excel model which does not follow this standard can simply not be used. The standard can be specified in more detail as follows:

1) **At the level of worksheets:** Separate worksheets with inputs from worksheets with output!
   a) In our example a worksheet called `Assumptions` serves as the worksheet for all inputs. No other input worksheets exist. Depending on the size and focus of the work file, it can also contain more than one worksheet for input variables.
   b) In our example, all worksheets to the right of the worksheet `Assumption` as well as the worksheet `Management Summary` contain output.
2) **At the level of cells:** Separate hard coded cells from formula cells and cell references! In the worksheet `Assumptions` for this case study, all hard coding cells (such as `E14`) are highlighted in the color light orange, while all formula cells and cell references (such as `E18`) are marked in light grey.

Figure 2.14 clarifies that by definition hard coding cells dominate in the input worksheet. Depending on the aim of the financial model, it can be necessary to also use formula cells and cell references in addition to hard coding cells in the input worksheet. As an example,



Income Statement			
€ million	Actual t_2	Actual t_1	Actual t_0
Total sales	36,528	39,741	40,157
- COGS	17,975	19,070	19,347
Gross profit on sales	18,553	20,671	20,810

Fig. 2.14 Hard coding cells and formula cells/cell references

cell `E18` could also be a hard coding cell, in which case the financial modeler would take the number for gross profit on sales from the annual report of Pharma Group. But in this specific case, the financial modeler decided to use a formula and calculate the gross profit on sales as the difference between sales and cost of goods sold. Hence the cell is marked as a formula cell.

However, this does not work the other way around! Hard coding cells in output worksheets are among the “mortal sins” of financial modeling. Hard coding cells are to be used exclusively in input worksheets. They have no place in output worksheets! The financial modeler wants to manage the calculations in the entire work file with his input worksheet. The input worksheet serves as his cockpit. A hard coding cell in an output worksheet means that the commands from the cockpit will not be implemented correctly and that the modeling results are faulty.

6.5 Choose a Unified Layout for the Worksheets

In a financial model, all worksheets of the same type share a unified layout. This refers specifically to standardized positioning, formatting and display of

✓ Headers for the worksheets,

✓ Hyperlinks,

✓ Columns and rows,

✓ Input cells for data,

✓ Grouping of rows or columns as well as the,

✓ Zoom and the screen settings.

Important aspects of this standard are presented with reference to Fig. 2.15:

One aspect of this standard is to leave the first column and the first row of the worksheet blank. If the first row and the first column of the worksheet are empty, it is easier to add new columns or rows. In addition, in all worksheets of the financial model, a fixed column is assigned to each year. In the case of Pharma Group, this means that the year t(1) is in column F in all worksheets.

Income Statement

€ million	Actual t_2	Actual t_1	Actual t_0	Plan t_1	Plan t_2	Plan t_3	Plan t_4	Plan t_5	Plan TV
Total sales	36.528	39.741	40.157	42.566	45.120	47.828	50.697	51.711	52.745

Assets

€ million	Actual t_2	Actual t_1	Actual t_0	Plan t_1	Plan t_2	Plan t_3	Plan t_4	Plan t_5	Plan TV
Goodwill	9,148	9,293	9,862	9,862	9,862	9,862	9,862	9,862	9,862

Equity and Liabilities

€ million	Actual t_2	Actual t_1	Actual t_0	Plan t_1	Plan t_2	Plan t_3	Plan t_4	Plan t_5	Plan TV
Subscribed capital of Pharma Group	2,117	2,117	2,117	2,117	2,117	2,117	2,117	2,117	2,117

Fig. 2.15 Unified layout of the worksheets for Pharma Group

Figure 2.15 also makes it clear that the headings of the individual output worksheets are uniformly structured and formatted (for example, cells `B2` and `B5`), similar data and information in different worksheets is found in the same cells (for example, cell `E7` contains current sales, the current goodwill or the current subscribed capital of Pharma Group), the work file contains hyperlinks to the table of contents (cell `L5`), no gridlines have been used, the entire text is visible inside cells, it can be determined easily for each cell whether it is an assumption or an output, color coding makes it clear whether the individual cells contain a formula, a combination of fixed values and formula or fixed values.

It is furthermore recommended to group several rows or columns in more complex work files if the data and calculations in that section are of minor interest to the developer of the model or if the length of the worksheet needs to be reduced. However, rows or columns should never be hidden, since this involves the danger that the user of the model ignores or overlooks them.

If it is impossible to reduce the length of complex worksheets in a way that allows visibility of the entire contents without the need to scroll down, the financial modeler can use the function "Fix Rows" so that the most important information will always be on the screen.

6.6 Use Unified Formatting

Unified formatting helps the financial modeler to develop clearly structured work books. The following five design elements are particularly important:

1. Headers
2. Cell colors
3. Lines
4. Numbers
5. Font colors

The importance of these design elements is shown with the help of Figs. 2.16 and 2.17:

Assets

I million	Actual t-2	Actual t-1	Actual t0
Goodwill	9,148	9,293	9,862
Other intangible assets	10,284	9,464	8,914
Property, plant and equipment	9,887	9,898	10,015
Investments accounted for using the equity method	265	225	203
Other noncurrent assets	1,773	1,849	1,699
Deferred taxes	1,312	1,579	1,596
Noncurrent assets	**32,669**	**32,308**	**32,289**
Inventories	6,370	6,991	7,129
Trade accounts receivable	7,060	7,433	7,569
Other assets	4,876	2,888	2,668
Cash and cash equivalents	1,771	1,698	1,662
Current assets	**20,077**	**19,010**	**19,028**
Total assets	**52,746**	**51,318**	**51,317**

Equity and Liabilities

I million	Actual t-2	Actual t-1	Actual t0
Capital stock of Pharma Group			
Capital reserves of Pharma Group	6,167	6,167	6,167
Other reserves	8,442	7,764	9,245
Net income	2,470	2,403	3,189

Fig. 2.16 Example for headers, cell colors, lines and numbers

Discounted Cash Flow (DCF) Valuation in accordance with the WACC Approach

€ million	Actual t_0	Plan t_1	Plan t_2	Plan t_3	Plan t_4	Plan t_5	Plan TV
WACC	5.95%						
Discount factors		0.944	0.891	0.841	0.794	0.749	0.749
Operating free cash flows		2,952	3,083	3,268	3,464	4,219	4,303
Terminal value							108,861
Present value of operating free cash flows		2,786	2,747	2,748	2,749	3,160	
Present value of terminal value							81,528
Enterprise value	95,717.4						
+ Non operating assets	-						
+ Cash and cash equivalents	1,662						
+ Investments accounted for using the equity method	203						
Entity value	97,582						
- Interest-bearing liabilities	16,399						
Equity value (incl. equity attributable to non-controlling interest)	81,183						
- Equity attributable to non-controlling interest	86						
Equity value	81,097						

Fig. 2.17 Examples of different font colors

1) **Headers:** Figure 2.16 makes clear that the financial modeler selects uniform formats for the headers. In this case, dark blue serves as the background color. The preferred color of the writing is white. Depending on the hierarchy level of the headers, the font size and the features bold or cursive are selected.

2) **Cell colors:** It also becomes clear that the financial modeler only selects a few colors, which are used consistently across the entire work file. Orange is used for all inputs (such as `E57`). These values are entered individually and constitute the assumptions made by the user. All calculations and output data have a dark grey background (such as `E71`). The light yellow background color is used for cells that are still being worked on (such as `E82`). Once the work on the cell has been completed, the background color needs to be changed to orange or dark grey. White is used consistently as a basic background color.

3) **Lines:** Figure 2.16 furthermore shows that individual modules that are not distributed over several worksheets (such as all assets of Pharma Group) are enclosed with an uninterrupted frame line. Areas that need to be separated among the assets (such as noncurrent assets in row 64, which are the sum of the positions above) are separated with black frame lines. The individual cells are separated by dotted lines instead of gridlines.

4) **Numbers:** As can be seen, the numbers are formatted uniformly. All values are stated in EUR million and thousands separators are used. Cells such as `E15` (see Fig. 2.17) are formatted as percentages. Normally, two decimal places are displayed.
5) **Font colors:** As can be seen in Fig. 2.17, the color black is used for formulas and fixed values (such as `E15`). Mixed formulas that contain both fixed numerical values and formulas are characterized by the font color green (such as `F16`). The green respectively red font color and background color can be used for controls, as shown in the part about the model review.

6.7 Avoid Complex Formulas and Use Only One Type of Formula

The standards about formulas and calculations support user-friendly modeling. Long formulas are hard to create, difficult to comprehend and a major source of error. For that reason it is desirable to partition long formulas into short ones. As Fig. 2.18 illustrates, the long formula for the calculation of the weighted average cost of capital (WACC) is broken down into smaller calculations. To calculate the WACC, only a few steps are needed: the cost of equity capital of the levered company (cell `E19`) is multiplied with the equity ratio based on market values (cell `E36`) and the cost of debt after taxes (cell `E31`) is multiplied with the debt ratio based on market values (cell `E37`). Finally, the two terms are added.

A more complex, but equally valid solution would be to combine all input variables in just one formula:

```
(E14 + E16 * E17) * (E36) + ((E24 + E25 - E29) * E37).
```

In the extreme, the WACC could be calculated by putting all the operations described above in just one formula as shown in Fig. 2.19:

It becomes apparent that the likelihood of errors goes up exponentially as the complexity of the formulas increases and different types of formulas are combined.

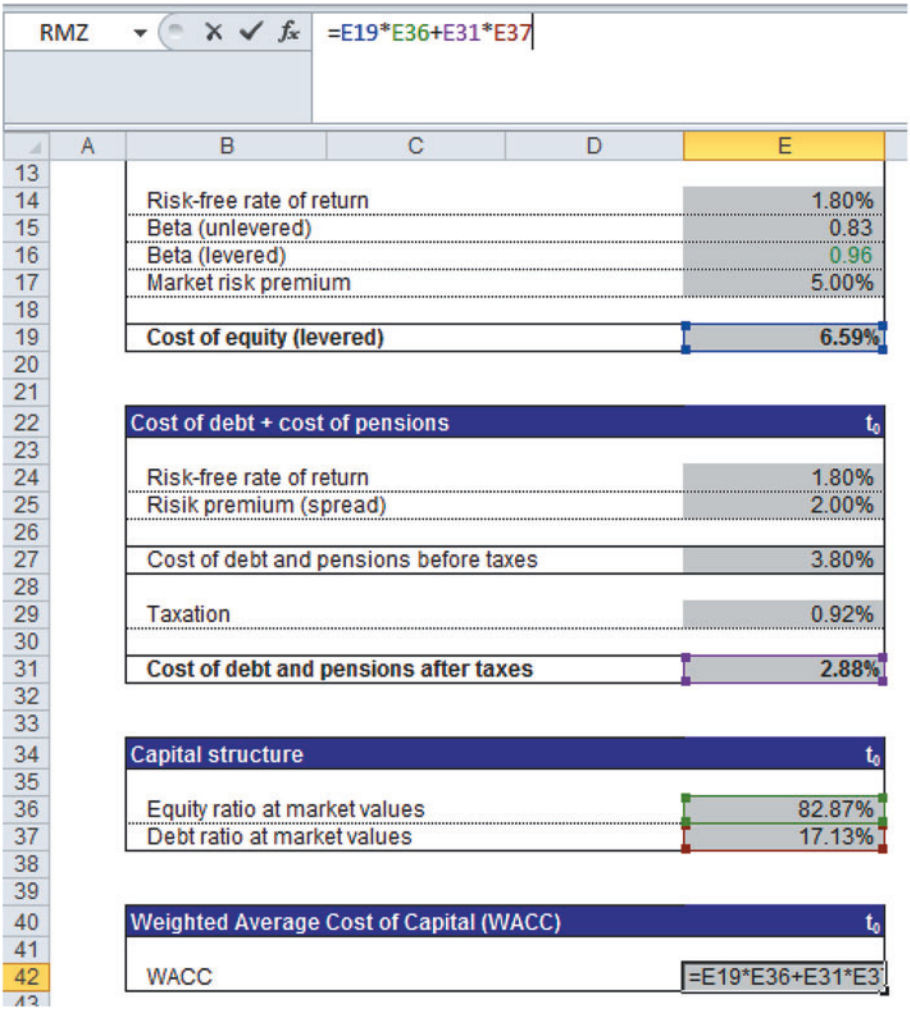


Fig. 2.18 Calculating the WACC of Pharma Group

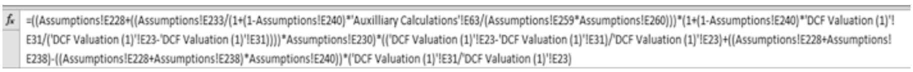


Fig. 2.19 Calculating the WACC of Pharma Group in one cell without compartmentalizing the formula

6.8 Avoid Circular References

A circular reference appears each time a formula or function references itself. The formula `=A1+1`, for example, contains a circular reference if it is entered in cell `A1`.

Circular references (see Fig. 2.20) are created quite frequently in financial modeling if changes are made to the table structure. This can happen if cell ranges, columns, rows or cell contents is deleted or inserted. In this case, the warning *Circular Reference* is displayed immediately. The financial modeler is made aware of the problem and can take appropriate measures to fix it immediately.

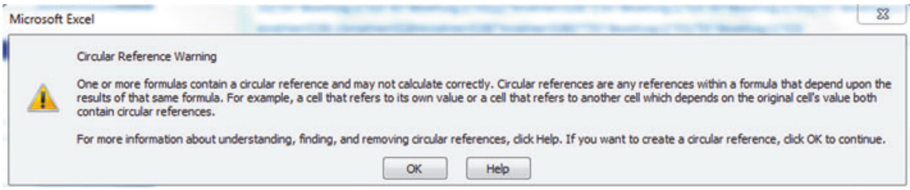


Fig. 2.20 Circularity warning

More severe than the circular references that appear because of such an error are circular references as a consequence of ignoring the financial modeling standards. They lead to unstructured models were the values reference each other. The best way to avoid circular references is to adhere to the financial modeling standards.

In a few cases, circular references are required and are added to the model on purpose. A typical example is the solution of the circularity problem in corporate valuation, which we will discuss in detail in the Corporate Finance chapter. In applied valuation work, the circularity problem is solved with the help of mathematical iteration.

6.9 Work with Control Functions

Control functions are important tools to catch errors early on during the modeling phase and to increase the reliability of the model. They give the modeler important information about the correctness of the input and output values and the calculations implemented. Several types of controls are available and their appropriateness depends mainly on the modeling purpose. The controls are best included as the various modules are created and not only upon completion of the model. This has the advantage that the controls on the one hand alert the developer of the model to the more error-prone parts of the formula and on the other hand assure that the later modules are based on error-free predecessors.

The implemented controls lose their value if their results are not communicated to the financial modeler. The red and bold font for the warning signal as well as the summary of the results of the controls which are placed in the field of vision assure that the developer and the user of the model are always aware of the information provided by the controls. In the following the working of the control function is explained with reference to the binary controls in the cash flow calculations for Pharma Group. If the control calculations are satisfactory, the word "OK" is shown in green letters against a green background (see Fig. 2.21).

	A	B	C	D	E	F	G	H	I	J	K
44											
45		**Net cash flow**				**1,242**	**1,390**	**1,589**	**1,798**	**2,042**	**2,102**
46											
47		Liquidity 01.01				1,662	2,904	4,294	5,884	7,682	9,724
48		Liquidity 31.12			1662	2,904	4,294	5,884	7,682	9,724	11,826
49											
50		**Change**				**1,242**	**1,390**	**1,589**	**1,798**	**2,042**	**2,102**
51											
52		Check				OK	OK	OK	OK	OK	OK
53											

Fig. 2.21 Binary control calculations in the worksheet "Cash Flow Calculation" for Pharma Group

Figure 2.21 shows that the net cash flow (`Row 45`) is calculated in the context of the consolidated statements of cash flow of Pharma Group. The change in liquid funds (`Row 50`) between end of the year (31. December – (`Row 48`)) and beginning of the year (01. January – (`Row 47`) must be exactly equal to the net cash flow. If this is the case in all years, the balance sheet is in equilibrium. If this is not the case, the financial modeler has made a mistake when setting up the planning. In our case, the worksheet for the balance sheet of Pharma Group in `Row 52` provides the output that there were no deviations among the positions. The balance sheet is in equilibrium.

6.10 Present the Results Professionally

An experienced financial modeler does not only provide reliable output, but is also able to derive a clear central message from the complex model. The task is not only to clearly structure complex topics, but also to present them convincingly. The worksheet "Management Summary" serves to present the results of the financial models in an attractive fashion. For that reason, it is the only worksheet in the work file where deviations from the financial modeling standards are allowed.

In order to present the different results obtained with the various valuation methods in a clear and concise manner, the financial modeler can make use of the so-called football field graph for the management summary. The football field graph helps to display the results to management in a way that is easily understood. The valuation results which are obtained by applying the various valuation methods are compared in a clear and structured manner. Nonetheless, a football field graph does not yet show the central message. Management wants to know if and at what price the valuation object should be purchased. What is the highest price the potential buyer can offer in negotiations with Pharma Group and what is his so-called "walk away price?" The question can be answered by the financial modeler by including the valuation range for the company (€84 billion to €90 billion) as well as the potential walk away price (€100 billion) into the document. This leads to the following football field graph (see Fig. 2.22):

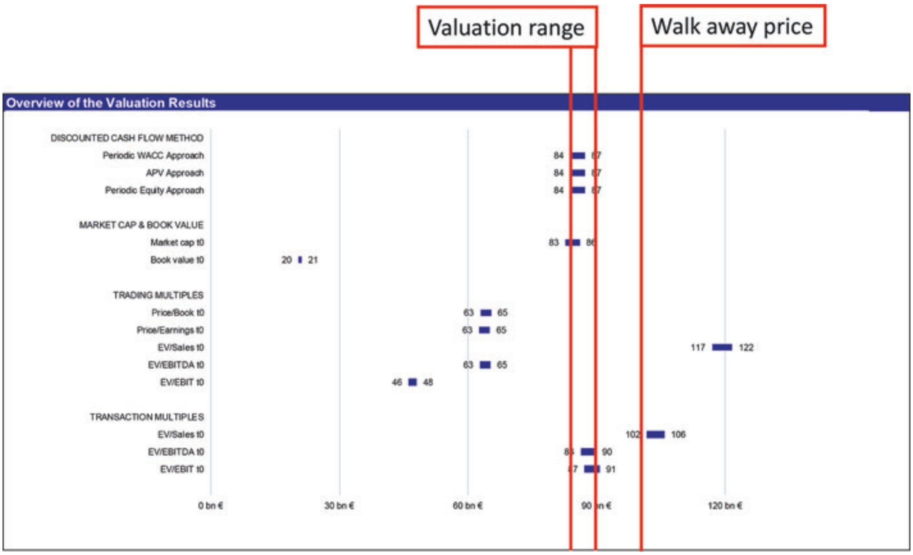


Fig. 2.22 The football field graph of Pharma Group

7 Summary

In the Financial Modeling standards chapter the financial modeler was provided with an overview of

- the fundamentals of financial modeling,
- the financial modeling literature,
- the financial modeling standards,
- as well as their implementation.

Foundations of financial modeling:

- Models are simplified representations of reality.
- The abstract presentation of complex objects, processes or structures serves to identify relevant linkages and characteristics and to reduce complexity.
- Advantages of models as compared to real objects include efficiency, time savings, feasibility and decision support, reduced risk, additional insights and knowledge transfer.
- At a minimum, a task list should cover the following points: functionality, prerequisites, timeline, quality criteria and documentation.
- The use of modules is a method that breaks down complex tasks into smaller, simpler and independent components. The solution progresses from big picture to detail, from abstract to concrete.

Modules offer a number of advantages: due to their size they are more transparent, have a simpler structure and are therefore easier to comprehend than the entire task. Additionally it is easier to do the calculations, the financial model can be more easily improved and expanded, teamwork is facilitated, modules with lower priority can be pushed back and modules can serve as blueprints for other tasks.

Financial modeling literature:

- The following three categories of financial modeling literature can be distinguished: textbooks on the topic of financial modeling, best practice financial modeling standards as well as specialized IT literature (the latter is not relevant for our purposes).
- Textbooks on the topic of financial modeling mainly deal with financial modeling approaches and techniques and frequently also

offer Excel-based cases. Best practice financial standards for financial modeling mainly focus on modeling techniques and the process of modeling.

- The following outstanding textbooks were considered in more detail: Barlow (2005), Benninga (2014), Day (2012), Powell/Baker (2009), Powell (2008), Read/Batson (1999), Rees (2008), Sengupta (2010), Swan,(2008), Tjia (2009).
- With regard to the best practice financial standards, the Spreadsheet Standards Review Board (SSRB), the European Spreadsheet Interest Group (EuSpRiG) as well as the FAST Standard Organisation are most important.
- The "House of Financial Modeling" consists of the following three modules: "Financial Modeling Standards," "Financial Modeling Tools" as well as "Practical Applications of Financial Modeling." There are three stages on the way toward proficiency in financial modeling: Module 1: The first two columns of the "House of Financial Modeling" (Chapters 2–7 of this book); Module 2 covers the third column of the "House of Financial Modeling" (Chapters 8–14 of this book) and in module 3 the theoretical knowledge is applied and a financial model is created in Excel.

Financial modeling standards:

- Provided are 5 process steps of financial modeling, 20 milestones and 150 recommendations for action in financial modeling. The financial modeler can structure his model according to these standards.
- Only the application of the financial modeling standards combined with current knowledge of finance and the application of the model review bring the financial modeler close to his target of compiling an Excel work file that has an error rate of 0%.
- At the level of process steps and milestones, the standards are structured as pointed out in Fig. 2.23:

Implementation of the financial modeling standards:

- The implementation of the financial modeling standards is shown with reference to the following top-10 financial modeling standards:
  1. Define the modeling purpose

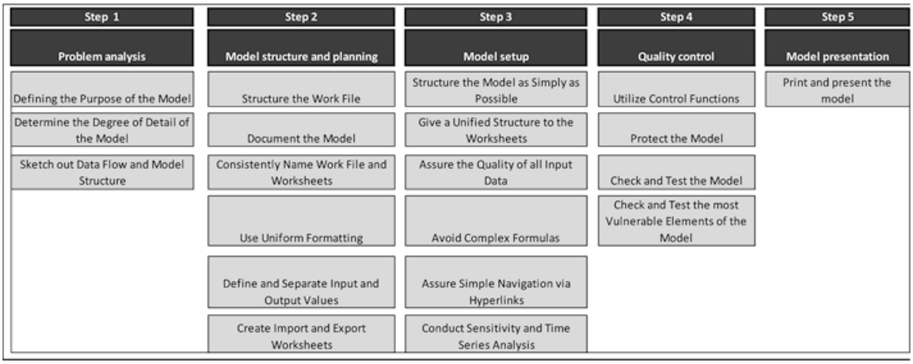


Fig. 2.23 The five process steps of financial modeling and the 20 milestones

2. Separate the problem into independent subunits (modules)
3. Provide a graph of the flow of data and the model structure
4. Separate inputs from outputs
5. Choose a unified layout for the worksheets
6. Use unified formatting
7. Avoid complex formulas and use only one type of formula
8. Avoid circular references
9. Work with control functions
10. Present the results professionally

Notes

1. See ICAEW (Institute of Chartered Accountants in England and Wales): http://www.icaew.com
2. The specific IT literature will not be considered in detail in the context of this book as it is outside the scope of business management.
3. See Powell/Batt (2008), p. 7; Read/Batson (1999), p. 1; Tjia (2009), p. 15.
4. See, for example, Read/Batson (1999) and Powell (2008).
5. See, for example, Spreadsheet Standards Review Board (2013) and Benninga (2014).
6. In addition to the approaches that are considered in more detail in the following figure, these influential textbooks also deserve to be mentioned: Benninga, S. (2011); Fabozzi, F. (2012); Fabozzi, F. J./Focardi, S. M./Petter N. K. (2006); Fairhurst, D. S. (2012); Graham, R. E. (1997); Ho, T. /Sang B. L. (2004); Holden, C. W. (2014); Jackson, M. / Staunton, M. (2001); Lynch,

P. (2010); Mayes, T. R. /Shank, T. M. (2011); Ongkrutaraksa, W. (2006); Pignataro, P. (2013); Proctor, S. (2009); Soubeiga, E. (2013); Winston, W. (2014).

7. See Day (2012) pages 79-80.
8. Spreadsheet Standards Review Board (2013) p. 9.
9. See Powell/Baker (2009) pages 52-94; Rees (2008) pages 1-48; Tjia (2009) pages 83-106.
10. See, for example, Powell/Batt (2008).
11. See Grossman/Özlük (2010) p. 1.
12. The basis for the 150 recommendations for action is provided by the literature listed in section 4 as well as the personal experience from corporate finance transactions of the authors and the German Institute of Corporate Finance (for additional information see www.gicf.de). In the literature, especially the eleven selected modeling approaches are utilized. Among these eleven modeling approaches, the publication of the Spreadsheet Standards Review Board (2013) plays a prominent role and should be considered as a path-breaking contribution.
13. See Ernst/Häcker (2011), pages 25-26.
14. See Ernst/Häcker (2011), pages 331-357.
15. Sourcee: Template "Journey to the top" from "prezi.com" as well as presentation of the milestone by the authors.
16. See Powell/Baker (2009), pages 26 following.
17. See Powell/Batt (2008), p. 20.

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3
Model Review

1 Executive Summary

The financial modeler has developed a financial model and now faces the challenge of assessing its quality in the context of the model review. The necessity to conduct a model review follows primarily from quality management. The financial modeler needs to assure that the financial model which he developed is free of errors, user friendly and works reliably. In the case of models that are built for third parties, there is an additional liability risk, which can be reduced through a careful model review.

The most important prerequisite for an efficient and successful model review is the adherence to financial modeling standards when building the model. Financial models that are not based on the financial modeling standards cannot be checked reliably during the model review process.

Models which do not fulfill the financial model standards and were not subject to a model review process should not be used internally, during consulting projects or passed along to third parties.

Models can contain different types of errors. Incorrect inputs or the flawed use of algorithms can be identified during the model review process. But mistakes that are caused by an incorrect modeling of economic relationships are very hard to detect. An additional complication during the model review process follows from the fact that no master model exists, which can serve as a baseline for the financial model.

J. Häcker and D. Ernst, *Financial Modeling*,
Global Financial Markets, DOI 10.1057/978-1-137-42658-1_3

The financial modeler has a number of instruments in Excel at his disposal, which facilitate the model review process. Specific model review software facilitates systematic error checking and should utilized in all cases were a professional model review and audit is conducted.

2 Introduction, Structure and Learning Outcomes and Case Study

Structure

This chapter is an introduction to the model review process and answers these questions:

- What is meant by model review?
- What is the difference between model review and model audit?
- What types of errors exist and what types of errors are made in financial models?
- How can errors in financial models be recognized?
- Which types of analysis tools exist and how are they used in applied work?
- What are the options provided by Excel for reviewing models?
- What are the limits of Excel with regard to reviewing models?
- Which additional functions are provided by professional model review software?
- What contributions can control calculations make in the process of reducing errors?
- How are models checked for plausibility?
- How is the model review process documented professionally?

Learning Outcomes

The practical implementation of reviewing a model is taught with examples from the corporate finance chapter. The financial modeler

- Can state and critically assess the importance of the model review for financial modeling,

- Is familiar with the financial modeling standards for the model review process,
- Can list types of errors and put their importance for the model review in perspective,
- Acquires the tools necessary to conduct a model review with Excel and a professional model review software,
- Is able, based on an understanding of these tools, to identify and eliminate errors in the financial model,
- Is able to set up control calculations and to incorporate those into the financial model,
- Can independently assess the plausibility of model results with the instruments of sensitivity analysis and scenario analysis,
- Can discuss the model review process at a professional level and
- Is able to steadily improve his knowledge of financial modeling through critical model review.

Case Study

The Excel applications and functions from the program Operis Analysis Kit (OAK) within the Chapter Model Review refer to the case study "Pharma Group" in the Corporate Finance chapter. The parts "Financial Modeling Standards" and "Corporate Finance" also utilize this case study. The three parts "Financial Modeling Standards," "Model Review" and "Corporate Finance" are very closely linked. For specialists in corporate finance, these three parts constitute the main tools for their work in companies, banks or investment banks, auditing firms or boutiques.

3 Fundamentals of Model Review

3.1 The Term "Model Review"

> Model review improves the quality of financial models.

Reliability, absence of errors, user-focus, and flexibility are key attributes of financial models. Professional evaluators of financial models analyze and scrutinize the financial model during the model review process, conduct various testing procedures, identify weaknesses and make suggestions for improvement. The primary goal of the model review stage is the improvement of the financial model's quality by revealing as many errors as possible.

Model audit is a complete model review that includes certification.

In applied financial modeling work, a distinction is made between model review and model audit. Model review and model audit are distinguished primarily due to the quality of the test results. In the context of the model review, an assessment of the financial model is conducted within a predefined framework. Additionally it is possible to only test parts of a model during model review. Any model review can be conducted both internally as well as externally. In the context of a model audit, a complete assessment of the financial model is conducted, at a minimum with a focus on the base case. This complete review is conducted by an external auditor who certifies the model. A certification in the context of the model audit can only be awarded if the financial modeling standards have been observed and are documented. Figure 3.1 summarizes the differences between model review and model audit:

Model Review	Model Audit
Assessment of the financial model in a predefined framework	Complete evaluation of the financial model (base case at a minimum)
It is possible to review only components of a financial model	Review by an external auditor plus certification
Model review can be done both internally and externally	A certification in the context of the model audit requires that the standards of financial modeling have been observed and are documented

Fig. 3.1 Differences between model review and model audit
Source: following PwC, 2014, p. 8.

The need for a model review follows from the high error rate of financial models. The authors of various studies concluded that errors in models are not the exception but rather the rule[1].

A meaningful unit of measurement is the Cell Error Rate (CER). The CER provides the ratio of faulty cells to total cells used in a financial model. For errors that are not related to poor design or layout, this number varied between 0.1% and 6.7%. The auditing firm PwC also determined that the quality of financial models is frequently unsatisfactory in applied work. Approximately 90% of all complex financial models contain serious errors that change the result by more than 5%, and 60% of the models suffer from a deficient structure and 70% of the companies do not conduct any type of formal quality control.[2] According to one study,[3] developers who work on complex tasks such as financial models have a success rate of 95% to 98% for all cell entries. This means that between 2% and 5% of all cell entries are faulty. Only 50% to 80% of all errors are caught according to that study. In order to reduce the overall level of errors in the financial model, it is mandatory to increase the precision of the inputs during the development stage. Furthermore it is mandatory to improve the success rate for capturing errors by implementing suitable methods of verification.

Such a substantial error rate in financial models appears unrealistic at first glance, but it is consistent with empirical studies about human error rates in complex tasks. When executing simple tasks such as typing, about 0.5% of undetected errors remain in every activity. For more complex activities such as writing source code or developing complex financial models, the error rate goes up to 5%.[4]

There are numerous reasons for the high error rates in financial models. Frequently cited explanations include a lack of general awareness as well as a missing acceptance and application of the previously presented financial modeling standards.

3.2 Steps in the Model Review Process

> The comprehensive review of financial models can reduce the likelihood of errors and increase their acceptance.

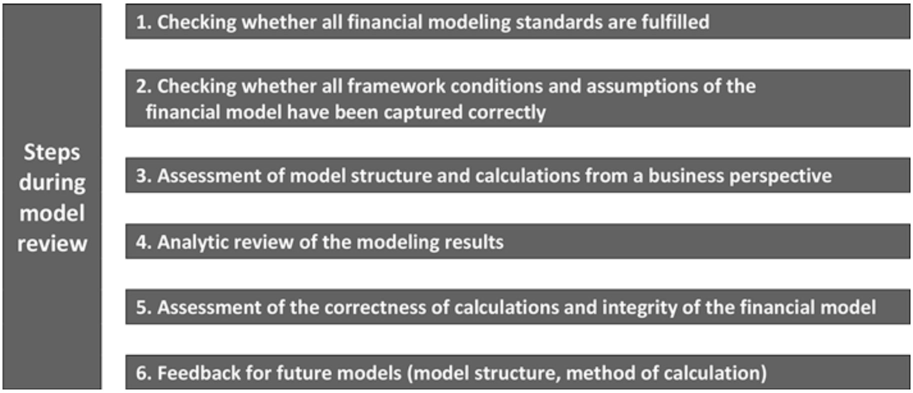


Fig. 3.2 Steps during model review

The most important aim of any model review is quality assurance. The model review comprises the following steps (see Fig. 3.2):

Initially, it must be assessed whether the **financial modeling standards** were fulfilled when the model was established. In this context, the documentation which was presented under the financial modeling standards is used. Strict application and documentation of the financial modeling standards is the central requirement for a professional model review. Financial models which are not based on the financial modeling standards, cannot be audited at all or require an inordinate expense of time and money. When in doubt, it is recommended to completely redo the existing model in line with the financial modeling standards. This is the only way to achieve the aim of quality assurance.

In the second step, it is analyzed whether the **framework conditions** of the financial model have been captured adequately. This step specifically assesses whether the financial model is suitable for the requirements of the individual projects. In addition, the correct implementation of the model assumptions is verified.

In the third step, it is assessed whether the **economic framework conditions** are reflected correctly in the model structure and the model calculations. This step is one of the most difficult tasks during the model review, since it clearly goes beyond the purely technical aspects and requires a deep understanding of methodologies and empirical facts by the assessor.

In the fourth step, the model results are checked for plausibility in the context of an **analytical review**. This review serves to assess whether the results of the model are reasonable and whether they show the expected reaction to changes in the input variables. Scenario and sensitivity analysis are possible methods during this stage.

The fifth step relates to the **assessment of the correctness of calculations and the integrity** of the financial model. This is the most comprehensive and time consuming step in the entire model review process. As we will see, the use of professional analysis software can offer support in this process step.

In closing, the sixth step is used to **draw conclusions for future models** by deriving options for optimizing the process from the results of the model review. Thus the model review allows for the continuous improvement of the process of financial modeling.

Still, it is almost impossible to assure the complete elimination of all errors in a complex model, even if a professional model review process is implemented. Nonetheless, comprehensive and systematic checks as well as a high degree of precision when developing the model – especially by structuring the process of model development along the lines of the financial modeling standards – can reduce the likelihood of errors in a model and increase the acceptance for the modeling results.[5]

4 Errors in Financial Models

> Errors can be caused knowingly or involuntarily.

An error is the failure to fulfill a specified demand. An error can result either from an intentional or an unintentional activity. In the context of financial modeling, this position is widely shared and “errors” are discussed in a general context, whether they are intentional or unintentional.

In order to work with an explicit and unified classification of the various errors that are possible in financial models, the “Taxonomy of Error Types” by PANKO and HALVERSON is used.[6] A distinction is made between qualitative and quantitative errors.

4.1 Qualitative Errors

Qualitative errors are violations of the standards of financial modeling.

Qualitative errors are violations of the financial modeling standards and do not necessarily affect the results of the financial model. But as the financial model is developed further, they can become the source of quantitative errors. Examples of qualitative errors are poor or confusing design, use of different formulas in one row or column, inconsistent model structure, an inconsistent timeline and so forth.

4.2 Quantitative Errors

Quantitative errors directly affect the results.

Quantitative errors in contrast have an influence on the output of the financial model and cause faulty results. Quantitative errors can have minor, unsubstantial or major effects on the result.

Quantitative errors are broken down into three categories as follows[7]:

- Mechanical errors,
- Logic errors and
- Omission errors

Mechanical errors, also called “simple mistakes,” can either be incorrect inputs, such as typing errors, or errors that are caused by incorrect links with other cells. **Logic errors** include the incorrect use of algorithms. As a consequence of the incorrect use of formulas or the inappropriate treatment of pertinent facts, actual economic or legal aspects are reflected incorrectly or incompletely in the financial model. Omission errors describe the failure to capture relevant features of the model. As will be shown later, even analysis tools are only of limited use in this case.

5 Error Detection – Recognizing and Finding Errors

> Recognizing and detecting errors is the most important task of the model review.

Recognizing and detecting is certainly the biggest, most time consuming and possibly the most difficult challenge during the process of model review. The closer the financial modeling standards are observed, the simpler it will become to detect errors. Or putting it more drastically: finding errors in models that are not based on the financial modeling standards is close to impossible.

Fundamentally, three methods to track errors exist[8]:

- Logic inspection,
- Testing and
- Use of analysis tools.

5.1 Logic Inspection

> During the logic inspection, each individual cell is checked.

Logic inspection is the most effective, but at the same time most time consuming method for detecting errors. Similar to software development, where the programming code is inspected line by line (code inspection), every cell is reviewed and checked in the case of financial models.

A systematic approach is possible for this task. It is not expedient to go through the entire financial model cell by cell once it has been completed. Instead it is preferable to check model components cell by cell upon completion. These partial reviews increase the probability of success. As already suggested in the financial modeling standards, it is possible to simplify or break down complex formulas into several brief and clearly arranged steps for review purposes. When programs such as Visual Basic (VBA) by Microsoft are used, it is necessary to inspect them line by line. Also an understanding of the programming language is required. If necessary, the review must be repeated several times, since in general only about 60% to 80% of all errors are captured in each round.[9]

The inspection of the financial model is conducted during the development phase and again upon completion. It should be done in stages and be limited to one or two hours per session, since the success rate of the inspector declines rapidly after that time.[10] It was also shown that more errors were caught in smaller components compared to comprehensive model parts.[11]

5.2 Tests

Tests ascertain whether the financial model gives the expected results.

The essence of testing is the controlled running of the entire financial model or of individual components in order to ascertain whether the expected results are obtained. Testing consists of several, partially complex and time consuming procedures. A frequently used method is the analysis and comparison of results which are generated by entering different input data in the financial model. Scenario and sensitivity analysis are among the testing procedures.

Testing of a financial model appears to be an efficient method to detect errors in the results of a financial model. The problem with errors is that it is usually impossible to predict when and where they appear. But tests allow evaluation and confirmation of the correct functioning of the calculations. Tests are conducted intuitively by experienced financial modelers during the stage of model construction, where they rely on their experience to check the results of the

Answers	Percentage
Almost None	24%
Under 10%	20%
11% to 25%	12%
Over 25%	17%
Nearly All	16%
Not Applicable	11%
Total	100%
Respondents	862

Fig. 3.3 Testing of material financial spreadsheets (Panko/Ordway, 2005, pages 4 and 40)

financial model for plausibility. Very helpful in this regard are also control calculations that serve as a test for the results obtained by the model. Scenario and sensitivity analysis are suitable tools to test the model once it has been completed. During the model review process, they can be used to check the reaction of the model to variation in input values.

An empirical survey by Panko revealed the interesting fact that only very few financial models are actually tested by the companies that employ them.[12] Figure 3.3 shows the results of the empirical analysis, where the following question was asked: "With regard to financial models that are material for financial reporting, what is the percentage of financial models tested in your company?"[13] Overall the numbers reveal that only few financial models undergo to testing. 17% of those surveyed stated that more than 25% of all models are tested. Only 16% of those surveyed answered that almost all models used by the company are tested. These numbers clarify that only a small percentage of companies is serious about testing their financial models. What makes matters worse is the fact that most respondents confused the superficial checking of a few cells with a comprehensive testing of all cells.[14] The results of this survey are in line with other studies that confirm the "exaggerated" self-confidence of developers of financial models.

A major problem in financial modeling – especially when conducting tests – relates to the absence of a master model which could be used as a comparison. This situation, the general lack of results that can serve as a benchmark for the financial model is called the "oracle problem" in applied financial modeling.[15] How is it possible to ascertain during the model review whether all linkages have been modeled correctly, if no comparable model exists? How can the reviewer assess whether the results of the test are correct, if no standard of comparison exists?

"In complex spreadsheets ... there usually is no oracle other than the spreadsheet calculations, which may not be correct."[16] Output values of complex calculations are almost impossible to verify since no alternative model exists. But exactly the development of an alternative model would be required in order to confirm the results from the first financial model. And if the results do in fact differ, it is still not clear which of the two models provides the faulty output. Thus it should be apparent that some testing procedures are only meaningful in the case where the oracle problem is not present or does not pose a risk. In applied work on financial modeling, the oracle problem can only be circumvented by a strict adherence of the financial modeler to the financial modeling standards and by the development of a range of models for similar tasks. This helps to identify solution patterns and approaches which can be used systematically to solve identical or related questions.

5.3 Analysis Tools

Analysis tools systematically screen the financial model and quickly detect errors.

Analysis tools are a promising method to detect errors in financial models. They systematically screen the financial model and quickly detect errors as well as possible errors or facilitate their recognition via numerous auxiliary instruments. The functionality can be compared to a spell checker, which highlights possible errors in a text. The presentation of the results differs among the various analysis tools. While some analysis tools simply compile short reports about "key facts" of the financial model, others include functions that provide comparisons, graphical presentations, formula recognition, recognition of potential errors etc.

6 Examples of Applications of Analysis Tools

> Analysis tools are an alternative to the time consuming manual review of financial models.

Analysis tools can either be integrated into the software or provided as independent programs. For that reason, the broad term analysis tool is used. It is the task of analysis tools to detect and highlight errors in a financial model. This facilitates the work during modeling and final testing. In the context of the model review, the financial model under scrutiny remains unchanged. As with any other testing procedure, it is nonetheless recommended to create copies of the original file (master).

Analysis tools provide an alternative to the manual review of financial models, which can be extremely time consuming. The notion that an analysis tool is able to independently detect errors in financial models or to confirm their accurateness is not realistic. The analysis tool merely provides support functions which facilitate the processing and analysis of the financial model. A financial model that passes the inspection of the analysis tool is not necessarily free of errors. Despite the use of analysis tools, reviewers must be careful to comprehensively assess the entire financial model.

Following a brief overview of the analysis tools that are available in the market, the options of a model review

1. with Microsoft Excel and
2. with the help of Operis Analysis Kit are presented.

6.1 Brief Market Overview of Analysis Tools

> Numerous analysis tools are available.

A number of analysis tools exist that can be used in the context of model review and model audit. The study by PHILIP HOWARD,[17] which covers the last ten years, provides a comprehensive market overview of analysis tools. It considers review and audit software suitable for spreadsheets.

HOWARD classifies the available review and audit software in three categories[18]:

- Auditor's Tools,
- Control & Compliance Tools and
- Automation Tools

Each review and audit software is assigned to one of these three categories (see Fig. 3.4):

Auditor's Tools
Among the auditor's tools are all programs used by internal or external auditors of financial models that support their review process. All these tools aim at detecting and identifying errors in a financial model. Some of the auditor's tools also support the financial modeler in

Auditor's Tool	Control & Compliance Tools	Automation Tools
• Operis OAK • Sheetware XDrill • Spreadsheet Advantage • Spreadsheet Detective • Spreadsheet Innovations • Spreadsheet Professional	• CIMCON Spreadsheet Compliance Solutions • ClusterSeven Enterprise Spreadsheet Management • Compassoft • Lyquidity ComplyXL • Mobius ABS for Spreadsheet Compliance • Prodiance Spreadsheet Compliance • ROISoft ExSafe • SmartDB eXpresso	• Actuate e.Spreadsheet • Qtier-Rapor • Risk Integrated Enterprise Spreadsheet Platform

Fig. 3.4 Overview of the review and audit software analyzed by Howard
Source: See Howard (2007), p. 19

model development. The following functions are shared by most of the auditor's tools:

- Spreadsheet comparisons – in other words comparisons either between two versions of the same spreadsheet or in some cases also between different spreadsheets.
- Formula mapping – in other words the ability to detect formulas and their use by comparing the contents of cells with the structure of neighboring cells. This function allows insights into the composition of the spreadsheets. Structural anomalies, mostly revealed by a lack of harmony in the overall appearance, can provide clues about the presence of an error.
- Precedent and dependent mapping – in other words the ability to map relationships and linkages among previous and following cells.
- Detection of formula and other errors – in other words the ability to capture and highlight errors in formulas and other errors.
- Facilities to understand formulas more easily – in other words the ability to comprehend formulas. This function facilitates an understanding for the structure of formulas and the importance of previous calculations for the final result.
- Circular reference detection – in other words the ability to identify incorrect references.

Control and Compliance Tools
Only authorized users are allowed to make changes to specific cells of the spreadsheet in programs of this category. Use of Excel remains unchanged and the system fulfills all demands concerning version control and security. For compliance tools, every modification to an existing spreadsheet is monitored and documented in a protocol.
Automation Tools
Programs that fall into the category of automation tools will automatically evaluate spreadsheets. In most cases, a spreadsheet is established as a sample, evaluated and then frequently used and modified.

Software in the category of auditor's tools is most relevant for the model review.

Software in the category of auditor's tools is most relevant for the model review and model audit in financial modeling. All review and audit software that was analyzed shares fundamental similarities. As an example, all products are available for download and typically a 30-day free trial is available. Support is done via email and prices are comparable. The biggest differences are found in the range of applications and the ease of operation.

Which auditor's tools should thus be used in the context of model review and model audit?

The choice of software for the purpose of model review and model audit depends largely on the range of required applications and the specific task. For that reason we recommend to download the free test version and apply it to the tasks at hand before purchasing the software.

The study by HOWARD highlights the following three auditor's tools and their strengths[19]:

1. Operis Analysis Kit (OAK): Recommended for complex financial models
2. Spreadsheet Detective: Recommended as a specialized auditor's tool
3. Spreadsheet Innovations: Recommended as a comprehensive auditor/developer tool

The software Operis Analysis Kit (OAK) is very suitable for model review and model audit in financial modeling, since it was developed specifically for applications in that field. "If you are a financial modeler, you should certainly consider the use of OAK."[20] For that reason, we will not only present Excel tools in the following, but also specific model review and model audit functions found in the Operis Analysis Kit (OAK). We are not so much interested in outlining the functionality of specific software, but rather to point out which additional functions besides those provided by Excel are available to the reviewer for the purposes of model review and model audit. We would also like to stress once again that similar functions are also offered by the other software solutions listed above. In addition to the functionality as analysis tool, the Operis Group next to BPM Analytics and the spreadsheet standards review board also made a big contribution with the derivation of standardized processes for the efficient construction of models.[21] Financial modeling standards were covered in Chapter 2 of this book.

6.2 Model Review with Microsoft Excel

> Excel also offers tools to review models.

As one of the most frequently utilized applications for end users, Microsoft Excel has a number of helpful integrated standardized functions that support the model review process.

Excel offers three approaches that efficiently support the model review:

- Monitoring the contents of cells
- Use of the watch window for formulas
- Recognizing errors and searching for them

6.2.1 Monitoring the Cell Contents

In order to monitor the contents of cells in a financial model, Excel provides the following functions:

- Watch window
- Camera
- Analysis of cells that contain formulas

Use of the Watch Window

> Watch Windows show cells that are outside the range of the screen, are hidden or are on different worksheets.

The dialogue window *Watch Window* offers the possibility in Excel to monitor formulas or cells during the modeling process. Cells that are outside the range of the screen, are hidden or are on different worksheets can be displayed separately. The advantage of a watch window is the ability to observe at a glance important intermediate results or calculations which are affected by changes in linked cells.

You can add a watch window as follows:

1. Go to the *Watch Window* via the path ➲ *Formulas* ➲ *Formula Auditing* ➲ *Watch Window*.
2. Click the button *Watch Window*.
3. Go to the worksheet which contains the data that needs to be monitored.
4. Mark the cells you want to monitor.
5. Click on the button *Add Watch*.
6. Close the opened dialogue window with the *Add* button.

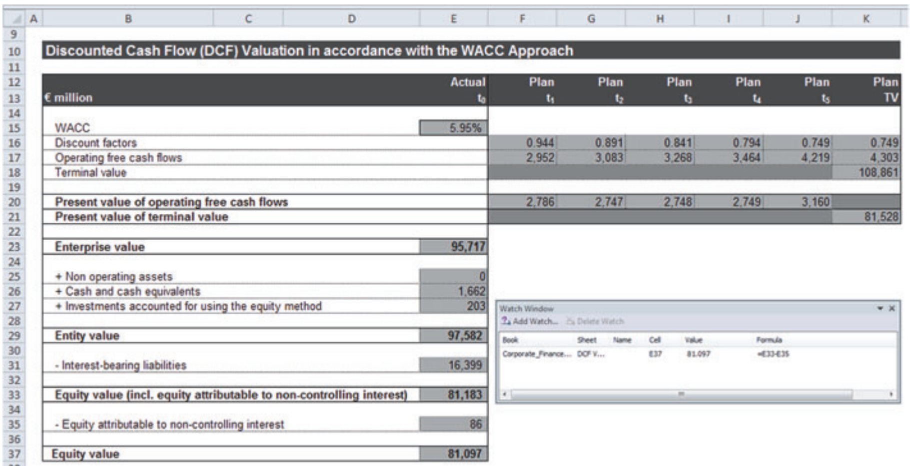
In the chapter on Corporate Finance it can make sense to monitor the results of the sensitivity analysis in the worksheet DCF_(1)_Sensitivity Analysis together with the result of the corporate valuation DCF_Valuation_(1) in the watch window (see Fig. 3.5).

The following suggestions facilitate the use of watch windows:

✓ Only cells that are contained in an opened worksheet are shown in the watch window.

✓ The content of the watch window is saved jointly with the file. It is again available once you reopen the file and the watch window.

✓ You can directly move to a monitored cell by double-clicking the corresponding entry in the watch window.



Discounted Cash Flow (DCF) Valuation in accordance with the WACC Approach

€ million	Actual t_0	Plan t_1	Plan t_2	Plan t_3	Plan t_4	Plan t_5	Plan TV
WACC	5.95%						
Discount factors		0.944	0.891	0.841	0.794	0.749	0.749
Operating free cash flows		2,952	3,083	3,268	3,464	4,219	4,303
Terminal value							108,861
Present value of operating free cash flows		2,786	2,747	2,748	2,749	3,160	
Present value of terminal value							81,528
Enterprise value	95,717						
+ Non operating assets	0						
+ Cash and cash equivalents	1,662						
+ Investments accounted for using the equity method	203						
Entity value	97,582						
- Interest-bearing liabilities	16,399						
Equity value (incl. equity attributable to non-controlling interest)	81,183						
- Equity attributable to non-controlling interest	86						
Equity value	81,097						

Fig. 3.5 Use of the watch window

✓ It is recommended to assign names to the monitored cells. This makes it easier to assess their relevance for the current calculations.

✓ Watch windows are deleted by marking one or more of the monitored fields in the watch window and then hitting *Delete Watch*.

Use of the Camera

With the camera it is possible to photograph and insert worksheet ranges or diagram objects.

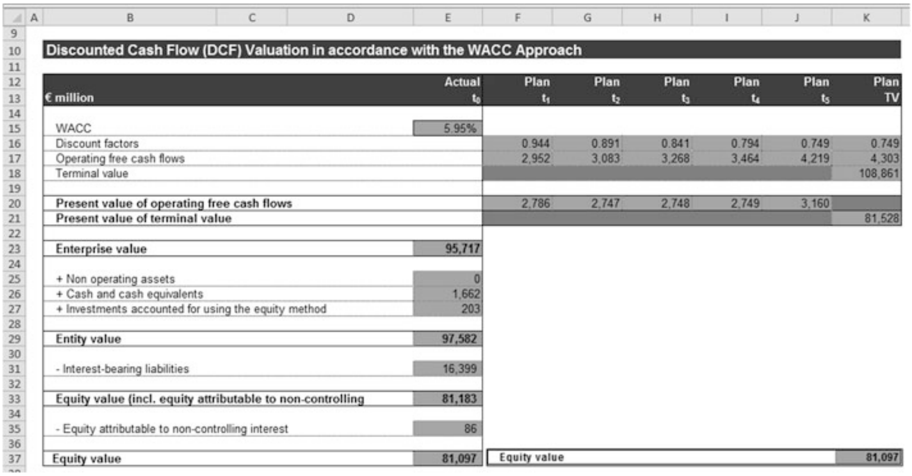
The functionality of the *Camera* tool is similar to that of the watch window. The camera is a symbol that activates a special type of link, namely a dynamic link with graphic objects. With the camera symbol you photograph ranges from worksheets or diagram objects. Starting with the Excel Version from 97, it is no longer contained in the standard toolbar. But the camera can be installed quickly. Follow these steps:

1. Go to ➲ *File* ➲ *Options* ➲ *Quick Access Toolbar*.
2. From the available commands select *Camera*, click *Add* and confirm with *OK*.
3. The *Camera* is now included in the *Quick Access Toolbar* in the Excel worksheet.

The *Camera* can be used as follows:

1. Mark the range you want to link and click on *Camera*.
2. The mouse pointer turns into cross hairs. Put these down in another range or worksheet by clicking on the left mouse button.
3. The *Camera* photographs the range and produces a linked copy as a graphics object.

The example which was previously chosen for the watch window is used again (see Fig. 3.6).



Discounted Cash Flow (DCF) Valuation in accordance with the WACC Approach							
€ million	Actual t_0	Plan t_1	Plan t_2	Plan t_3	Plan t_4	Plan t_5	Plan TV
WACC	5.95%						
Discount factors		0.944	0.891	0.841	0.794	0.749	0.749
Operating free cash flows		2,952	3,083	3,268	3,464	4,219	4,303
Terminal value							108,861
Present value of operating free cash flows		2,786	2,747	2,748	2,749	3,160	
Present value of terminal value							81,528
Enterprise value	**95,717**						
+ Non operating assets	0						
+ Cash and cash equivalents	1,662						
+ Investments accounted for using the equity method	203						
Entity value	**97,582**						
- Interest-bearing liabilities	16,399						
Equity value (incl. equity attributable to non-controlling	**81,183**						
- Equity attributable to non-controlling interest	86						
Equity value	**81,097**	**Equity value**					**81,097**

Fig. 3.6 Use of the camera

Analyzing Cells that Contain Formulas

With Excel the structure of formulas used can be assessed.

During the model review it is important to analyze the financial model with an eye on the structure of the formulas used. This makes it possible to recognize approaches that violate the financial modeling standards.

For example, Excel offers the option of

- Searching for cells that contain formulas,
- Searching for formulas with specific attributes,
- Searching for cells that contain constants.

Searching Worksheets for Cells that Contain Formulas

In order to get an overview of all the cells in a worksheet that contain formulas, follow these steps:

1. Go to *Home,* then go to *Edit*
2. Click on *Search and Select.*
3. Choose *Formulas* from the opened list. All cells that contain formulas are now automatically marked.

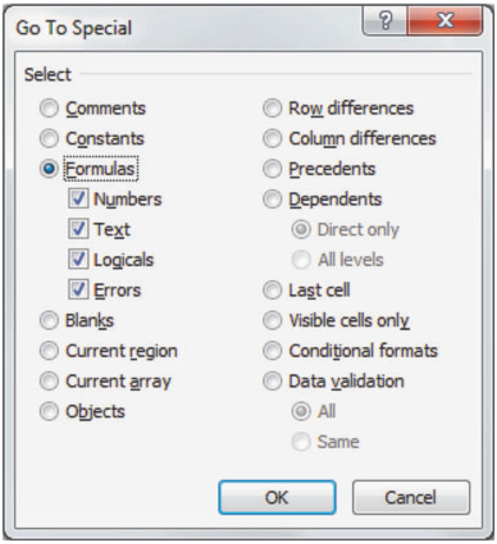


Fig. 3.7 Worksheets are checked for formulas with specific attributes

Searching Worksheets for Formulas with Specific Attributes

Also under *Search and Select* you find the Excel function *Select Content.* Use of this function allows under *Formulas* to determine whether formulas contain *numbers*, *text*, *Boolean values* or *errors*. This function allows a systematic search without requiring a complete manual inspection (see Fig. 3.7).

Searching Worksheets for Cells that Contain Constants

During the model review it is frequently assessed whether the output worksheets erroneously contain fixed values which actually belong into the worksheet that lists the assumptions. In addition, mixed formulas are assessed that contain cell references as well as fixed numeric values. If you want to see the cells in a worksheet that contain constants, follows these steps:

1. Go to *Home,* then go to *Edit*
2. Click on *Search and Select.*
3. Choose *Constants* from the opened list. All cells that contain constants are now automatically marked.

6.2.2 Using Formula Auditing

With formula auditing it is possible to graphically display linkages between cells.

In the group *Formula Auditing*, which can be reached via the register *Formulas*, it is possible to graphically display linkages between cells. Excel uses tracer arrows to display the flow of data and formulas in a worksheet. In this way *Precedents* (cells that are referred to by a formula in another cell) or *Dependents* (contain formulas that refer to other cells) are recognized. The arrows are also useful for detecting errors. In *Formula Auditing* it is also possible to access the items *Show Formulas* and *Evaluate Formula*.

Formula auditing is recommended during the model review especially for an explicit assessment of the links to precedents and dependents or for an in-depth analysis of formulas. The following functions are available during formula auditing:

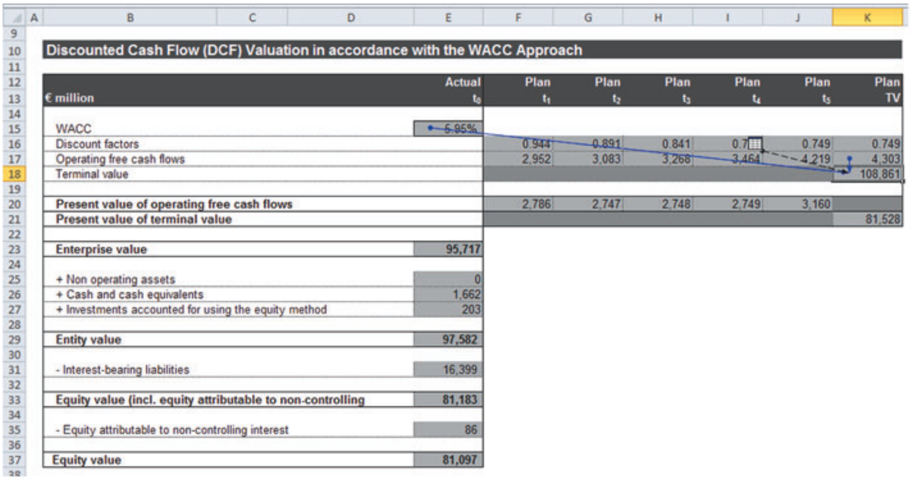
- Showing trace to the precedents
- Showing trace to the dependents
- Showing trace to the error
- Removing arrows
- Showing formulas in the worksheet
- Formula evaluation: evaluating formulas step by step

Showing Trace to the Precedent

Trace Precedents shows the cells which influence the result of a formula cell.

If you want to find out which cells influence the result of a formula cell, the function *Trace Precedents* can be used. Proceed as follows (also see Fig. 3.8):

1. Mark the cell you want to check.
2. In the tab *Formulas* go to *Formula Auditing*.
3. Here you find the tracer arrows under *Trace Precedents*.



Discounted Cash Flow (DCF) Valuation in accordance with the WACC Approach							
€ million	Actual t_0	Plan t_1	Plan t_2	Plan t_3	Plan t_4	Plan t_5	Plan TV
WACC	5.95%						
Discount factors		0.944	0.891	0.841	0.7[illegible]	0.749	0.749
Operating free cash flows		2,952	3,083	3,268	3,464	4,219	4,303
Terminal value							108,861
Present value of operating free cash flows		2,786	2,747	2,748	2,749	3,160	
Present value of terminal value							81,528
Enterprise value	95,717						
+ Non operating assets	0						
+ Cash and cash equivalents	1,662						
+ Investments accounted for using the equity method	203						
Entity value	97,582						
- Interest-bearing liabilities	16,399						
Equity value (incl. equity attributable to non-controlling	81,183						
- Equity attributable to non-controlling interest	86						
Equity value	81,097						

Fig. 3.8 Traces to the precedent

In Fig. 3.8 you can see how the terminal value is embedded in the cell `K19` of the worksheet DCF_Valuation_(1).

Showing Trace to the Dependent

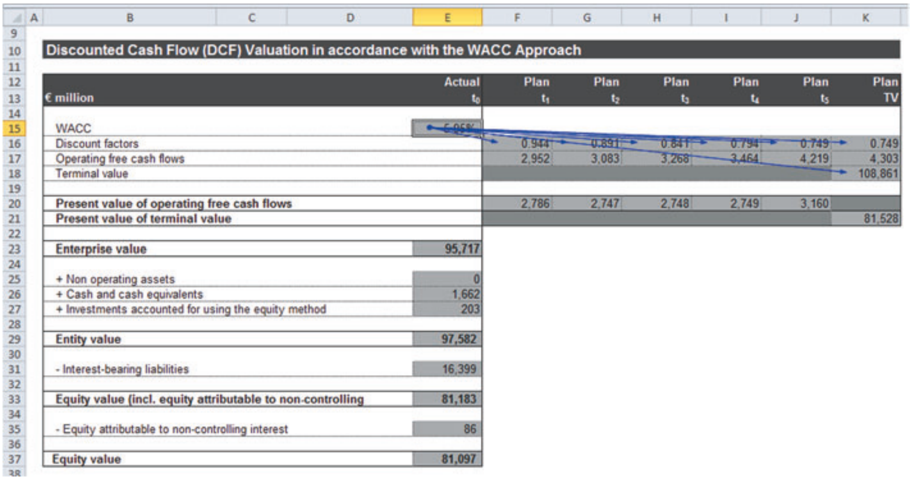
> *Trace Dependents* shows the formula cells that are influenced by the value in a marked cell.

With *Trace Dependents* you can also find out which formula cells are influenced by the value in a marked cell. Proceed as follows:

1. Mark the cell you want to check.
2. In the tab *Formulas* go to *Formula Auditing*.
3. Here you find the tracer arrows under *Trace Dependents*.

Traces to the precedent which lead to a different worksheet are marked with the symbol . In this case you can quickly switch to the preceding or dependent cells by double-clicking the tracer arrow.

Figure 3.9 displays the worksheet DCF_Valuation_(1). Shown are the cells that use the WACC in cell `E15`.



€ million	Actual t_0	Plan t_1	Plan t_2	Plan t_3	Plan t_4	Plan t_5	Plan TV
Discounted Cash Flow (DCF) Valuation in accordance with the WACC Approach							
WACC	[illegible]						
Discount factors		0.944	0.891	0.841	0.794	0.749	0.749
Operating free cash flows		2,952	3,083	3,268	3,464	4,219	4,303
Terminal value							108,861
Present value of operating free cash flows		2,786	2,747	2,748	2,749	3,160	
Present value of terminal value							81,528
Enterprise value	95,717						
+ Non operating assets	0						
+ Cash and cash equivalents	1,662						
+ Investments accounted for using the equity method	203						
Entity value	97,582						
- Interest-bearing liabilities	16,399						
Equity value (incl. equity attributable to non-controlling	81,183						
- Equity attributable to non-controlling interest	86						
Equity value	81,097						

Fig. 3.9 Traces to the dependent

Displaying a Trace to the Error

> With *Trace Error* the source of the error is displayed.

If a cell contains an error value, it is possible to detect the source of the error with the help of tracer arrows. This relies on the function *Trace Error.* The arrows then point to the source of the error. Proceed as follows:

1. Mark the cell you want to check.
2. In the tab *Formulas* go to *Formula Auditing*.
3. Here you go to *Error Checking* and then to *Trace Error*.

Removing Tracer Arrows

> The tracer arrows can be deleted using *Remove Arrows*.

All existing tracer arrows are automatically deleted by Excel once you save the workbook. If you want to delete the tracer arrows without saving the workbook, use the function *Remove Arrows*. Proceed as follows:

1. In the tab *Formulas* go to *Formula Auditing*.
2. Click on *Remove Arrows.* Here you have a choice of removing all arrows, removing arrows to the precedent or removing arrows to the dependent.

Showing Formulas in the Worksheet

> With *Show Formulas* the underlying formulas can be displayed.

Excel offers the option to show the underlying formulas in the formula cells instead of the values via the function *Show Formulas*. This can be helpful during the model review if you are looking for a specific formula or want to copy parts of the formula.

If you want to display the formulas in a worksheet, proceed as follows:

1. In the tab *Formulas* go to *Formula Auditing*.
1. Click on *Show Formulas.*
1. By clicking *Show Formulas* again, you go back to the standard table view.

Evaluating Formulas: Checking Formulas Step by Step

> *Evaluate Formulas* shows the individual calculations in a cell step by step.

Evaluate Formula is a helpful function for hard to identify shortcomings in a financial model that are caused primarily by conceptual errors. During the model review, *Evaluate Formula* is particularly helpful in the case of poorly structured financial models, where it can help to recognize the structure of formulas and to identify sources of error.

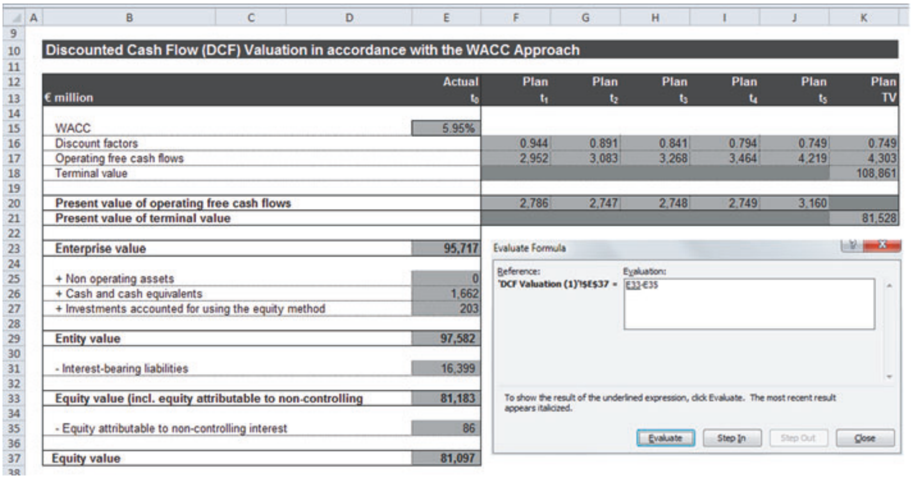


Fig. 3.10 Evaluate formula

Excel shows the various calculations in a cell step by step (argument for argument) (see Fig. 3.10):

1. Place the mouse pointer on the cell that contains a potential error.
2. Activate *Evaluate Formula* via *Formulas* ➲ *Formula Auditing* ➲ *Evaluate Formula*.
3. The formula is shown in the evaluation window and the first part of the formula is marked.
4. In order to calculate the components of the formula separately, select *Step In*. The underlined part of the formula is calculated and the relevant result is shown in the window.

6.2.3 Recognizing and Tracking Errors

In the following, you will learn how to recognize and track errors in the context of the model review. We begin with the error values that Excel displays when a formula contains incorrect input. Next, we will deal with searching for errors in formulas and with checking worksheets for errors in formulas. Finally we demonstrate how to find errors made during the modeling phase.

Error values	Possible causes and methods for error correction
####	**Cause:** This error value is shown for example if numbers cannot be shown correctly due to insufficient column width. **Solution:** Adjust the column width so that the number can be displayed.
#REF!	**Cause:** A cell reference in the formula is invalid, for example because it has been changed due to the deletion of cells. **Solution:** Check the cell references used in the formula.
#DIV/0!	**Cause:** Excel has attempted division by 0. This can be the case if an empty cell is used as the divisor. **Solution:** Check whether the formula references the correct cells.
#NAME?	**Cause:** The text in a formula is not recognized, for example because the name of the function was misspelled. **Solution:** Check the spelling of the function name.
#NULL!	**Cause:** Cell references cannot be found, for example because several ranges were listed, but not separated by a semicolon. **Solution:** Check the syntax of the arguments for correctness.
#N/A	**Cause:** The formulas possibly reference empty cells. **Solution:** Check the cell references in question.
#VALUE!	**Cause:** The data type of the argument does not match the needed syntax. **Solution:** Check the arguments in the formula.
#NUM!	**Cause:** The formula contains invalid numerical values. **Solution:** Check whether the arguments fall within the required range (for example between 0 and 1).

Fig. 3.11 Error values: Possible causes and methods for correcting errors
Source: PwC: MS Office Excel 2010 for Professionals, 2012, p. 252.

Error Values in Formula Cells

An error value is an error report in Excel, which can have various causes.

If Excel cannot determine the result from a formula, an error value is shown in the formula cell. An error value is an error report. Excel distinguishes several error values. Figure 3.11 provides an overview of the various error values and possibilities for error correction.

Usually a small green triangle will appear in the left upper corner of the cell that contains an error value (an exception is the error value ####). When you mark this cell, the Error Checking Options Button  appears (see Fig. 3.12).

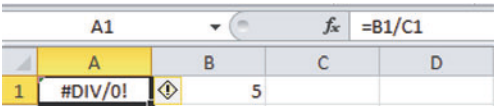


Fig. 3.12 Error values

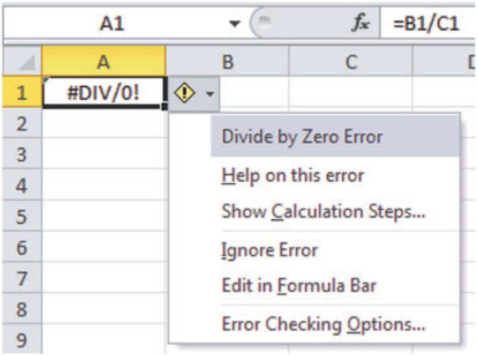


Fig. 3.13 Checking, respectively, correcting errors in the case of error values

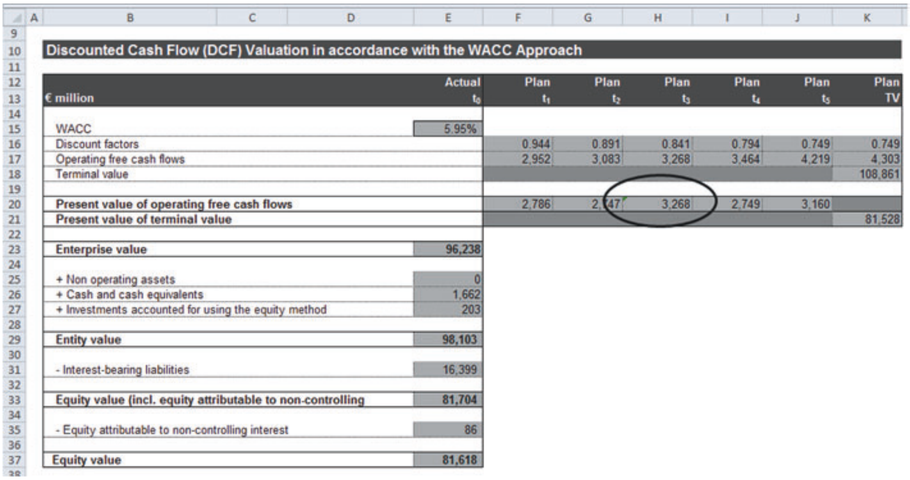
Clicking this button provides you with several options to check, respectively correct errors (see Fig. 3.13).

Finding Errors in Formula via Error Checking

An error in a formula or function spotted by Excel is marked in the cell with a green triangle.

Occasionally the financial modeler is faced with the situation that a model does not provide the result expected of the calculations. In this case, *Error Checking* can provide support (see Fig. 3.14).

In Fig. 3.14 there is apparently an error in the calculation of the present values of the operative free cash flows: The result in cell `H20` is based on a calculation that differs from the other cells. At first glance, this may have gone unnoticed, but Excel has identified the error. An error that was identified by Excel in a formula or function is marked in



Discounted Cash Flow (DCF) Valuation in accordance with the WACC Approach

€ million	Actual t_0	Plan t_1	Plan t_2	Plan t_3	Plan t_4	Plan t_5	Plan TV
WACC	5.95%						
Discount factors		0.944	0.891	0.841	0.794	0.749	0.749
Operating free cash flows		2,952	3,083	3,268	3,464	4,219	4,303
Terminal value							108,861
Present value of operating free cash flows		2,786	2,747	3,268	2,749	3,160	
Present value of terminal value							81,528
Enterprise value	96,238						
+ Non operating assets	0						
+ Cash and cash equivalents	1,662						
+ Investments accounted for using the equity method	203						
Entity value	98,103						
- Interest-bearing liabilities	16,399						
Equity value (incl. equity attributable to non-controlling	81,704						
- Equity attributable to non-controlling interest	86						
Equity value	81,618						

Fig. 3.14 Help from error checking

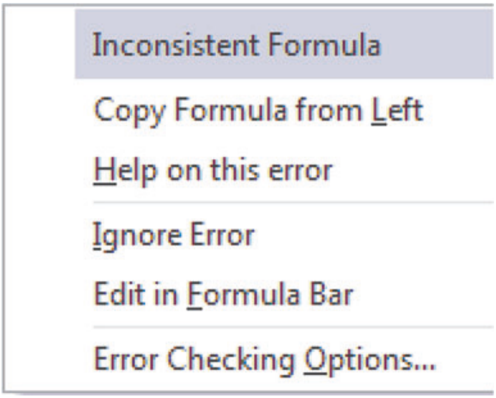


Fig. 3.15 Options for error checking and error correction

the relevant cell with a green triangle and the Error Checking Options Button.

The Error Checking Options Button offers several choices for error checking and error correction (see Fig. 3.15).

Error checking allows for the systematic search and correction of errors in a worksheet. Complex formulas can be checked step by step with the formula evaluation.

Checking the Worksheet for Formula Errors

> With error checking, Excel offers the option of checking all errors in formulas of one worksheet one by one and to immediately correct them if needed.

Error Checking, similar to the spell checker, is an option provided by Excel to check for errors in all formulas of a worksheet one by one and to immediately correct them if needed.

1. In the tab *Formulas* go to *Formula Auditing*.
2. Go to *Error Checking* and then to *Error Checking*. . .

In case Excel notices an error in the selected worksheet, the dialogue window *Error Checking* appears. For each error identified, it offers various options for error checking and error correction (see Fig. 3.16).

Circular References

> In the case of circular references, it must be determined whether they make economic sense or whether they are the result of faulty modeling.

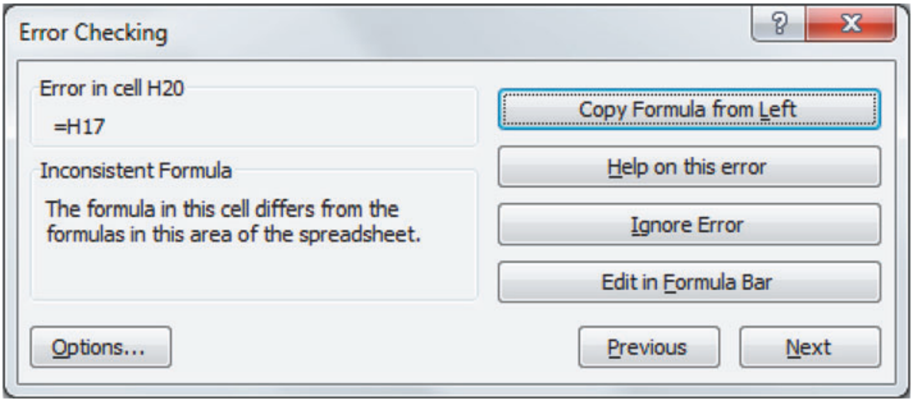


Fig. 3.16 Checking the worksheet for errors

The problem of circular references was already discussed in the financial modeling standards. There we recommended that only economically meaningful circular references should be used.

In the context of the model review, the financial model must be checked for the presence of circular references. If circular references are present, it must be determined whether they can be justified from an economic perspective and were included on purpose or whether they are the result of faulty modeling.

A circular reference is created every time a formula or function references itself. As an example, the formula `= A1+1` includes a circular reference if it is put into the cell `A1`.

Circular references frequently appear in financial models as a consequence of changes to the table structure. This can happen if cell ranges, columns, rows or cell contents is deleted or added. In this case, the warning message *Circular Reference* is displayed. The financial modeler is made aware of the problem and can immediately take the necessary corrective action.

If the warning concerning a circular reference is displayed during programming, the circular reference was most likely included inadvertently (see Fig. 3.17). In this case you must look for the incorrect reference and delete it. We suggest the following approach:

To understand the cause of the circular reference, you can initially choose the function *Trace Error*. Now the circular reference is displayed with arrows.

Suggestion: You can switch between the cells involved in a circular reference by double-clicking the tracer arrows. Tracer arrows show the cells which have an effect on the value of the currently selected cell.

Alternatively you can also select the function *Circular References*  (see Fig. 3.18).

1. Mark the cell you want to check.
2. In the tab *Formulas* go to *Formula Auditing*.
3. Go to *Formula Auditing* and then to *Circular References*.

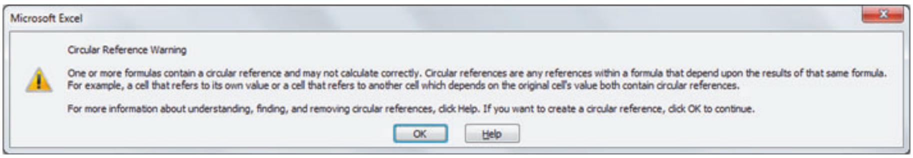


Fig. 3.17 Warning about a circular reference

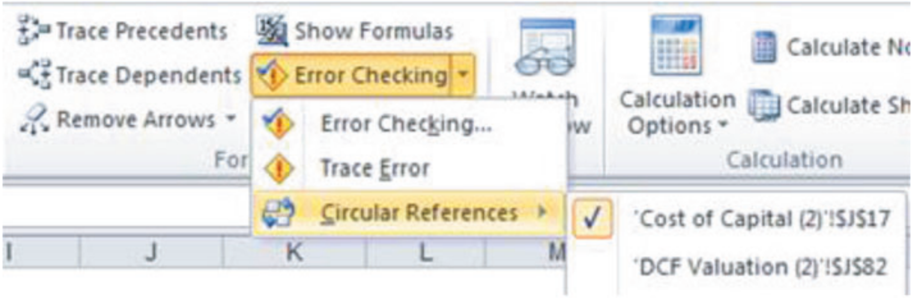


Fig. 3.18 Using circular references

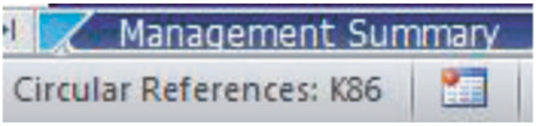


Fig. 3.19 Displaying circular references in the status bar

The circular reference is shown in the status bar followed by a reference to one of the cells involved in the circular reference (such as Circular Reference: `A4`) (see Fig. 3.19). If circular references are found in a worksheet that is not currently the active worksheet, only *Circular Reference* without any cell address is shown.

More severe than the erroneously included circular references are circular references which arise from neglect of the financial modeling standards. Unstructured models and cells that reference each other are the result. In applied work it is frequently the case that established model structures are replaced with improvised ad-hoc solutions due to a lack of time or knowledge. The problem of circular references is solved via inadequate tools such as the goal seek feature or by assigning a fixed value. This is then called a "quick fix."[22] In complex models these "quick fixes" will result in inconsistencies in other parts of the model. An additional complication is the fact that "quick fixes" are very hard to detect during the model review. Once again it holds that the most effective method of preventing circular references is the strict adherence to the financial modeling standards.

It is also possible that circular references are economically meaningful and are used on purpose in the model. A typical example is the circularity problem in corporate valuation, which will be discussed

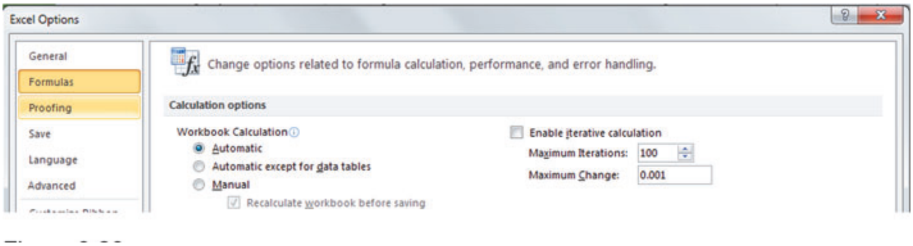


Fig. 3.20 Solving the circularity problem with Excel

in detail in the chapter Corporate Finance. The circularity problem is solved in applied valuation work with the help of mathematical iteration. This can either be done manually by trying different values or with the help of the iterative function *Enable Iterative Calculation*.

To activate the iterative function, you need the following sequence of commands: ➲ *File* ➲ *Options* ➲ *Formulas* ➲ *Enable Iterative Calculation* (see Fig. 3.20).

Suggestion: In order to recognize circular references in the context of the model review, turn off the iteration. This is done as follows:

➲ *File* ➲ *Options* ➲ *Formulas* ➲ *Enable Iterative Calculation* ➲ *Disable*

Please note that this also disables all other iterations, which may be needed. Therefore the results of the model may change.

Syntax Errors

> Typos are a frequent cause of syntax errors.

Syntax Errors are typical errors of data entry that are made by every financial modeler. A typical example is the use of a comma instead of a semicolon (for example, in an IF-function). Syntax errors are usually detected immediately by Excel (see Fig. 3.21).

Logical Errors

> Logical errors result from the incorrect modeling of economic relationships in the financial model.

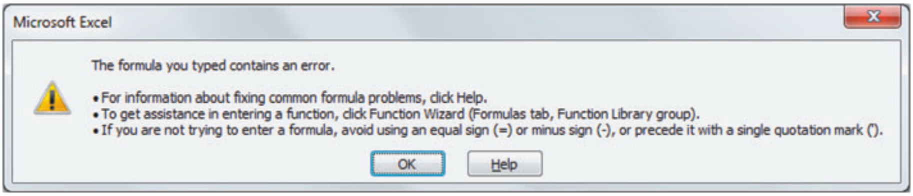


Fig. 3.21 Warning message for a syntax error

Logical errors are the result of incorrect modeling of economic relationships in the financial model. The formulas thus provide results that are not economically valid. Excel will usually not recognize these errors. Logical errors pose the greatest challenge during the model review. For their detection, auxiliary calculations, as well as scenario and sensitivity analysis are needed.

6.3 Model Review with Operis Analysis Kit (OAK)

Operis Analysis Kit (OAK) is a model review software solution for professionals.

Several model review software packages are available and the financial modeler can choose the software that is most appropriate for his needs. For the case study "Pharma Group" presented in this book, the software Operis Analysis Kit (OAK) appears well suited. Handling, degrees of freedom and functionality of the software are adequate for our purposes.

The software Operis Analysis Kit is a model review software solution for professionals which can be purchased from Operis Engineering Limited. A free 30 day trial period is available. On top of the options available in Excel, it also offers instruments for development and review of financial models.

The software OAK is an Excel add-in. Following the installation of OAK, two more registers, *OAK Development* and *OAK Review,* are shown in the Excel ribbon command bar. In addition, several functions can be accessed and selected directly in the cell by right-clicking with the mouse.

As can be guessed from the name of the register, *OAK Development* serves to support the development of new financial models, while *OAK Review* focuses on the review of financial models.

OAK Development contains functions which search the financial model for specific problematic types of cells such as cells without cell reference or formulas with constants. The graphical layout of O*AK Review* helps to visualize structures of formulas. It furthermore offers several additional functions for the evaluation of formulas.

Some functions are identical to the ones provided in MS Excel. Others extend the range of Excel. One example is the function *Conditional*. It can be accessed as follows:

➲ Register *OAK Development* ➲ Group *Search* ➲ Function *Conditional* . This function is similar, but more powerful compared to the standard function *Search and Select* in Excel.

Formulas in particular are prone to error since they are hard to comprehend, can be overwritten unwittingly or contain a faulty algorithm. They are a particular challenge for the auditor during the model review. Therefore the focus is on the functions which are helpful during the analysis of formulas.

6.3.1 Map

The *Map* function serves to detect structural irregularities of a financial model.

A particularly helpful and efficient function for the detection of structural irregularities of a financial model is the construction of a visual overlay. A visual overlay allows the recognition of formula structures by comparing cell contents with the structures of the neighboring cells. This function enables the auditor an insight into the structure of the financial model.

In OAK, this function can be selected under *Map*. The *Map* function is likely to be among the most useful features of an analysis tool. It has a particularly high success rate of detecting errors. In addition, the time needed to review a comprehensive financial model is significantly reduced when a visual overlay is used.

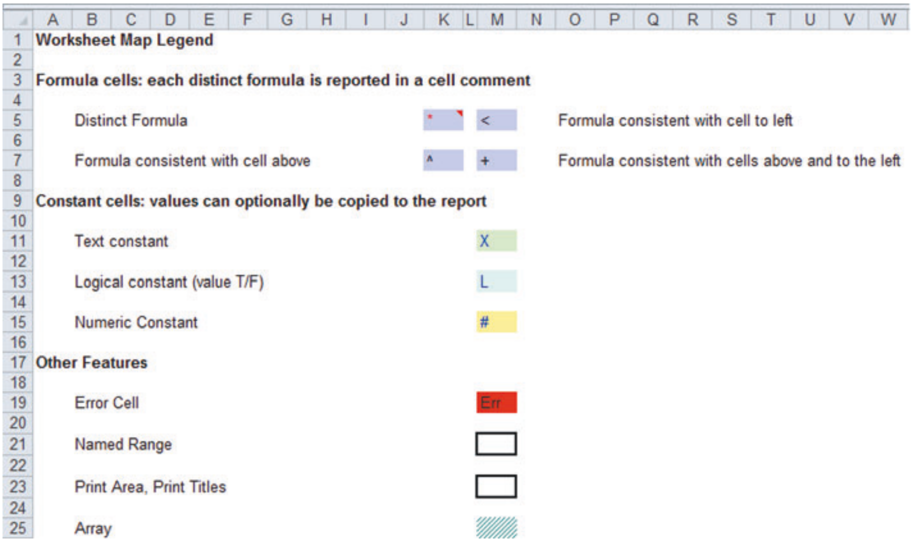


Fig. 3.22 OAK Map: The Map function explained

The *Map* function is accessed as follows:

➲ *OAK Review* ➲ *Map*

The tool is able to recognize the structure of the financial model and to visualize it in detailed and coded fashion (*map*). While the actual content of the cell is not shown, the main elements (labeling [text], values [figures] and formulas [calculations]) are visualized through the use of colors and/or symbols.

Figure 3.22 shows the symbols used in the *Map* function

If the modeling is correct, the coded *Map* will be a harmonious representation of the model, which is generated in a new workbook. It can be displayed next to the original financial model and checked at the same time. Figure 3.23 shows the *Map* for the calculation of the operative free cash flows in the chapter Corporate Finance.

In the above Figure, the complete correspondence between the various elements in the master and the *Map* document is apparent. The coding appears well structured. Next to the cell labels, a "unique formula" (*) is found while neighboring cells contain copies of that formula (<). Thus the task of the auditor is limited to checking the "unique formulas."

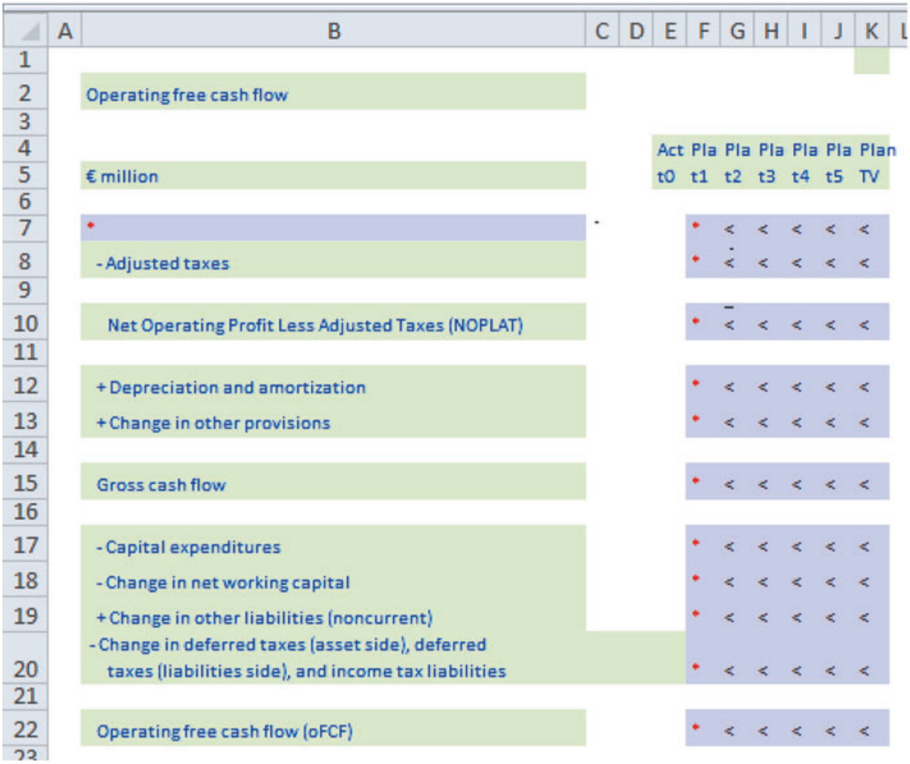


Fig. 3.23 OAK function Map: A coded graphical layout of the section selected

6.3.2 Reconstruct

> The OAK function *Reconstruct* offers a detailed categorization of the structure of calculations.

With the OAK function *Reconstruct* it is possible to reconstruct formulas schematically. An essential step when reviewing complex models is to gain an understanding of the underlying relationships in the calculations and their effect on the final result. Once the relevant formulas and critical ranges have been identified and localized with the help of the function *Map*, the much more demanding part of the audit follows. The auditor must understand the composition of the cell contents.

A tool which was already presented in this context is *Formula Auditing* in Excel, which is very suitable for use in smaller financial models. The OAK function *Reconstruct* offers a detailed decomposition of the structure of calculations. It begins with the formula in the marked initial cell, shows all values involved, intermediate outputs and formulas and ends with the last fixed value, generated in a separate workbook. In short, all values which contribute towards the result of the calculation are reproduced in a structured way.

The OAK function *Reconstruct* is accessed as follows:

➲ *OAK Review* ➲ *Formula* ➲ *Reconstruct*

The cell which contains the formula that needs to be reconstructed is highlighted in the financial model. The command *Reconstruct* opens the *Reconstruction Options* in a window. In addition to other settings, the depth of the display of the tracing can be adjusted. This is done with the help pf *Levels*. Each level is reproduced in a separate worksheet ("Level 0," "Level 1," and so forth) including captions of rows and columns. Each reconstructed value or formula in the chain of calculations is shown in a separate section. This segmentation allows the reconstruction via intermediate values of the marked starting value. The higher the level chosen, the more linkages and sections of values are usually displayed.

The example listed below shows the result of the function *Reconstruct*. For a cash flow calculation, the formulas for the item "Net Current assets" in "t_1" were reconstructed up to level 4. The results of the function *Reconstruct* are always shown in a separate workbook while the results of the individual levels are shown in separate worksheets. Figure 3.24 shows the results for level 0 to level 2. To improve the presentation, we have combined the results in one worksheet.

In **level 0** the original value is shown in cell `F2`. The reconstructed value in cell `F3` is calculated as the difference between net working capital in t_1 (cells `F10` to `F14`) and net working capital in t_0 (cells `E10` to `E14`). From **level 1** it can be seen that the net working capital consists of the following items: inventories, trade accounts receivable, other financial assets (current), trade accounts payable and other liabilities (current). From **level 2** it can be derived that these values are taken from the planning for balance sheet assets and balance sheet liabilities. Since Operis uses a separate worksheet for each level, level 3 and 4 cannot be presented in Fig. 3.24 due to space restrictions.

	A	B	C	D	E	F	G	H	I	J	K
1	Item										
2		Original				651					
3		Reconstructed				651					
4		Discrepancy				0					
5											
6	WORKBOOK: Corporate Finance										
7											
8	WORKSHEET: Auxiliary Calculation										
9											
10		Inventories	6370	6991	7129	7491	7940	8416	8921	9100	9282
11		+ Trade accounts receivable	7060	7433	7569	8071	8555	9068	9612	9804	10000
12		+ Other assets (current)	4876	2888	2668	2828	2998	3178	3368	3436	3504
13		- Trade accounts payable	3785	4305	4473	4769	5055	5358	5680	5793	5909
14		- Other liabilities (current)	1632	1315	1281	1358	1439	1526	1617	1650	1683
15											
16	WORKSHEET: Assets										
17											
18		Inventories	6370	6991	7129	7491	7940	8416	8921	9100	9282
19		Trade accounts receivable	7060	7433	7569	8071	8555	9068	9612	9804	10000
20		Other assets	4876	2888	2668	2828	2998	3178	3368	3436	3504
21											
22	WORKSHEET: Equity and Liabilities										
23											
24		Trade accounts payable	3785	4305	4473	4769	5055	5358	5680	5793	5909
25											
26		Other liabilities	1632	1315	1281	1358	1439	1526	1617	1650	1683

Fig. 3.24 Results of the OAK function Reconstruct for level 0 to level 2

Level 3 clarifies that the values for the planning of the balance sheet are in turn taken from the assumptions. **Level 4** shows the derivation of the assumptions.

The reconstruction of individual formulas is a very useful instrument and reveals a lot about the flow of data and the structure of the financial model. However, this approach is time consuming, since each individual formula must be considered separately. For that reason, the OAK function *Reconstruct* also offers the possibility to reconstruct the formulas for entire tables. For that purpose, the formulas that need to be reconstructed are marked and then the *Reconstruct* procedure is started.

The OAK function *Reconstruct* assumes a consistent model structure. This is best accomplished through the strict adherence to the financial modeling standards. In case the standards have not been considered during the modeling phase, the system will either completely refuse the execution and provide the error message *Selection is not left to right consistent* or will stop the procedure if inconsistencies are encountered during the reconstruction process.

6.3.3 Analyze Discrepancies

> The OAK function *Analyze Discrepancies* helps in understanding discrepancies between two cells.

The OAK function *Analyze Discrepancies* allows to track discrepancies between two selected cells by reconstructing the most important calculations. Deviations, for example between a model calculation and a control that should be identical in theory can put in doubt the reliability of the entire financial model. In such a situation, the developer or auditor has to determine whether the error is in the control calculation or in the actual model.

To utilize this function, the calculations that need to be compared are marked and the OAK function *Analyze Discrepancies* is selected as follows:

➲ *OAK Review* ➲ *Formula* ➲ *Analyze Discrepancies*

The cells that are compared need not necessarily be adjacent. Additional settings can be selected in an options window. In the next step an additional workbook is opened and a hierarchy of the various discrepancies is generated. At the top of the hierarchy is the actual deviation. Taking this as a starting point, all subsequent calculation steps which can give rise to the discrepancy are executed (see Fig. 3.25).

The OAK function *Analyze Discrepancies* offers a useful tool for the determination of deviations among elements in the chain of calculations. Alternatively it also allows visualization of different calculation methods that yield identical results.

Formulas that are based on different algorithms can cause minor deviations in the results. To eliminate this source of deviations, it is necessary to use the simplest possible version of formulas and to focus

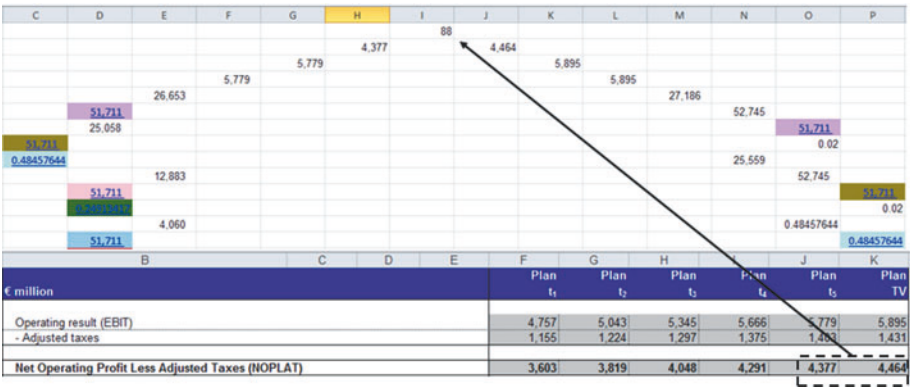


Fig. 3.25 OAK function Analyze Discrepancies: Reconstructs discrepancies among values

on their consistency. It is also possible to align different calculations via rounding (=ROUND).

6.3.4 Optimize

> The OAK function *Optimize* allows formula simplification while maintaining the same result.

The OAK function *Optimize* allows the simplification of formulas while maintaining the same result. Superfluous variables and labels in the formula are eliminated. This makes it easier for financial modeler and auditor to understand the structure of calculations.

There are many different possible solutions for the modeling of complex tasks. For that reason, many different versions of formulas exist, which can lead to identical results. However, as the formula becomes longer and the underlying calculations increase in complexity, the process of review and auditing will also become more difficult and time-consuming.

The OAK function *Optimize* is selected as follows:

➲ *OAK Development* ➲ *Formula* ➲ *Optimize*

For the transformation of formulas in simple equations, OAK offers two possible options:

- *Conservative* and
- *Aggressive*.

The first option *Conservative* makes suggestions for simplification which can be accepted without any doubts (according to the supplier OAK) and incorporated into the financial model. Suggestions that are provided under the setting *Aggressive* require a careful assessment, since it is possible that changes to the algorithm affect the meaning of the formula.

The OAK function *Optimize* transforms long and complicated chains of calculations into simpler formulas without affecting the result. However, this does not replace auditing, testing or other measures to verify the correctness of the formulas. It also does not fix any contextual errors. In other words, preexisting errors will be accepted.

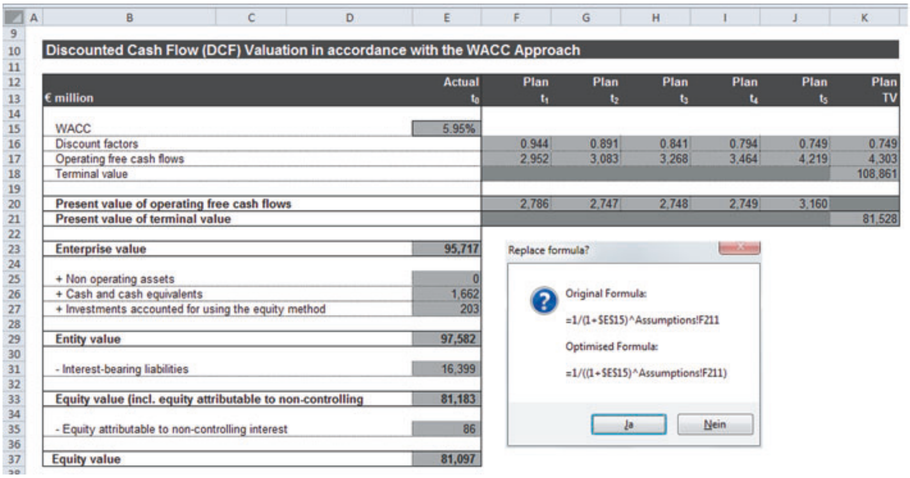


Fig. 3.26 OAK function Optimize: Suggestion for optimizing the original formula

Figure 3.26 shows a simple applied example of the *Optimize* function for the calculation of the discount factors. The original formula and the suggested *Optimized Formula* are shown next to each other and the suggestion can be either accepted or rejected.

7 Control Calculations

> Control calculations check results of the financial model and are best incorporated into the model during the modeling process.

The purpose of control calculations is to assess the results of the financial model and to serve as a test of the financial model. It is best to incorporate control calculations into the model during the modeling process in order to recognize and eliminate errors early on. The integration of control calculations is advisable if the financial modeler has already built several models with similar contents and is familiar with the relevant economic linkages. If errors are detected during the model review process, control calculations serve to eliminate the parts which were modeled incorrectly and help to quickly and effectively identify the sources of error.

The review of entire models is complicated by the absence of comparable approaches (the oracle problem mentioned above) and therefore "unit testing" of components is recommended. Effective tests include automated and permanently integrated methods. They assess the status of correctness of the calculations and are characterized by a simple structure.[23] This allows the user to understand which parts are included and verified by the test. The individual "unit tests" in the financial model at least assure the correctness of the respective sections. However, the correctness of the final result must be verified with the help of a superordinated test.[24]

7.1 Control Calculations that Show the Concrete Numerical Deviation

> Control calculations can be structured in such a way that they provide concrete numerical results for the deviations among the controlled values.

The first version of control calculations shows the concrete numerical deviation from the original values. This version facilitates the analysis of errors, since the degree of deviation is immediately apparent and the source of the error must be in the controlled area. If the controlled values show no deviations, the number "0" is shown against a green background. In case of a deviation, the size of the deviation is shown and the red background color further points to a discrepancy. The background color is chosen as discussed in the workshop Excel via

➲ *Home* ➲ *Conditional Formatting* ➲ *Highlight Cells Rules*

The following formula serves as a control calculation (see Fig. 3.27). Figure 3.28 contains examples of cash flow calculations and the corresponding control calculations.

A disadvantage of control calculations that provide the concrete numerical deviation is the fact that the number of correct and incorrect control calculations cannot be summarized in a comprehensive worksheet. Binary control calculations are required for that task.

Position	Worksheet and cell	Excel implementation
Control calculations that provide the concrete numerical deviation (`=Cash_Flow_Statement_(1)!F52 to K52`)	=ROUND(Net cash flow-change liquidity;5 decimal places)	`=ROUND(F45-F50;5)`

Fig. 3.27 Control calculations that provide the deviation

	A	B	C	D	E	F	G	H	I	J	K
44											
45		Net cash flow				1.242	1.390	1.589	1.798	2.042	2.102
46											
47		Liquidity 01.01				1.662	2.904	4.294	5.884	7.682	9.724
48		Liquidity 31.12			1.662	2.904	4.294	5.884	7.682	9.724	11.826
49											
50		Change				1.242	1.390	1.589	1.798	2.042	2.102
51											
52		Check				0	0	0	0	0	0

Fig. 3.28 Cash flow calculations and corresponding control calculations

7.2 Binary Control Calculations

> Binary control calculations merely distinguish between correct and incorrect results.

Version 1:

In the first version of the binary control calculation, "OK" against a green background signifies that the control calculation arrived at the same value as the corresponding model computation. In the case of a deviation the word "DEVIATION" is shown against a red background. This version is used in our chapter Corporate Finance.

The following IF-formula serves as a control calculation (see Fig. 3.29).

Figure 3.30 shows how to implement the binary control calculation in version 1.

Position	Worksheet and cell	Excel implementation
Binary control calculations (`=Cash_Flow_Statement_(2)!F52 to K52`)	=IF(ROUND(Net cash flow-change liquidity;5 decimal plac-es)=0;"OK";"DEVIATION")	`=IF(ROUND(F45-F50;5)=0;"OK";"DEVIATION")`

Fig. 3.29 Binary control calculation – version 1

	A	B	C	D	E	F	G	H	I	J	K
44											
45		Net cash flow				1.242	1.390	1.589	1.798	2.042	1.698
46											
47		Liquidity 01.01				1.662	2.904	4.294	5.884	7.682	9.724
48		Liquidity 31.12			1.662	2.904	4.294	5.884	7.682	9.724	11.421
49											
50		Change				1.242	1.390	1.589	1.798	2.042	1.698
51											
52		Check				OK	OK	OK	OK	OK	OK

Fig. 3.30 Binary control calculation – version 1

Version 2:
In the second version of the binary control calculation the values "0" and "1" are displayed as the result. The formula contains a calculation which displays "0" if correct and "1" in case of a deviation. The number of control calculations that yielded an unsatisfactory result can be added up and reported in a central location.

Two steps are needed for this binary control calculation:

Step 1: It is checked whether the formula contains error values.
The function *ISERROR* returns a logical value for the selected data range. In combination with the *IF* function an output of either "1" or "0" is generated. The output is "1" if an error value is found and "0" otherwise (see Fig. 3.31).

Figure 3.32 shows how to implement version 2 of the control calculation.

Step 2: The formula is checked for the correctness of the control calculation.
The formula presented above only shows the presence of an error value. In the next step it needs to be checked whether the control calculation is correct. All results that differ from "0" are also incorrect and must be declared as a "1." This leads to the following approach (see Fig. 3.33):

- The formula initially checks whether error values were found in the first step. If this is the case, the error is already captured and a value of "0" is shown for the control calculations.

Position	Worksheet and cell	Excel implementation
Binary control calculation for error values (`=Cash_Flow_Statement_(2)!F54 to K54`)	=IF(ISERROR(Control calculations that provide the concrete numerical deviation);1;0)	`=IF(ISERROR(F52);1;0)`

Fig. 3.31 Error checking version 2 with the function ISERROR

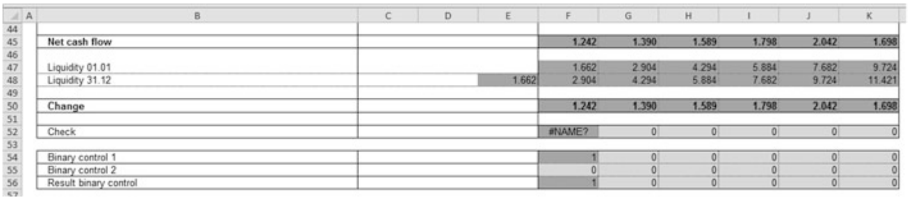

	A	B	C	D	E	F	G	H	I	J	K
44											
45		Net cash flow				1.242	1.390	1.589	1.798	2.042	1.698
46											
47		Liquidity 01.01				1.662	2.904	4.294	5.884	7.682	9.724
48		Liquidity 31.12			1.662	2.904	4.294	5.884	7.682	9.724	11.421
49											
50		Change				1.242	1.390	1.589	1.798	2.042	1.698
51											
52		Check				#NAME?	0	0	0	0	0
53											
54		Binary control 1				1	0	0	0	0	0
55		Binary control 2				0	0	0	0	0	0
56		Result binary control				1	0	0	0	0	0

Fig. 3.32 Binary control calculation – version 2

Position	Worksheet and cell	Excel implementation
Binary control calculation checking for correctness of the control values (=Cash_Flow_Statement_(3)!F55)	IF(Binary control<>0;IF(ROUND(Net cash flow-change liquidity;5 decimal places)=0;0;1)	=IF(F54<>0;0;IF(ROUND F45-F50;5)=0;0;1))

Fig. 3.33 Error checking version 2 with the IF function

	A	B	C	D	E	F	G	H	I	J	K
44											
45		Net cash flow				1.242	1.390	1.589	1.798	2.042	1.698
46											
47		Liquidity 01.01				1.662	2.904	4.294	5.884	7.682	9.724
48		Liquidity 31.12			1662	2.904	4.294	5.884	7.682	9.724	11.421
49											
50		Change				1.238	1.390	1.589	1.798	2.042	1.698
51											
52		Check				4	0	0	0	0	0
53											
54		Binary control 1				0	0	0	0	0	0
55		Binary control 2				1	0	0	0	0	0
56		Result binary control				1	0	0	0	0	0

Fig. 3.34 Step 2 of the binary control calculation

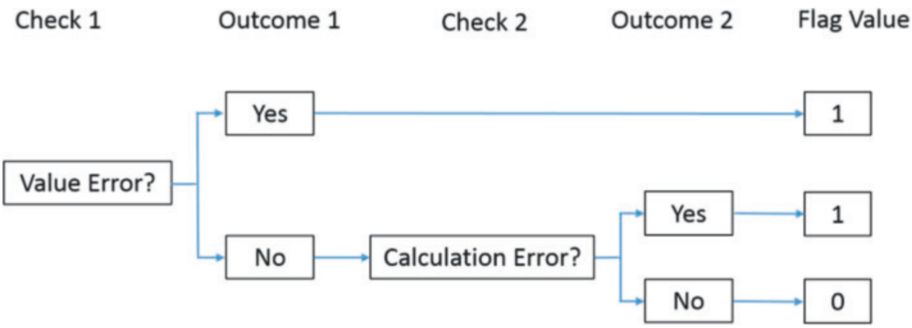


Fig. 3.35 Error checking – Error formula example
Source: BPM Analytical Empowerment Pty Ltd and associated entities: Best Practice Spreadsheet Modeling. Version 7, p. 203

- If no error value was found, it is checked whether the result of the control calculation corresponds to the model value. If this is not the case, the error is identified by assigning the value "1."[25]

Figure 3.34 shows how an error in the control calculation is captured in step 2 of the binary control calculation.

Figure 3.35 provides an overview of the processes of the above function.

It is recommended to place controls as close as possible to the calculations that need to be checked – at a minimum they should be on the same worksheet. This enables the financial modeler to easily trace all needed measures. In addition it is also advisable to combine all controls and their results (checks) in one location of the workbook. This can be done for example with the help of a listing "Check Summary" which combines all checks of the control calculations that are distributed throughout the workbook and can be directly accessed via hyperlinks. During the model review, such a listing reveals whether and where errors have occurred in the financial model.

8 Measures to Assess the Plausibility of the Results

> Sensitivity analysis and scenario analysis are measures to assess the plausibility of results.

The measures which are described in the following serve to assess the plausibility of the results of the financial model. A model is stress tested during the model review process in order to assess its stability and to see whether it also provides plausible results if extreme values are provided or whether it malfunctions due to a modeling error.

8.1 Sensitivity Analysis

> The sensitivity analysis tests the reaction of the model results to changes in various value drivers.

The sensitivity analysis, also called stress test provides the financial modeler with valuable information about the causal relations between input and output variables in the model. As one instrument of the model review process, it assesses the sensitivity of the results to changes in specific values drivers. It additionally shows whether the model remains stable or crashes once these changes are implemented.

The instrument of sensitivity analysis was already discussed in the chapter Excel Workshop and is once again used extensively in the chapter on Corporate Finance. For that reason we direct you to those sections.

8.2 Scenario Analysis

> The scenario analysis tests which model results are obtained under differing framework conditions.

With the help of scenario analysis it is possible to determine the alterations in results which are the consequence of differing framework conditions and the corresponding changes in input data.

The instrument of scenario analysis was already discussed in the chapter Excel Workshop and is once again used extensively in the chapter on Corporate Finance. For that reason we direct you to those sections.

9 Documentation

> The results of the model review and the model audit are documented professionally.

An important component of any professional model review and audit is the documentation of the results. In the documentation, the process of the model review is described, a detailed listing of all critical issues is maintained (so called "list of findings") and the critical issues are categorized by relevancy. The documentation serves as the basis for additional coordination between auditor and client and helps the client to improve his modeling process in the future.

In the chapter Financial Modeling Standards we already discussed how adherence to the financial modeling standards needs to be documented. This documentation is an important part of the model review materials.

In addition, the actual results of the model review are listed. The components which most likely contain errors are classified and sorted by type or priority of the error and listed in a register.

Errors/findings can be described during model review with reference to the following attributes:

- Design
- Hidden assumptions
- Deviations from the financial modeling standards
- Possible errors
- Errors

The following list of priorities when eliminating errors or working on the findings can be assigned:

- Errors that do not have an effect on the final result
- Errors that have an indirect effect on the result
- Errors that have a significant effect on the result (for example calculation errors, omissions, errors of interpretation)

In addition, the status of the work is given. A distinction is made between:

- Ok: resolved
- UAsmp: Assumptions not documented
- Report: Exceptions that need to be explained
- o/s: Open, needs to be resolved

With the help of this documentation, the results of the financial model can be successively reviewed, processed, corrected or amended. Suggestions for changes and improvements are only documented during the model review process. The implementation is the responsibility of the customer, who is responsible for the financial model. This gives the developer of the financial model the option of either accepting or rejecting the proposed measures.

10 Summary

In the chapter Model Review the financial modeler has gained insights into methods and processes used during the model review:

Basics of Model Review

- In the context of the model review, financial models are analyzed and checked for errors. The errors are documented and suggestions for improvement are provided.

- The aim of the model review is to improve the quality of the financial model by detecting all errors if possible.
- Model review and model audit are distinguished primarily by the quality of the results.
- During the model review, the financial model is assessed in the context of a predetermined framework.
- During the model audit a complete assessment of the financial model is conducted by an external auditor.
- A certificate for the model audit can only be issued if the financial modeling standards have been applied and are documented.
- The model review includes the following steps: assessment of adherence to the financial modeling standards, check whether the framework conditions and assumptions have been captured correctly, economic assessment of the model structure and calculations, analytical review of the model results, checks for computational accuracy and integrity of the financial model and feedback for future models.

Errors in Financial Models

- An error is the failure to perform with regard to a required specification.
- An error can result either from an intended or from an unintended activity.
- A distinction is made between qualitative and quantitative errors.
- Qualitative errors are violations of the financial modeling standards and initially do not affect the results of the financial model.
- Quantitative errors influence the result of the financial model and give incorrect results. Mechanical errors, logical errors and errors of omission are types of quantitative errors.

Error Detection – Recognizing and Finding Errors

- Recognizing and detecting errors is the biggest, most time-intensive and probably most difficult task during the model review process.
- In principle, three methods for the detection of errors can be identified: review (logic inspection), tests (testing) and the use of analysis tools.

- The review is the most effective, but also the most time-consuming method for the detection of errors. It involves looking at each individual cell and assessing its content.
- Tests involve the controlled running of the entire financial model or of certain components in order to check whether the expected results are returned.
- A frequently used approach is the evaluation and comparison of results which were generated by entering and varying input data for the financial model.
- Scenario and sensitivity analysis are also among the testing procedures.
- Analysis tools are a promising method to detect errors in financial models.
- Analysis tools systematically screen the financial model and identify errors or possible errors with the help of review software.

Examples of Applications of Analysis Tools

- Excel is equipped with a number of integrated standard functions which are extremely helpful and support the model review process.
- Excel offers three approaches for the efficient support of the model review: monitoring of cell contents, use of formula auditing, recognizing and searching errors.
- Some functions that facilitate a professional model review are missing in Excel.
- These functions can be provided by model review software for professionals.

Control Calculations

- Control calculations are added to check the results of the financial model. This is a specific testing method for financial models.
- Ideally, control calculations are already added to the model during the modeling process. This helps to detect and eliminate errors early.
- The integration of control calculations is particularly advisable if the financial modeler has already built similar models and is familiar with its relevant economic linkages.

Measures to Assure the Plausibility of the Results

- Stress testing is used during the model review process in order to assess the stability of a model.
- Furthermore it is determined whether the model also provides plausible results if extreme values are used or if it fails due to inappropriate modeling.
- For that reason some instruments take on a dual role in the financial modeling process, namely support in gaining insights as well as tool to conduct tests.
- Sensitivity analysis and scenario analysis are instruments to assess the plausibility of the model output.

Documentation

- The documentation of the test results is an integral part of any professional model review and audit.
- The model review process is described in the documentation and a detailed listing (so called "list of findings") of all critical issues provided.
- The documentation serves as the basis for further coordination between auditor and client and helps the client to improve his modeling process in the future.

Notes

1. See Panko, 2008a, p. 5.
2. See PwC, 2014, p. 6.
3. See Aurigemma/Panko (2010), p. 1.
4. See Panko, 2008a, p. 9.
5. See Prüher-von Au, 2010, p. 78.
6. See Panko, 2008a, p. 15; Panko, 2008b, pp. 208–209.
7. See Panko, 2008b, p. 205.
8. See Panko, 2006, pp. 73–74.
9. See Panko/Ordway, 2005, p. 23.
10. See Panko, 2006, p. 81.
11. See Panko, 2006, p. 81.
12. See Panko/Ordway, 2005, p. 4 and p. 40.
13. See Panko/Ordway, 2005, p. 40.
14. See Panko/Ordway, 2005, p. 4.

15. See Prüher-von Au, 2010, p. 78.
16. Panko, 2006, p. 78.
17. Howard (2007).
18. Howard (2007), pp. 13–15.
19. Howard (2007), p. 108.
20. Howard (2007), p. 108.
21. See Grossman/Özlük, 2010, p. 1.
22. See Prüher-von Au, 2010, p. 68.
23. See Pryor, 2004, p. 1.
24. See Pryor, 2004, p. 3.
25. See BPM Analytical Empowerment Pty Ltd and associated entities: Best Practice Spreadsheet Modeling. Version 7, p. 203.

Further Reading

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4

Workshop Excel Part I

1 Executive Summary

In this chapter, the financial modeler acquires the skills needed to develop Excel software solutions.

In the Workshop Excel Part I, the financial modeler is introduced to the structure of a financial model. Initially, the task list is defined, the key tasks are identified and visualized with the help of a diagram. An optimal visual display helps in structuring and documenting the financial model. The financial modeler learns how to create menus, buttons and borders and to highlight important elements using color. Professional financial modelers utilize key combinations when developing financial models. For that reason, the topics of key combinations with "Ctrl," function keys and also commands via the ribbon are addressed.

2 Introduction, Structure, Learning Outcomes and Case Study

Structure

The workshop serves as an introduction to financial modeling and answers the following questions:

- How to approach the solution of complex financial modeling tasks in Excel in a structured manner?

J. Häcker and D. Ernst, *Financial Modeling*,
Global Financial Markets, DOI 10.1057/978-1-137-42658-1_4

- How to structure financial models in an appealing and user-friendly way?
- How does the financial modeler work ergonomically in Excel?

Learning Outcomes

The workshop uses a case study to demonstrate how to build financial models in Excel in a structured manner.

The financial modeler

- Learns how to create professional financial models step by step, which generate robust and useful results related to issues in the field of finance;
- Learns how to transfer abstract models and qualitative information into an Excel model;

Case Study

Suggestions for use of the book and the download offering: Learning will be most successful if the insights are directly applied. The examples provided in the download offering (folder Workshop Excel) allow you to deepen your knowledge from the book by applying it to the case study.

Use the workbooks of the workshop as you go through the text. The individual learning steps are contained in small units on separate worksheets in eight workbooks. They can be used in two different ways:

> The contents of the download offering complements the text and supports active learning.

1. Open a new workbook and recreate the financial model from the case study step by step by your own. This is the most challenging approach which also promises the greatest reward. Start with `Create Menus` and continue all the way to the `Diagrams`. In that way, you get to know all the steps needed to create a financial model.

2. Or you can use the workbook in the folder of the `Workshop Excel` to directly tackle individual issues of particular importance to you. The different topics in the individual worksheets can be used independently of each other.

Excel Software Version
Workshop Excel was prepared with the latest desktop version of Excel (Excel 2016 for Windows, 32-bit). In general, the information also applies to Excel 2013 and Excel 2010. If you use these earlier versions, in exceptional circumstances menus and commands can deviate from the demonstration here.

Security
Security is an important topic when using macros and VBA. VBA programs are deactivated in the standard settings of Excel. Therefore, all security settings need to be changed in order to work with the applied examples (*disable all macros with notification*).

1. Once you open the workbook from the download offering, Excel will provide a security warning below the ribbon.
2. With the button *Options* followed by *Activate this contents* you allow running of the macro.

More information is found in the Workshop VBA in the Section Correct setting of Virus Protection – Activating Macros.

3 Why Study Excel?

Why should Excel be studied? It is apparent that Excel allows the quick and effective completion of complex tasks. But other software programs can do the same thing. So what are the specific advantages of Excel?

The advantages of the office software “Excel” are:

1. **Excel is frequently used:** Excel is the global leader in spreadsheet applications. Complicated and costly interfaces with different types of spreadsheet are thus not needed.
   - **Excel is extremely variable:** Excel facilitates the individual and relatively quick completion of tasks. Problems for which no

standard solutions are available can be solved with great precision. If the requirements change during the process of problem solving, Excel is very suitable to deal with the new constraints.

2. **Quick decisions:** Excel allows the efficient management and analysis of data. The user is thus easily enabled to get an overview of the main linkages and as a consequence reach decisions quickly.
3. **Relative large volumes of data can be handled:** Excel can deal with relatively large volumes of data. With the introduction of Excel 2007, the user can utilize 1,048,576 rows and 16,384 columns per worksheet. However, as the workbook becomes larger, the above mentioned advantage of time savings becomes less relevant. The use of a number of techniques, such as a data filter in Excel, can help to mitigate this problem. It is still true that Excel is not a database and extremely large data volumes should be organized in a database.
   - **Basic functions are easily understood:** Excel is a program with basic functions that are very easily understood. Only a few fundamental rules are needed to work in Excel and the most important calculations are easily implemented. Therefore the user is very quickly in a position to start solving problems. Specialized additional knowledge needed to expand or deepen the analysis can be obtained step by step.
4. **It can be easily checked:** Each formula that was created by the user can be easily checked by clicking on the field that contains the formula. If needed, the formula can be modified. In Chapter 3, "Model Review," it is shown how controlling of the entire financial model is best implemented in Excel.
5. **It can be quickly automated:** Numerous Excel functions can be automated easily by creating macros that are relatively simple to write. In that way it is possible to automate and speed up monotonous and repetitive tasks as well as manual activities. Complex processes that would be very difficult or even impossible otherwise can be completed by pressing a single button. The macros utilized help to eliminate typical sources of error and allow the unified presentation of results. The precise approach is demonstrated in Chapter 5, "VBA Workshop."
6. **It has numerous fields of application:** Excel can be used for a very large number of different tasks. Examples include the optimization of production and storage in the context of general

business processes or budget planning in the context of financing and accounting. In this financial modeling book we present applications of Excel in four central fields of finance. These are Investment Appraisal (Chapter 8) and Financing (Chapter 9), Corporate Finance (Chapters 10 and 11), Portfolio Management (Chapters 12 and 12) and Derivatives (Chapter 14).

4 Developing a Financial Model

Do not immediately enter financial models in Excel.

Excel is an easy to use spreadsheet software. It is tempting to quickly enter formulas without careful planning. Frequently columns are added or deleted and just as frequently the question about the relevance of a specific cell reference arises.

When compiling a financial model, it is generally recommended to pursue a structured approach. A structured approach requires a certain degree of preparation, but at the same time it significantly reduces development times as well as error correction. In an effective development process, completing the worksheets is mostly a mechanical task.

4.1 Defining the Task List

Define the task list.

First comes the development stage, which serves to analyze and define the task list. The key issues are studied during this stage.

The workshop is accompanied by a comprehensive applied example.

Applied Example

Investment decisions for a medium-sized company

The management assistant at Supplier Inc. has been given the task to develop a financial model that can serve as the basis for investment decisions. Currently this task is the responsibility of the accounting team, which focuses primarily on the issues profitability and financing. The assistant, who successfully completed his training as financial modeler is aware of the fact that such a management information system requires a more comprehensive approach than before. Primarily backward-looking accounting data needs to be supplemented with additional aspects which allow forecasts about future developments and thus provide a better foundation for investment decisions. This workshop reviews the steps needed to arrive at a robust and efficient financial model which can be presented to top management.

In order to define a task list, the following questions must be answered.

- Concretely, what is the expected outcome?
- What exactly is required of the financial model?
- How is it used and who uses it?
- Which resources concerning time, personnel and financing are available?

Focus on concrete targets.

The assistant develops a task list together with the management team. Pertinent issues are discussed during a meeting.

Based on a careful assessment, the financial modeler at Supplier Inc. has developed the following task list in collaboration with the management team. It contains the following items:

Applied Example

Task list for the financial model

- **Aim:** A decision tool suitable for assessing the purchase of major investment goods needed in the production process.
- **Responsibility:** The management team transfers the required responsibilities for the project to the financial modeler. At the same time, he bears sole responsibility for success or failure of the project.
- **Budget:** A five figure budget is available.

- **Persons involved:** Persons with responsibility in the fields of production, accounting and marketing.
- **Future users:** Top-management and staff from the accounting department.
- **Quality control:** Testing using prototypes and the final version of the financial model is conducted by the user and an external consultant.
- **Time period:** 16 weeks until completion are budgeted.

4.2 Identifying the Key Tasks

> The key tasks define the problems to be solved.

The next major step in financial modeling is to clearly define and delineate the problem, in other words to identify the key tasks. The key task defines the minimal and essential requirements – without getting sidetracked by details. The available knowledge about the problem at hand is collected and structured.

Applied Example

Narrowing down the task
A selection of questions that need to be answered by the management assistant in order to narrow down the task:

Questions	Answers by the financial modeler that help to narrow down the task
Which external factors need to be considered?	Simplified definition of the external environment (peer group).
For which types of investments?	Investments for rationalization or expansion.
Which method?	Dynamic method (net present value).
Which variable should be valued?	Cash flow consideration.
Which planning period?	Medium-term planning period (5 years).
Which data sources?	External sources (market research reports, analyst opinions, engineering experts and so on), internal sources (such as accounting and production)
Treatment of the accounting data?	If there are indications that the values from the past are not representative of the future (caused for example, by a switchover to a new product), the figures need to be adjusted.

Include influence on result and additional investment costs?	Identified as important value drivers are maintenance, service, employee training and additional revenues.
Consider savings from productivity increase?	Personnel redundancies.
Which types of financing?	Equity capital is used to finance investment.
Tax considerations?	Not relevant.
Incorporate inflation?	Not relevant.
Additional potential decisions and results?	Total loss of the investment object before the end of the period of usage is ruled out. Strong revenues generated by the newly manufactured products.

The list of relevant topics could easily be expanded. A careful assessment is highly relevant, since determining the scope at the same time limits the potential solutions.

4.3 Visualizing Abstract Relations with Bubble Charts

A picture is worth a thousand words.

A suitable method to capture unstructured amounts of data is the optical assessment with a simple chart or diagram which captures all important linkages. Graphics tools that are frequently used in financial modeling include bubble charts and influence diagrams. A detailed introduction to the topic including applied examples can be found in the *Workshop VBA* as well as in the section *Implementation of the Top-10 Standards*.

Practical Tip

Drawing bubble charts:

1. Start with the final result (net present value).
2. Break down the final result into smaller sub-units (such as cash flows p.a., sum of expenditures or receipts).

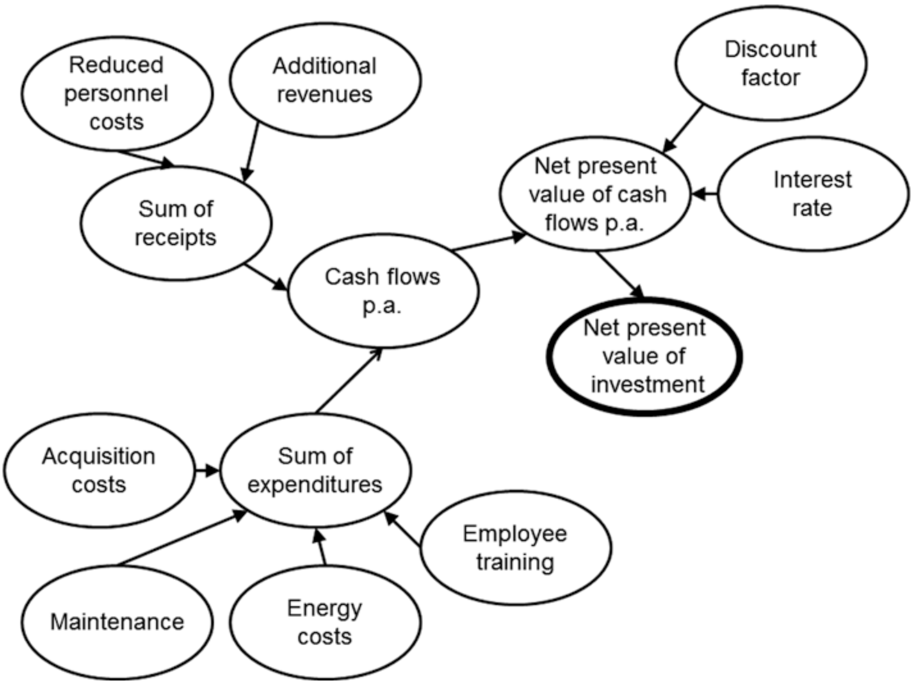


Fig. 4.1 Bubble chart for the investment calculation of Supplier Inc.

3. The sub-units are again broken down into their components (reduced personnel costs, additional revenues and so forth). Each variable is drawn only once.
4. Related elements are connected using arrows (Fig. 4.1).

5 Visual Display of a Financial Model

5.1 Structuring a Financial Model

From a financial modeling workshop, the assistant of Supplier Inc. is familiar with the importance of an appealing visual structure of the financial model which is just as important as the actual results.

Up to this point, all involved persons have only dealt with the abstract linkages of the task. In order to arrive at a more tangible display of the investment calculations, the assistant provides a first draft

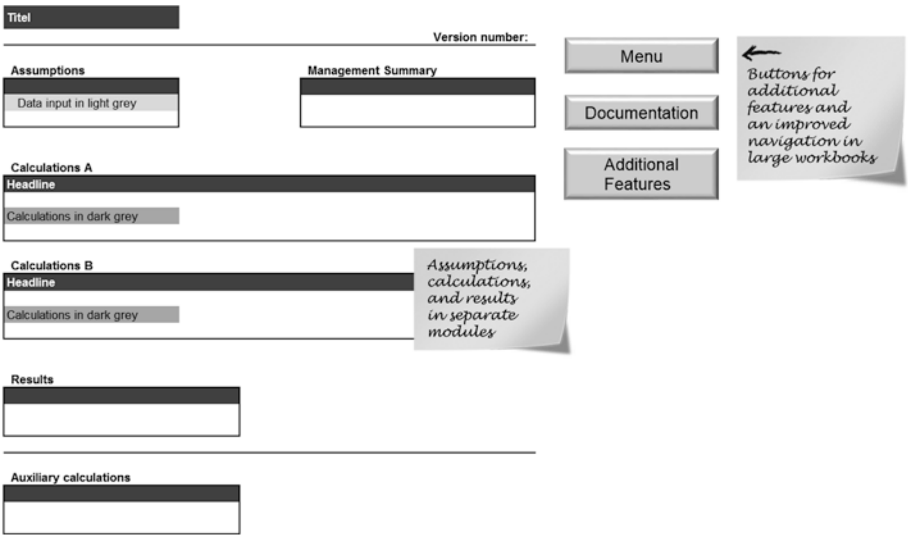


Fig. 4.2 The surface and the modules of the financial model (Excel File Workshop Excel_1, Worksheet Layout)

of the user surface. Such a surface does resemble the final financial model, but does not show any figures or links. This allows all participants to get a concrete impression about the future look of the financial model (Fig. 4.2). The management assistant compartmentalizes the financial model into modules.

Applied Example

Module

The financial modeler of Supplier Inc. considers the following modules to be important for his task:

- Input fields for the assumptions.
- Short overview which serves as management summary.
- Module for the calculations.
- Sensitivity analysis and scenarios.
- Diagrams.
- Menu and documentation.

The planning of the modules only involves the analysis of investments in productive capacity in line with the task list.

5.2 Documenting a Financial Model

In most actual applications, financial models are not documented at all or only incompletely. This is disadvantageous, since it makes it more difficult for the financial modeler or user to further develop the model.

Applied Example

Documentation for the financial model

The assistant of Supplier Inc. has documented his financial model. The main elements are all contained in the documentation (Fig. 4.3).

Documentation	
Project name:	Workshop Excel
Financial Modeler:	The team of the Financial Modeling book
File name:	Workshop Excel
Last changed:	June 2016
Changes made:	Final edits
Task and Aim:	Learning will be most successful if the insights are directly applied. The examples provided in the download section (folder Workshop Excel) allow you to deepen your knowledge from the book by applying it to the case study. The Excel files of the workshop can be applied while going through the text.
Instructions for Use:	The individual learning steps are contained in small units on separate worksheets in eight files. They can be used in two different ways: 1. Open a new workbook and recreate the financial model from the case study step by step by your own. This is the most challenging approach which also promises the greatest reward. Start with "Create Menus" and continue all the way to the "Diagrams". In that way, you get to know all the steps needed to create a financial model. 2. Use the Excel files to directly tackle individual issues of particular importance. The different topics in the individual worksheets can be used independently from each other.
Conventions of color selection:	Assumptions and input fields: Orange Calculations and output: Grey

Fig. 4.3 Example of a documentation on the first worksheet of a financial model (Excel File Workshop Excel_1, Worksheet Menu_and_Docu)

5.3 Structuring Large Financial Models Ergonomically

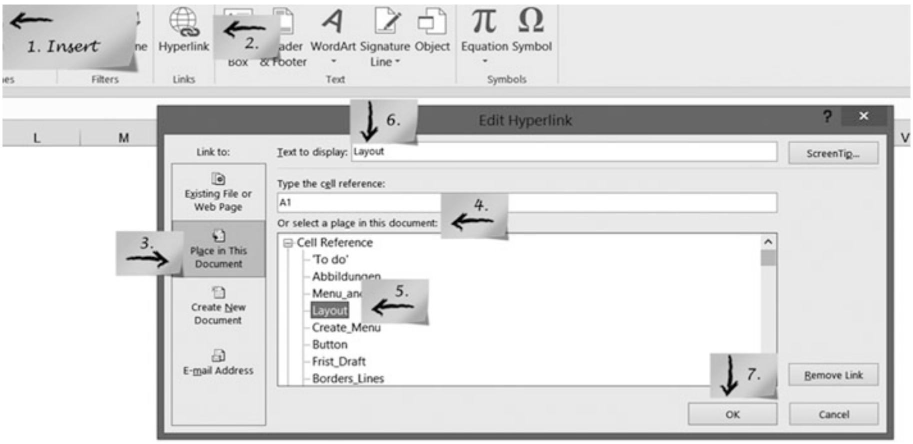
Complex financial models regularly consist of a large number of worksheets. This is already apparent in this workshop, where more than 20 worksheets are included. In order to facilitate the use of a financial model for its users, a menu and buttons should be included. This allows the ergonomic navigation between the various sections.

5.3.1 Creating a Menu

Every user of word processing programs is accustomed to the possibility of creating a table of contents at the push of a button. Such a comfortable function does not exist in Excel. In the workshop VBA you learn how to program such a tool. Without any knowledge of VBA, you can also construct an overview of the worksheets with so-called *hyperlinks*:

An exercise: Create a menu in the Excel File Workshop Excel_1.

1. Go to *Insert* tab.
2. Click on *Hyperlink* in group *Links*.
3. In the left column under *Link to* choose *Place in This Document*.
4. Go to the box *Or select a place in this document*.
5. Scroll to *Cell Reference* and select worksheet *Layout*.
6. In the *Text to display* box type in: Layout
7. Close with *OK*.



The new *Hyperlink* appears as a simple text. If you want to improve the layout, proceed as follows (Fig. 4.4):

1. Mark the *Hyperlink* “Layout” using the right mouse button.
2. In the context menu go to *Format Cells*...
3. Select the tab *Number*.
4. Under *Category* select *Custom*.
5. Overwrite the word *Standard* in the text field *Type* with: “• @”

The symbol • is generated by holding down the *Alt*-key and entering the sequence 0 1 4 9 on the numerical keypad. Once you release the *Alt*-key, the symbol • appears.

6. Confirm with *OK*. The complete menu is displayed in Fig. 4.4.

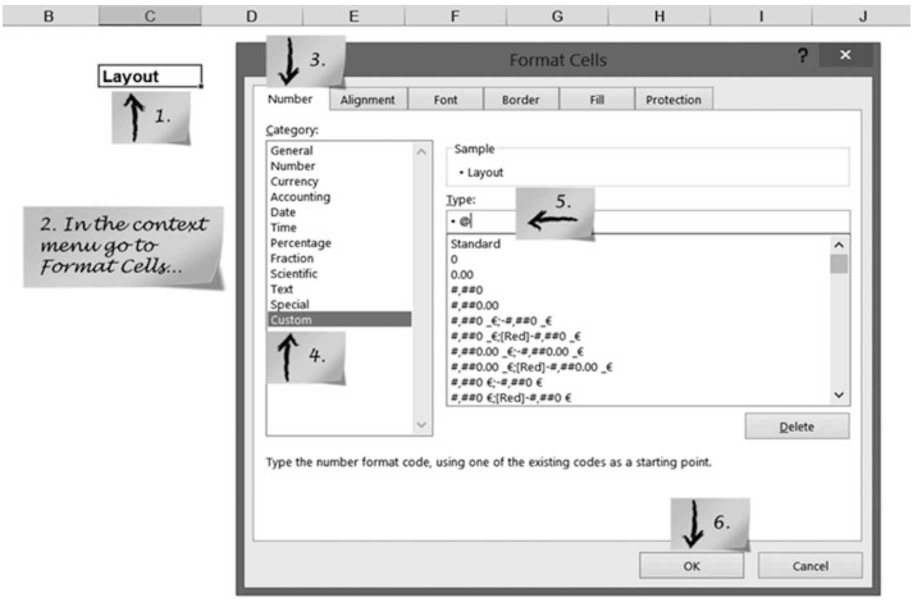


Fig. 4.4 Formatting a hyperlink for a menu (Excel File Workshop Excel_1, Create_Menu)

In this way, a complete menu based on *Hyperlinks* to all worksheets can be created (Fig. 4.5).

Fig. 4.5 Menu of the Workshop Excel (Excel File Workshop Excel_1, Worksheet Menu_and_Doc)

In the Excel File Workshop Excel_1 in the Worksheet Menu_and_Doc you find the menu for the workshop.

5.3.2 Creating Buttons

An exercise: Excel File Workshop Excel_1, Worksheet Button.

The structure of the template in Figure 4.2 is reminiscent of a classical calculator with displays (such as results and brief explanations) and buttons. The buttons facilitate navigation and orientation. This is an advantage especially in the case of financial models with a large number of worksheets. They effectively connect relevant information and avoid the need for time-consuming scrolling. The buttons allow, for example, to directly access a table of contents, a documentation or additional features.

So-called *Macros* facilitate the comfortable construction of command buttons, which can be given specific functions. Details can also be found in the Workshop VBA. But it is possible to generate buttons even without any knowledge of programming with the help of *Text Boxes* and the previously introduced *Hyperlink* (see Fig. 4.6).

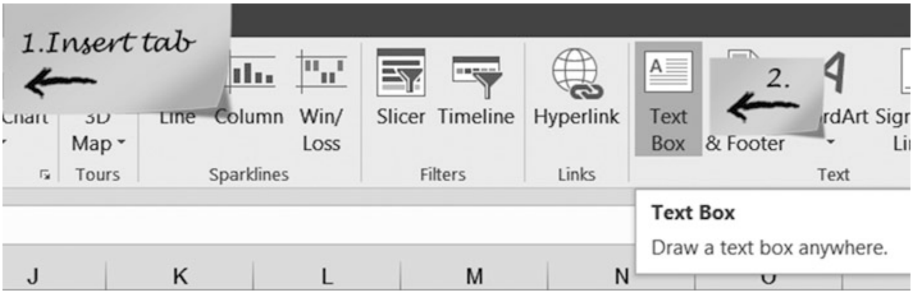


Fig. 4.6 Creating a button

1. Go to *Insert* tab.
2. Insert a *Text Box*: In the group *Text* click *Text Box*.
3. Hold down the mouse key and drag the *Text Box* to the desired size (Fig. 4.7.).

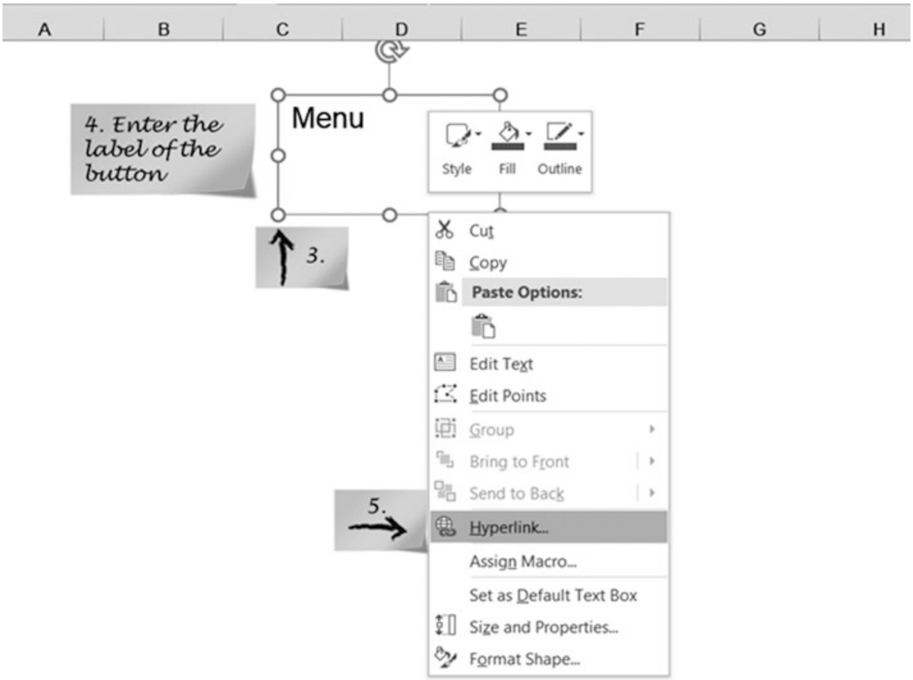


Fig. 4.7 Creating a button from a Text Box (Excel File Workshop Excel_1, Worksheet Button)

4. The label of the future button can be entered into the blinking text marker.
5. Right-click on the *Text Box* with your mouse. You will get to a context menu, from which you can select *Hyperlink*.
6. In the following, the dialog box *Insert Hyperlink* opens up (Fig. 4.8).
7. Select *Place in This Document*.
8. As cell reference please enter the cell `A1`.
9. Create a link between the *Button* and the worksheet *Create_Menu* by selecting the relevant row in the dialogue below.
10. Confirm with *OK*.

With the linked text box it is now possible to directly move to the worksheet *Create_Menu*. However, the layout is still not convincing. To clearly mark it as a button, it needs to be formatted:

1. Mark the *Text Box* with the right mouse button (Fig. 4.9).

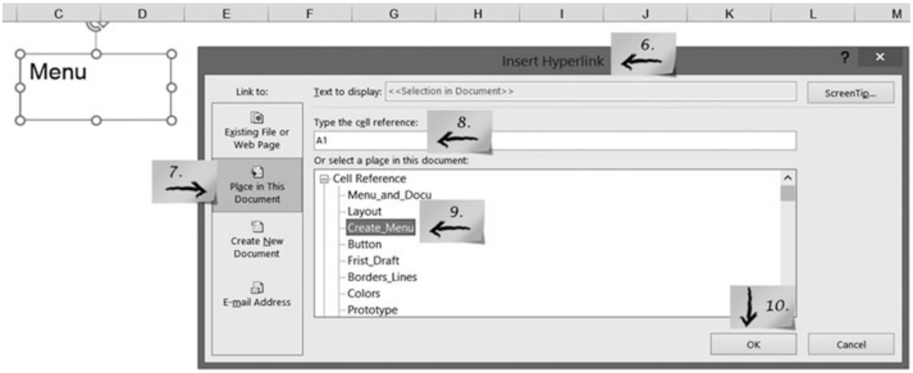


Fig. 4.8 Linking the button with a hyperlink (Excel File Workshop Excel_1, Worksheet Button)

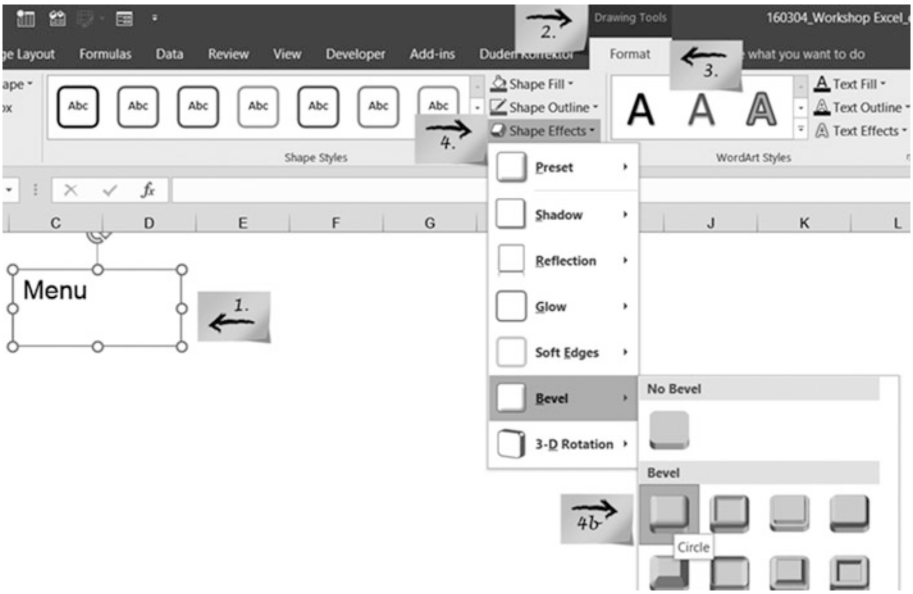


Fig. 4.9 Creating a button with format control

2. You get to the tab *Format* and the contextual tab *Drawing Tools* appears.
3. Click on *Format*.
4. Select a suitable presentation from *Shape Effects*. Recommended are tapered forms (option *Bevel*).

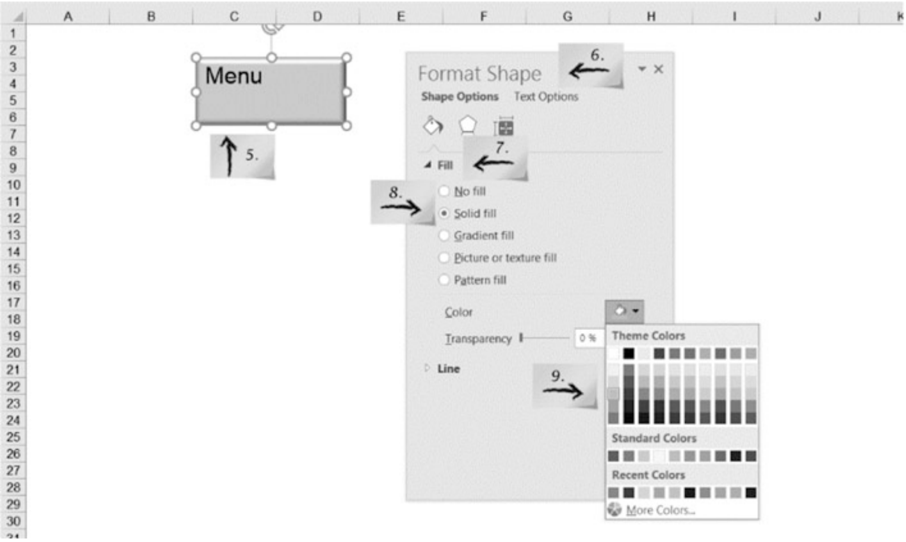


Fig. 4.10 Coloring the button

5. Fill the button with a color. Mark the *Text Box* with the right mouse key (Fig. 4.10).
6. In the context menu use *Format Shape*. . .
7. Open the option *Fill*.
8. Click on the option *Solid Fill*.
9. Select a *color*.

5.4 Borders and Lines: Providing Structure to the Data

You will witness in the following sections how the financial modeler of Supplier Inc. creates a template with lines, borders and colors. Without borders, lines and colors, the intended surface (Fig. 4.2) is barely recognizable in Fig. 4.11.

Borders and lines highlight the structure of a financial model.

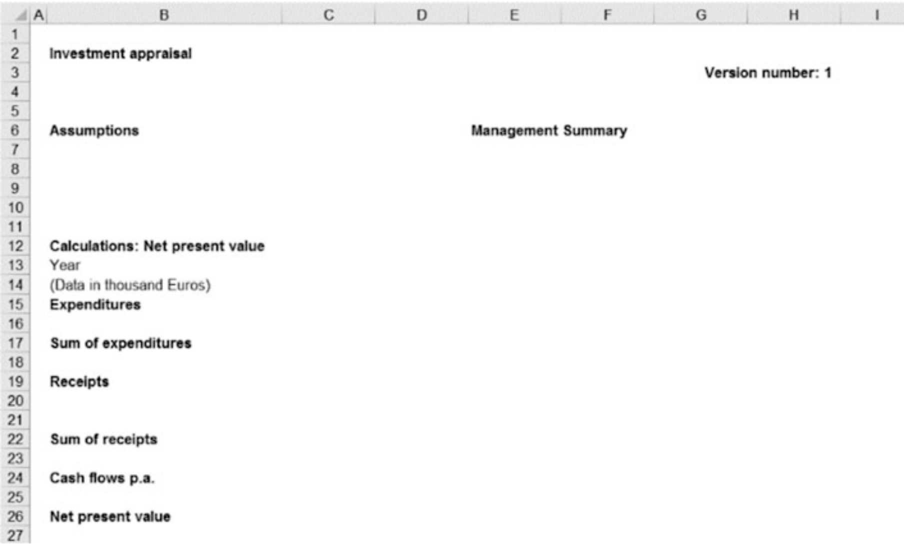


Fig. 4.11 The surface of the financial model without formatting (Excel File Workshop Excel_1, Worksheet First_Draft)

Providing borders and lines in Excel:

> An exercise: Excel File Workshop Excel_1, Worksheet Borders_Lines.

1. Highlight for example the module *Assumptions* (cell range `B6:C8`).
2. Go to *Home*.
3. Click with the mouse in the group *Font* on the small triangle in the lower right (dialog box launcher).
4. Switch to the tab *Border*.
5. Select a thick line among the choices in *Style*.
6. Provide an outside border by selecting *Outline* from the choices under *Presets*.
7. Confirm with *OK* (Fig. 4.12).

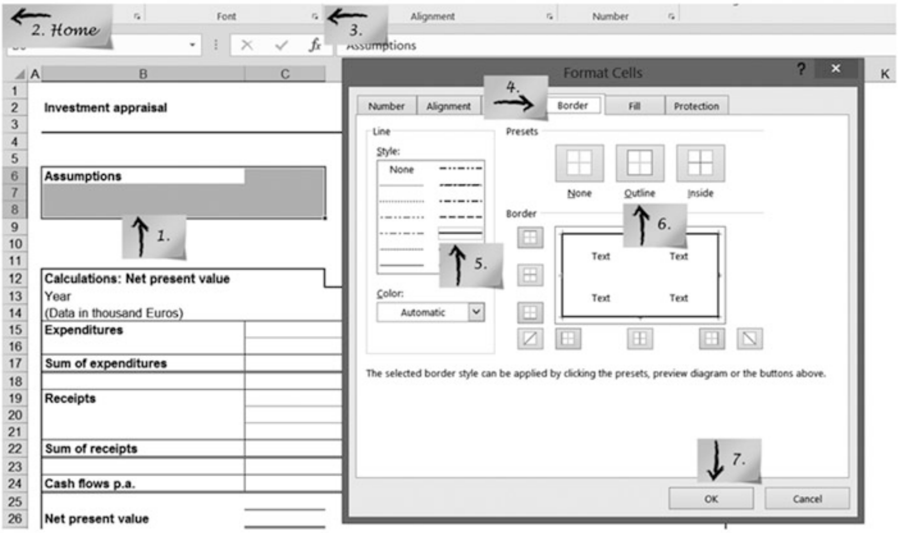


Fig. 4.12 Financial Model with borders and lines (Excel File Workshop Excel_1, Worksheet Borders_Lines)

5.5 Using Colors to Highlight Important Elements

Colors can be used effectively to draw attention towards the main elements of the financial model. But it should be kept in mind that only dark colors are suitable for texts, since they are also legible on copies. Cells that are highlighted using light colors might still be legible on printouts, but on copies or faxes they are frequently barely legible.

Colors should be used sparingly and with purpose. In the applied example, cells that are marked in color indicate data input (orange) and calculations (gray).

An exercise: Excel File Workshop Excel_1, Worksheet Colors.

Determining cell colors in Excel (Fig. 4.13):

1. For example, mark a cell that contains assumptions.
2. Go to *Home*.
3. Click with the mouse in the group *Font* on the small triangle in the lower right (dialog box launcher).
4. Switch to the tab *Fill*.

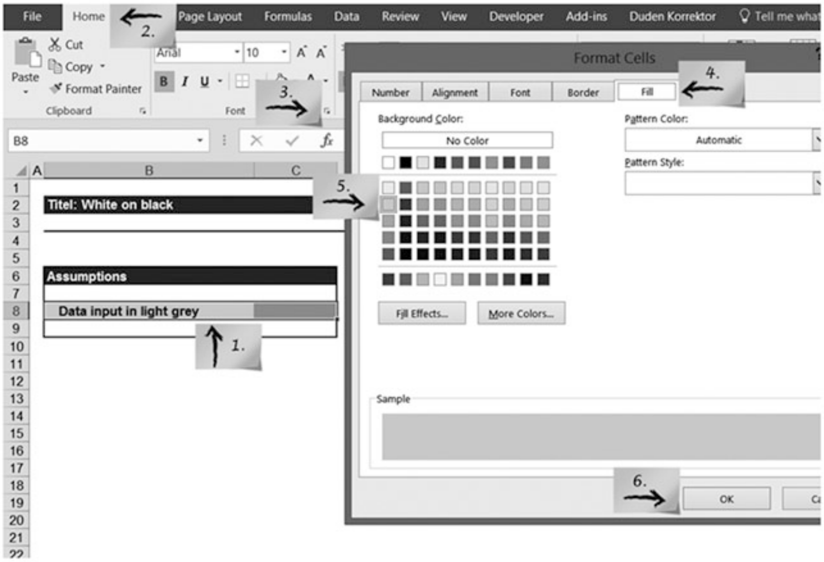


Fig. 4.13 Determining cell colors

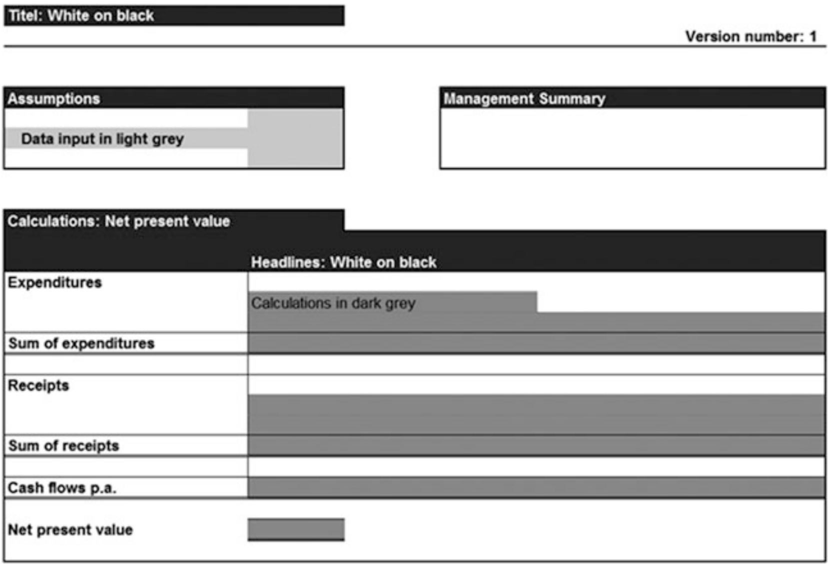


Fig. 4.14 The financial model in color (Excel File Workshop Excel_1, Worksheet Colors)

5. Here you can select a standard color from the choices provided. A gray is selected in the applied example.
6. Confirm with *OK* to exit the menu (Fig. 4.14).

6 Side Note: Using Key Combinations and the Ribbon to Work in Excel

Every user who has spent significant amounts of time with Excel and acquired a certain familiarity with the program will realize that the use of the computer mouse and the touchpad is frequently inefficient. Working time is increased due to the required number of sequences of mouse clicks and the workflow is interrupted because the hand needs to move back and forth between keyboard and mouse. An apparent alternative which is likely to speed up the workflow is the use of key combinations or sequences on the keyboard.

Professional financial modelers, who work with Excel on a daily basis are able to create entire Excel files consisting of several worksheets without using the mouse. However, this approach does require the continuous use of the numerous key combinations. Every financial modeler needs to determine for himself whether studying the key combinations makes sense for him personally and how quickly the time savings will pay off.

But even when creating the financial models in this book, a lot of time can be saved when utilizing important key combinations. Especially in the field of financial modeling, a professional use of Excel is indispensable. For that reason, we will cover important keyboard commands in Excel and show how a modeling worksheet can be created without any use of the mouse.

6.1 Key Combinations and Sequences in Excel

The following tables show the most important key combinations and sequences in Excel. Combinations of keys are shown with "+" between the keys which must be pressed simultaneously. In the case of sequences, the keys are separated by "," and are pressed sequentially.

The standard layout of a keyboard (Fig. 4.15) – which serves as the basis for our additional examples and explanations – should already be known. However, many users fail to utilize keys such as *Ctrl*, *Alt*, *Alt Gr* or the *F*-key. The keys which are most important for our purposes in Excel are marked with a border. Their respective functions and uses are discussed in more detail on the following pages.

Fig. 4.15 The layout of the keyboard

6.2 Different Types of Key Combinations in Excel

Different types of key combinations exist in Excel. This will be clarified later with reference to an example.

It also must be kept in mind that some functions can be reached via different key combinations. This is due firstly to the age of Excel and the continuity between the different versions and secondly to the differences in complexity of the various types of key combinations. It is necessary, for example, to memorize the approach for some key combinations, while help is provided on screen for others. A fundamental distinction is made between

- Commands via the *Ribbon*,
- Key combinations using ***Ctrl***,
- Function keys (***F-keys*** such as ***F1***).

In the following sections, we will take a closer look at the various types of key combinations and their advantages and disadvantages.

6.2.1 Commands via the Ribbon

Ribbon

Using the keyboard in Excel to enter commands via the *ribbon*, is a simple possibility to work in Excel without a mouse and still not have to memorize the relevant key combinations. Only the function of the Alt-key must be known: it activates the use of the ribbon via

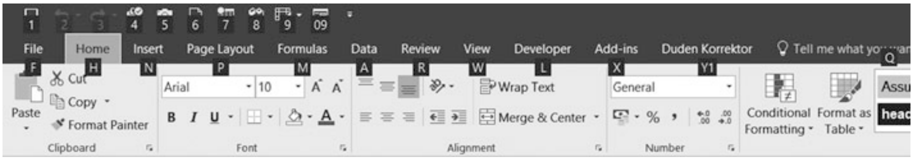


Fig. 4.16 Ribbon

the keyboard. At the same time, the keys which need to be pressed are shown next to the functions in the *ribbon* (Fig. 4.16). Once the tabs on the ribbon are pressed, the keys for functions one level below become visible and can thus be selected.

The disadvantage of this type of key sequence is the relatively high number of keys that must be pressed and the corresponding time requirement. In addition it must be known where in the *ribbon* under which tabs the relevant functions are positioned.

Practical Tip

Adjusting the *Ribbon*
The *Ribbon* in Excel can also be expanded individually to include more functions and tabs. These can be functions that were previously not included in the *Ribbon* or personally created macros or specifically programmed functions of a company. However, the tabs provided by Microsoft cannot be changed.

6.2.2 Key Combinations with Ctrl

Ctrl-combinations

An additional option to use Excel without a mouse is the utilization of combinations involving the ***Ctrl-key***. These commands, which frequently involve 2 or 3 keys that need to be pressed simultaneously already require some practice. The advantage is that these functions and commands can be used very quickly.

The following table describes some of the important key combinations which involve the **Ctrl-key**.

Shortcut Key	Action
	Format
Ctrl + 1	Displays the Format Cells dialog box
Ctrl + 2	Applies or removes bold formatting
Ctrl + 3	Applies or removes italic formatting
Ctrl + 4	Applies or removes underlining
Ctrl + 5	Applies or removes strikethrough
Ctrl + 6	Display or hide objects
Ctrl + 7	Display or hide standard toolbar
Ctrl + 8	Displays or hides the outline symbols
Ctrl + 9	Hides the selected rows
Ctrl + D	Uses the Fill Down command
Ctrl + Shift + %	Applies the Percentage format
Ctrl + Shift + $	Applies the Currency format
Ctrl + Shift + &	Applies the outline border to the selected cells
Ctrl + Shift + _	Removes the outline border from the selected cells
Ctrl + Shift + (	Unhides any hidden rows within the selection
Ctrl + Shift + P	Opens the Format Cells dialog box
	Worksheet commands
Ctrl + `	Alternates between displaying cell values and formulas
Ctrl + F	Displays the Find and Replace dialog box
Ctrl + G	Displays the Go To dialog box
Ctrl + L	Displays the Create Table dialog box
Ctrl + T	
Ctrl + O	Displays the Open dialog box
Ctrl + P	Displays the Print dialog box
Ctrl + W	Closes the selected workbook window
Ctrl + Y	Repeats the last command
Ctrl + "+" or "-"	Inserts or deletes a cell
Ctrl + N	Creates a new workbook
Ctrl + A	Selects the entire worksheet
Ctrl + X	Cuts the selected cells
Ctrl + C	Copies the selected cells
Ctrl + V	Insert
Ctrl + Z	Undo command
Ctrl + S	Saves the active file
Ctrl + Shift + '	Copies the formula from the cell above the active cell into the cell or formula bar
Ctrl + Shift + "	Copies the value from the cell above the active cell into the cell or formula bar
Ctrl + Shift + U	Displays or hides formula bar
Ctrl + Shift + O	Selects all cells with comments
Ctrl + Shift +;	Enters the current data
Ctrl + Shift +:	Enters the current time

6.2.3 Function Keys (F-keys)

F-keys

The third possibility to work with functions in in Excel is the use of the so-called ***Function-*** or ***F-keys***. Several commands are assigned to each key: in addition to the key itself without pressing a combination also in combination with various other keys. Many of the functions that are directly assigned to an F-key turn out to be very useful for professional financial modeling. The following Table lists the most important F-keys and their assigned functions.

F-Key	Combination	Action
F1		Excel Help
	+ Ctrl	Displays or hides Ribbon
	+ Alt	Creates a chart
	+ Alt + Shift	Inserts a new worksheet
F2		Edits the active cell
	+ Shift	Adds or edits a cell comment
F3	+ Shift	Displays the Insert Function dialog box
F4		Repeats the last command
	+ Shift	Repeats the last command
	+ Alt	Closes Excel
F5		Displays the Go To dialog box
F6	+ Ctrl	Switches to the next workbook window
F7		Displays the Spelling dialog box
F8	+ Shift	Adds a nonadjacent cell
	+ Alt	Displays the Macro dialog box
F9		Calculates all worksheets in the workbook
	+ Shift	Calculates the active worksheet
	+ Ctrl + Shift + Alt	Rechecks dependent formulas
F10		Turns key tips on or off
	+ Shift	Shows the shortcut menu
	+ Ctrl	Maximizes or restores the selected workbook window
F11		Creates a chart of the data
	+ Shift	Inserts a new worksheet
F12		Displays the Save As dialog box

Additional important key combinations

A listing of all possible key combinations in Excel would take up a lot of space and time and is also not the intention of this digression. While it is most likely that every command is covered by one or two combinations, some of them are hardly ever used by the majority of users – learning all these combinations is thus not really an option. In the following Table, some of the important commands that do not fit into any of the previous categories are listed.

Key	Combination	Action
PgDn	+ Alt	Move one screen to the right
	+ Ctrl	Switches between worksheet tabs, from left-to-right
	+ Shift + Ctrl	Selects current and next worksheet
PgUp	+ Alt	Move one screen to the left
	+ Ctrl	Switches between worksheet tabs, from right-to-left
	+ Shift + Ctrl	Selects current and previous worksheet
Return	+ Alt	Start a new row in the same cell
	+ Shift	Selects the cell above
Spacebar	+ Ctrl	Selects an entire column
	+ Shift	Selects an entire row
	+ Ctrl + Shift	Selects the entire worksheet
	+ Alt	Shows the Control menu for the Excel window
Arrow Keys	+ Shift	Extends the selection of cells by one cell
Tab	+ Shift	Moves to the previous cell
	+ Ctrl	Switches to the next tab
	+ Ctrl + Shift	Switches to the previous tab
Home	+ Ctrl	Moves to the beginning of the worksheet
	+ Ctrl + Shift	Extends the selection of cells to the beginning of the worksheet
End	+ Ctrl	Moves to the last used cell on the worksheet
	+ Ctrl + Shift	Extends the selection of cells to the last used cell on the worksheet

7 Summary

The financial modeler acquired the following skills in this workshop:

Financial modeling in Excel:

- Efficient modeling requires a structured and thoughtful approach and thorough preparation.
- There are only very few cases where the result for a complex topic can be derived directly.

- In applied work, the approach of developing a series of increasingly complex and improved prototypes has shown its effectiveness (iterative approach).

1. Structure:
   - The first phase in the process of financial modeling is to obtain clarity about the question at hand, the purpose of the financial model and the related aims.
   - The key tasks define the problems that need to be solved. A minimum requirement is a description of the knowledge available at this point.
   - This leads to the development of a task list, which defines the contents, the type of solution and the structure of the solution.
2. Optical structure of a financial model:
   - The use of modules helps to split tasks into small and independent components. They facilitate the work and can be used as samples for the solution of related tasks.
   - A suitable master specifically requires elements such as the separation of input and output data as well as the use of a uniform layout for the user surface in Excel (user-defined data formats, borders, colors, buttons and menus).
   - A stringent setup and a documentation that can also be understood by people who are not directly involved in the process are major elements of a professional financial model.

Further Reading

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Sengupta, C. (2010) *Financial Analysis and Modeling using Excel and VBA*, 2nd edn (New Jersey: John Wiley & Sons).

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5

Workshop Excel Part II

1 Executive Summary

In this chapter, the financial modeler acquires the skills needed to develop Excel software solutions.

In the Work Shop Excel Part II, the financial modeler learns to develop a prototype in Excel, to provide management with the appropriate signals, to correctly assemble the data set, to provide a sensitivity analysis of the results, to calculate scenarios and to check the financial model for errors. In addition to these important milestones, the financial modeler is familiarized with the use of important applications. He learns how to activate and use so-called add-ins, how to import data via VLookup and Index/Match and how to generally import data from the internet into Excel and work with that data in Excel.

2 Introduction, Structure, Learning Outcomes and Case Study

Structure

The workshop serves as an introduction to financial modeling and answers the following questions:

- How can the financial modeler utilize the numerous functions in Excel?
- How is data collected in Excel?

J. Häcker and D. Ernst, *Financial Modeling*,
Global Financial Markets, DOI 10.1057/978-1-137-42658-1_5

- How does a financial modeler analyze and test the sensitivity of the data?
- How can the performance of a financial model be tested?

Learning Outcomes

The workshop uses a case study to demonstrate how to build financial models in Excel in a structured manner.

The Financial Modeler

- Knows the correct use of the most important Excel tools and functions;
- Can develop his own templates and give them a user-friendly and ergonomic look as well as improve existing financial models in Excel;
- Knows how to improve the quality of a financial model in Excel with the help of analysis methods (such as sensitivity and scenario analysis);

Case Study

Suggestions for use of the book and the download offering: Learning will be most successful if the insights are directly applied. The examples provided in the download offering (folder Workshop Excel) allow you to deepen your knowledge from the book by applying it to the case study.

Use the workbooks of the workshop as you go through the text. The individual learning steps are contained in small units on separate worksheets in eight workbooks. They can be used in two different ways:

> The contents of the download offering complements the text and supports active learning.

1. Open a new workbook and recreate the financial model from the case study step by step by your own. This is the most challenging approach which also promises the greatest reward. Start with `Create Menus` and continue all the way to the `Diagrams`. In that

way, you get to know all the steps needed to create a financial model.

2. Or you can use the workbook in the folder of the `Workshop Excel` to directly tackle individual issues of particular importance to you. The different topics in the individual worksheets can be used independently of each other.

Excel Software Version
Workshop Excel was prepared with the latest desktop version of Excel (Excel 2016 for Windows, 32-bit). In general, the information also applies to Excel 2013 and Excel 2010. If you use these earlier versions, in exceptional circumstances menus and commands can deviate from the demonstration here.

Security

- Security is an important topic when using macros and VBA. VBA programs are deactivated in the standard settings of Excel. Therefore, all security settings need to be changed in order to work with the applied examples (*disable all macros with notification*).
- Once you open the workbook from the download offering, Excel will provide a security warning below the ribbon.
- With the button *Options* followed by *Activate this contents* you allow running of the macro.

More information is found in the Workshop VBA in the Section Correct setting of Virus Protection – Activating Macros.

3 Creating a Prototype in Excel

Once the previous steps have been completed successfully, the implementation in Excel is mostly a mechanical task. In the following, you will learn how a simple draft (for example in the form of a bubble diagram) can be turned into a professional financial model.

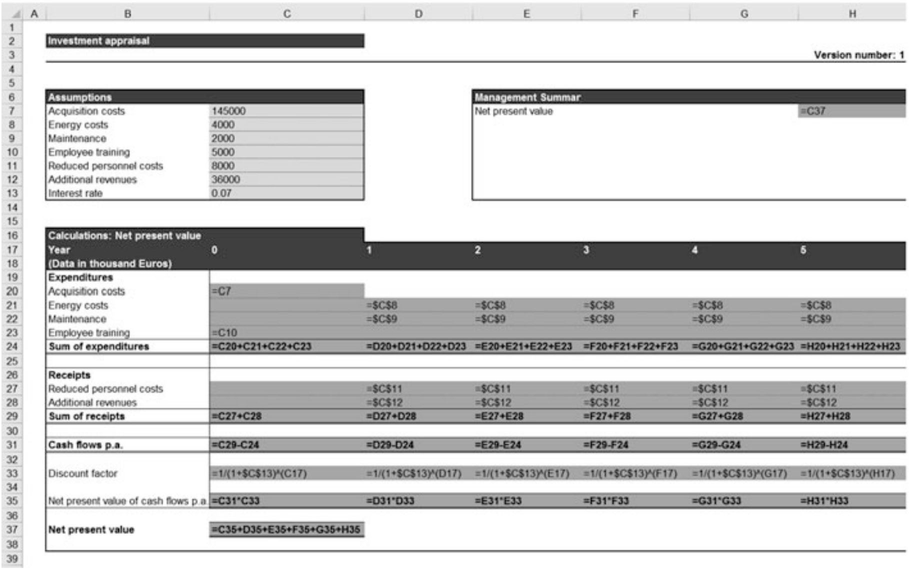
3.1 The Formula Sheet – The Translator

Visual presentations such as bubble diagrams only show the qualitative linkages. In order to generate a financial model that can be used in

Excel, an intermediate step is required: The information that is available in an intuitive and descriptive manner needs to be translated into the language of spreadsheets. Needed are calculations such as `A3=D7-F1`. A direct transfer of a handwritten diagram into an Excel formula is not yet possible – as desirable as it might be.

The formula sheet for Supplier Inc.

Position	Task and contents	Explanation
`C7`	Input field	Acquisition costs
`C8`	Input field	Energy costs
`C9`	Input field	Maintenance
`C10`	Input field	Employee training
`C11`	Input field	Reduced personnel costs
`C12`	Input field	Additional revenues
`C13`	Input field	Interest rate
`C20`	Link to input field "Acquisition costs" `=C7`	The assumptions about "Acquisition costs" are transferred to the module *Calculations*. This item is only relevant in the first year.
`C23`	Link to input field "Employee training" `=C10`	The assumptions about "Employee training" are transferred to the module *Calculations*. This item is also only relevant once, namely only in the year when the machine is acquired.
`D21:H22`	Links to the input fields (such as "Energy costs"): `=$C$8`	The assumptions about energy costs and maintenance are transferred to the module *Calculations*. The amounts are identical in all years starting in year 1.
`C24:H24`	Sum of expenditures: for example `=C20+C21+C22+C23`	In the respective plan years all expenditures are added.
`D27:H28`	Link to the input fields (such as "Reduced personnel costs"): `=$C$11`	The assumptions about "Reduced personnel costs" are transferred to the module *Calculations*. The amounts are identical in all years starting in year 1.
`C29:H29`	Sum of receipts: for example `=D27+D28`	In the respective plan years all receipts are added.
`C31:H31`	Difference between receipts and expenditures: `=C29-C24`	Calculating the annual cash flows p.a.
`C33:H33`	For example for `C33`: `=1/(1+$C$13)^(C17)`	Calculation of the discount factor. `$C$13` is the interest rate from the assumptions. `C17` is the year (here year 0).
`C35:H35`	`=C31*C33`	Net present value of cash flow p. a.: product of cash flow p.a. and discount factor.
`C37`	`=C35+D35+E35+F35+G35+H35`	Net present value of investment: Sum of the individual annual discounted cash flows p.a.
`H37`	`=C37`	Net present value of investment (results).



	B	C	D	E	F	G	H
2	Investment appraisal						
3							Version number: 1
6	Assumptions			Management Summar			
7	Acquisition costs	145000		Net present value			=C37
8	Energy costs	4000					
9	Maintenance	2000					
10	Employee training	5000					
11	Reduced personnel costs	8000					
12	Additional revenues	36000					
13	Interest rate	0.07					
16	Calculations: Net present value						
17	Year	0	1	2	3	4	5
18	(Data in thousand Euros)						
19	Expenditures						
20	Acquisition costs	=C7					
21	Energy costs		=$C$8	=$C$8	=$C$8	=$C$8	=$C$8
22	Maintenance		=$C$9	=$C$9	=$C$9	=$C$9	=$C$9
23	Employee training	=C10					
24	Sum of expenditures	=C20+C21+C22+C23	=D20+D21+D22+D23	=E20+E21+E22+E23	=F20+F21+F22+F23	=G20+G21+G22+G23	=H20+H21+H22+H23
26	Receipts						
27	Reduced personnel costs		=$C$11	=$C$11	=$C$11	=$C$11	=$C$11
28	Additional revenues		=$C$12	=$C$12	=$C$12	=$C$12	=$C$12
29	Sum of receipts	=C27+C28	=D27+D28	=E27+E28	=F27+F28	=G27+G28	=H27+H28
31	Cash flows p.a.	=C29-C24	=D29-D24	=E29-E24	=F29-F24	=G29-G24	=H29-H24
33	Discount factor	=1/(1+$C$13)^(C17)	=1/(1+$C$13)^(D17)	=1/(1+$C$13)^(E17)	=1/(1+$C$13)^(F17)	=1/(1+$C$13)^(G17)	=1/(1+$C$13)^(H17)
35	Net present value of cash flows p.a.	=C31*C33	=D31*D33	=E31*E33	=F31*F33	=G31*G33	=H31*H33
37	Net present value	=C35+D35+E35+F35+G35+H35					

Fig. 5.1 Displaying the formulas of the first prototype (Excel File Workshop Excel_1, Prototype)

In Fig. 5.1 you see the formulas of model (*Formulas* ➲ *Show formulas*). This view is very suitable for a quick and direct documentation of the worksheet.

In order to return to the standard view with numbers instead of formulas, the function *Show Formulas* needs to be deactivated by clicking with the mouse on the command button (Fig. 5.2).

Applied Example

Assumptions about the Investments of Supplier Inc.

Following an intensive analysis phase, the management assistant makes the following assumptions:

Assumptions	Data sources	Notes	Assumptions about costs (rounded to €thousand)
Acquisition costs	Purchasing department	Offers from three manufacturers	145.000
Employee training	External providers	Based on experience: 10 employees need two days of training each	5.000

(Continued)

(continued)

Energy costs	Purchasing department	5-year contract with fixed prices	4.000
Maintenance	Offers by manufacturers	Based on experience of the manufacturer	2.000
Reduced personnel costs	Personnel department	Two employees will be assigned new tasks	8.000
Additional revenues	Marketing department	Stable competitive environment: constant earnings margins, prices remain at the current level.	36.000
Interest rate	Analyst reports of banks		7%

Investment appraisal

Version number: 1

Assumptions	
Acquisition costs	145,000.00
Energy costs	4,000.00
Maintenance	2,000.00
Employee training	5,000.00
Reduced personnel costs	8,000.00
Additional revenues	36,000.00
Interest rate	7.0%

Management Summary	
Net present value	5,807.50

Calculations: Net present value Year (Data in thousand Euros)	0	1	2	3	4	5
Expenditures						
Acquisition costs	145,000.00					
Energy costs		4,000.00	4,000.00	4,000.00	4,000.00	4,000.00
Maintenance		2,000.00	2,000.00	2,000.00	2,000.00	2,000.00
Employee training	5,000.00					
Sum of expenditures	**150,000.00**	**6,000.00**	**6,000.00**	**6,000.00**	**6,000.00**	**6,000.00**
Receipts						
Reduced personnel costs		8,000.00	8,000.00	8,000.00	8,000.00	8,000.00
Additional revenues		36,000.00	36,000.00	36,000.00	36,000.00	36,000.00
Sum of receipts	**0.00**	**44,000.00**	**44,000.00**	**44,000.00**	**44,000.00**	**44,000.00**
Cash flows p.a.	**-150,000.00**	**38,000.00**	**38,000.00**	**38,000.00**	**38,000.00**	**38,000.00**
Net present value	**5,807.50**					

Fig. 5.2 Standard view of the first prototype (Excel File Workshop Excel_1, Worksheet Prototype)

3.2 Use of Formulas

Let us take a first look at the prototype (Fig. 5.2). Notable is the fact that all calculations are lined up nicely (for example sum of receipts and expenditures).

Only one formula per row or column

This is a major advantage and — if at all possible — should be a guiding principle. Always formulate calculations in such a way that they can be easily copied across the entire column or row. Instead of entering all calculations manually, it is possible to use the commands *Copy* and *Paste* to quickly enter structurally identical calculations. Be alert during this process, since thoughtless copying is also a source of error if inappropriate entries are selected.

It is also noteworthy that all calculations were entered explicitly, such as the sum of expenditures `=C20+C21+C22+C23` or the discount factor `=1/(1+$C$13)^(C17)`. A quicker and safer way is the use of *Excel functions.*

This can be studied with reference to the following example: The net present value is calculated with the function for the net present value (*NPV*). Before you do that, delete the rows `33–36` which are no longer needed. They are intermediate steps that are covered by the Excel command.

Use of the formula assistant.

Excel offers a large number of formulas for different applications in its library of functions.

If you are not sure which function is needed to solve a specific task, Excel provides a comfortable search function. The following sequence of commands guides you to the input field *Search Function*. Initially mark cell `C33`, where the needed function will be inserted:

An exercise: Excel File Workshop Excel_1, Worksheet Formulas.

1. Go to tab *Formulas* (Fig. 5.3).
2. Select *Insert Function*.
3. Enter a description of the desired function (Fig. 5.4) such as "Investments" in the text field *Search Function*.

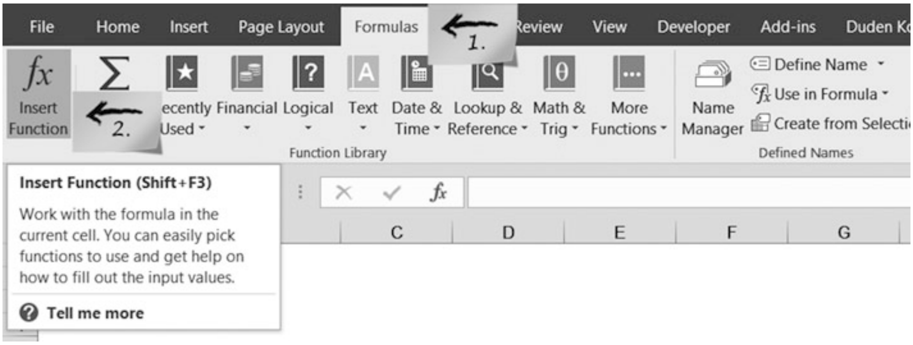


Fig. 5.3 The function library

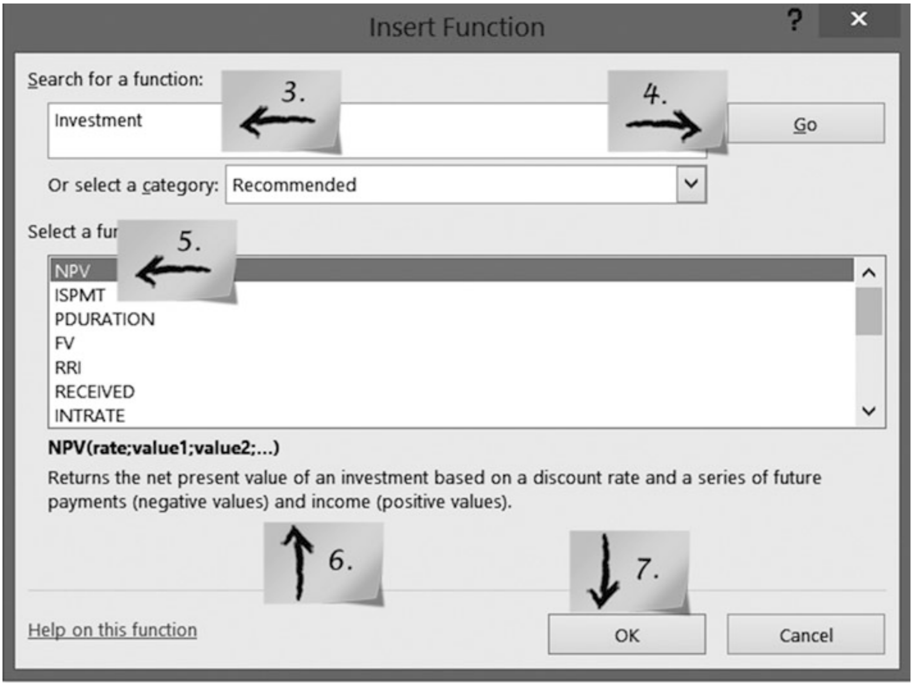


Fig. 5.4 Function search

4. Confirm with *OK* or press the *Return* key.
5. Excel will now present you a selection of functions which are potentially helpful for your purposes. At the top of the list is the function *NPV* (net present value).

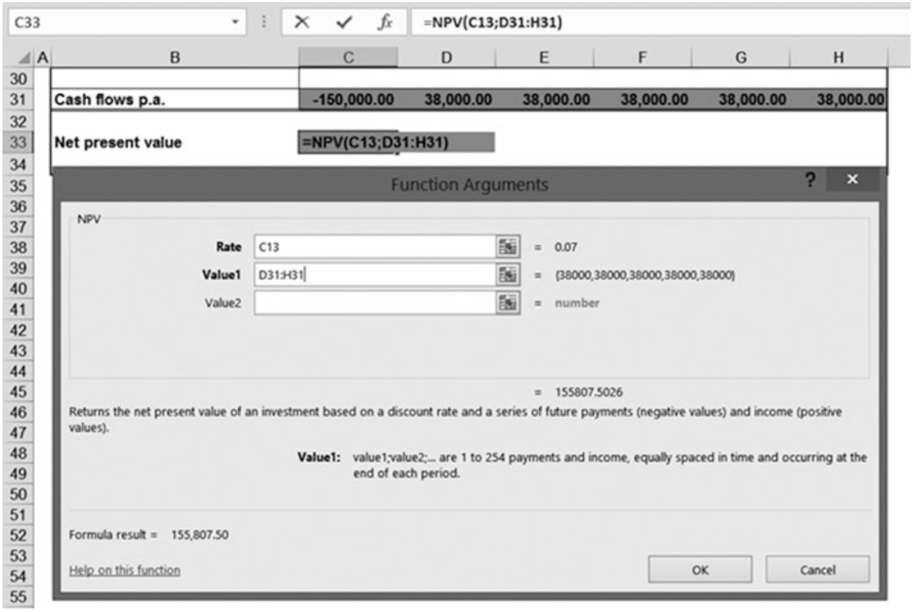


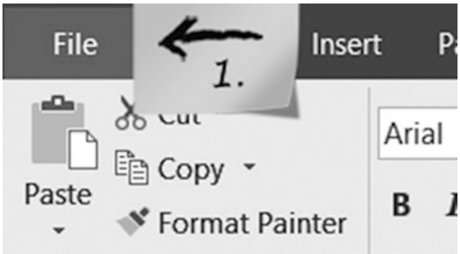
Fig. 5.5 Dialog box *Function Arguments* (Excel File Workshop Excel_1, Worksheet Formulas)

6. The information in the lower part of the dialog box suggests that the function *NPV* is appropriate for the task.
7. Press *OK* to insert the function.
8. The dialog box *Function Arguments* appears (Fig. 5.5). Select cell `C13` for *Rate* and range `D31:H31` for *Value1*.

For a correct calculation of the net present value of the investments, add the cash flow in year 0 to the new formula in cell `C33`. The complete formula is `=NPV(C13;D31:H31)+C31`

3.3 Activating Add-ins

When installing Excel, only the standard functions are typically considered. A large number of additional formulas (so-called *Add-ins*) are not immediately available. This also includes formulas with relevance for financial mathematics.



Find out whether the additional functions are already installed on your computer:

1. Go to tab *File* and select *Options*.
2. Select *Add-ins* (Fig. 5.6).
3. In the dialog box *Add-ins* you see the *Inactive Application Add-ins*.
4. In the field *Manage*, select the entry *Excel Add-ins*.
5. Click on *Go*. . .
6. In dialog box *Add-ins* (Fig. 5.7), the available *Add-ins* are listed. If, for example, the *Analysis ToolPak* is not listed, click on *Search*. Here you can search for the missing *Add-Ins*.

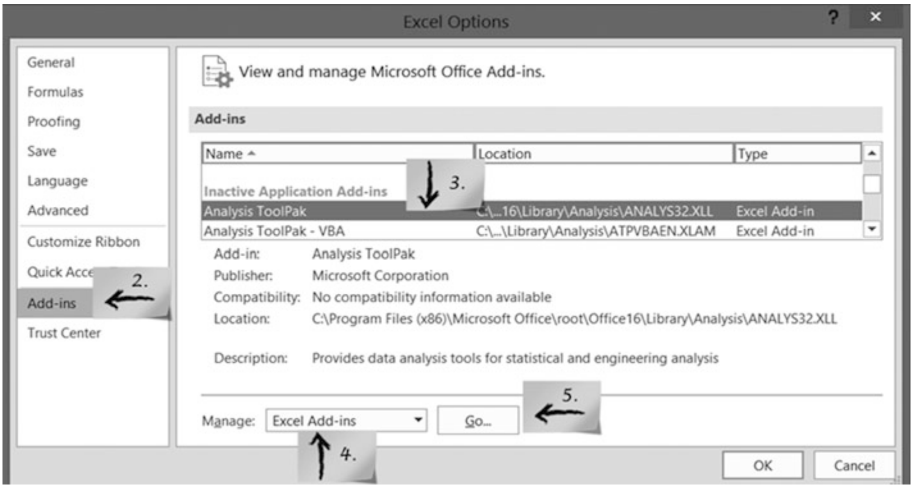


Fig. 5.6 Checking for the installation of *Add-Ins*

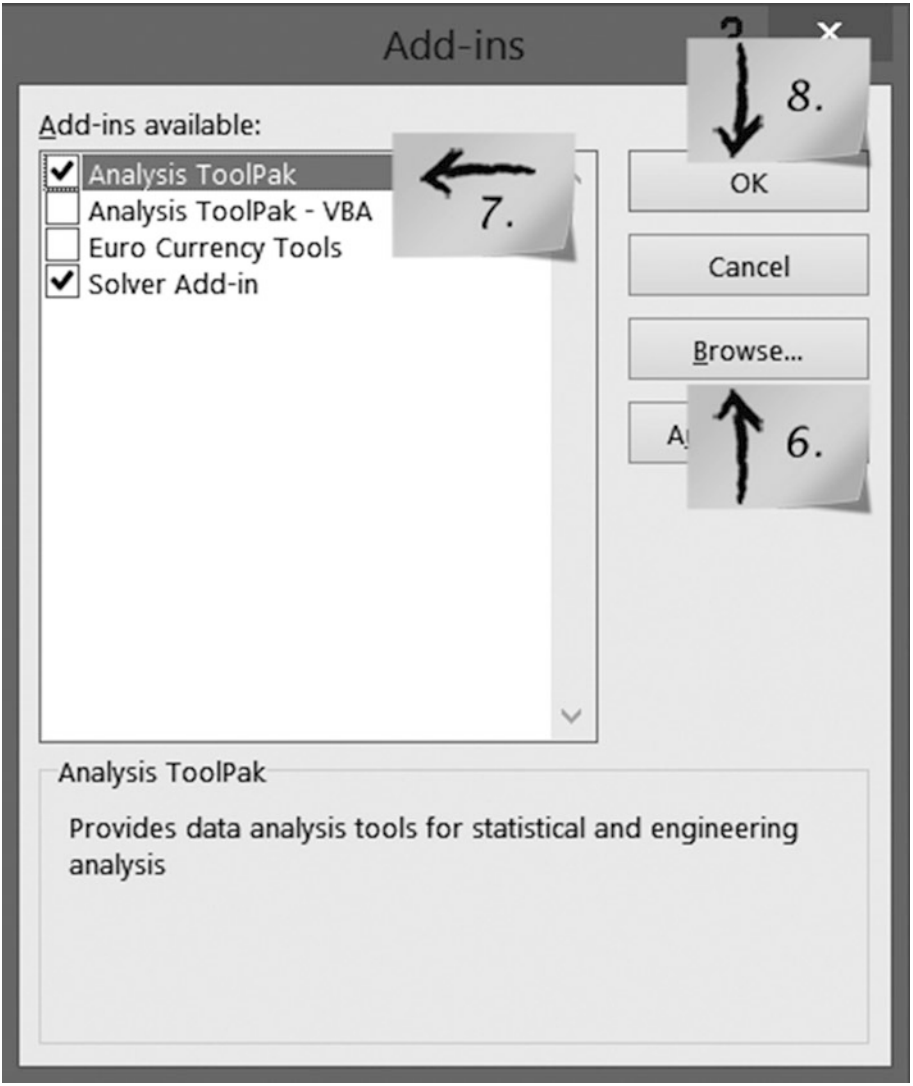


Fig. 5.7 Including *Add-Ins*

7. Select the needed *Add-In*: *Analysis ToolPak*
8. Confirm with *OK*.

If no search path is specified, go to the directory C:\Programs\Microsoft Office\Office12\Library. This is where the *Add-Ins* are saved during a standard installation.

3.4 Making Use of Additional Functions

The functions which have just been activated (*Add-ins*) facilitate the implementation of formulas in the field of financial mathematics. Here we will demonstrate how the easily manageable function *Edate* can be used to enhance the row which contains the dates. So far, we have only worked with numbers instead of actual year dates (row `16`).

The function *Edate* allows adding or subtracting entire months to or from a date:

An exercise: Excel File Workshop Excel_1, Worksheet Additional_Functions.

1. Initially add a new row to the module *Assumptions* (row `14`). With the input in cell `C14`, the user can determine the starting point for the calculations.
2. Format the cell with the starting date as a *date*: mark cell `C14` (Fig. 5.8).
3. Go to *Home* tab.
4. In group *Number* click on the small triangle in the lower right (dialog box launcher).
5. In *Category* select *Date*.

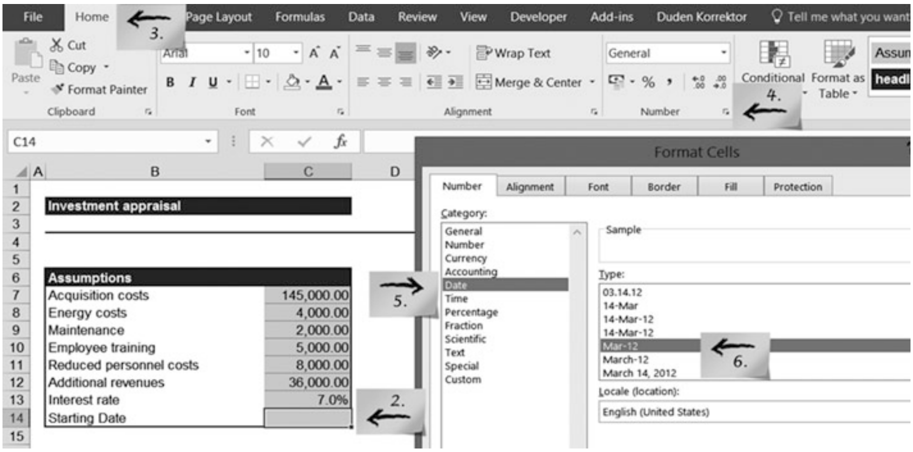


Fig. 5.8 Formatting a cell as a date

Fig. 5.9 Additional functions (Edate) (Excel File Workshop Excel_1, Worksheet Additional_Functions)

6. Select in box *Type* a *date format*.
7. Now enter a starting date in cell `C14` (such as 31.12.2016).
8. Add the Excel function *Edate* to the module *Calculations* in row `18`. Please enter the formulas as shown in Fig. 5.9.
9. Format the newly added cells `C18` to `H18` with a date format (see step 2 following).

As you certainly noticed, the commands in row `18` differ:

- Cell `C18` reads `=EDATE($C$14;0)`. The first year is taken from cell `C14`. Therefore the second part of the function parameter of *Edate* has the value 0.
- In Cells `D18` to `H18` the previous year is always used as the starting point and the second part of the function parameter of *Edate* has the value 12. This means that 12 months are added to the date from the previous cell.

3.5 Using Names to Improve Clarity of the Formulas

With Excel, a *Name* can be assigned to cells, ranges and formulas. Formulas can thus be formulated in natural language. This is an additional option to document a financial model. It speeds up the development process and reduces the risk of incorrect cell references.

The formula for the calculation of the sum of receipts in year 2017 `=SUM(reduced_personnel_costs+additional_revenues)` can be compiled and read more easily than `=SUM (D28:D29)`.

An exercise: Excel File Workshop Excel_1, Worksheet Names_1.

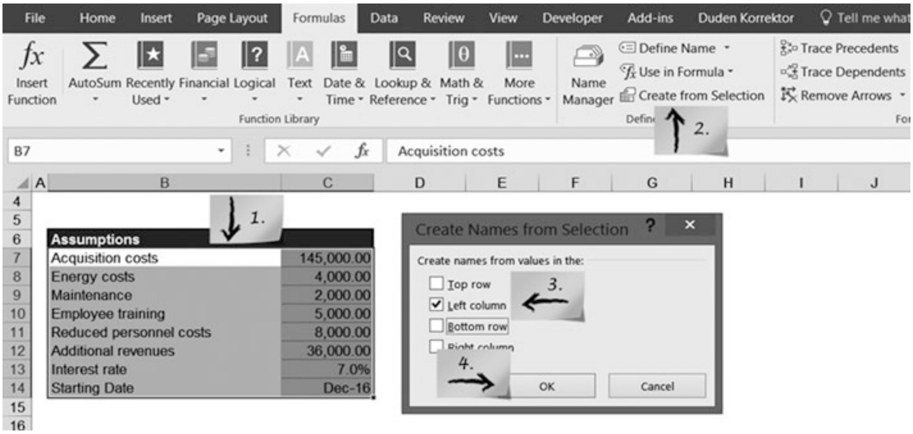


Fig. 5.10 Creating *Names* (Excel File Workshop Excel_1, Worksheet *Names_1)*

Creating *Names*

1. Mark the range `B7:C14` (Fig. 5.10).
2. Follow *Formulas* ➲ *Defined Names* ➲ *Create from Selection.*
3. In the box *Create Names from Selection* select *Left Column*.
4. Confirm *OK*.

You have now assigned *Names* to all assumptions, which can now be used for your calculations.

Using *Names*

Names facilitate the work of the user, since it is not necessary to enter the entire *Name*. The intelligence of Excel helps (Fig. 5.11):

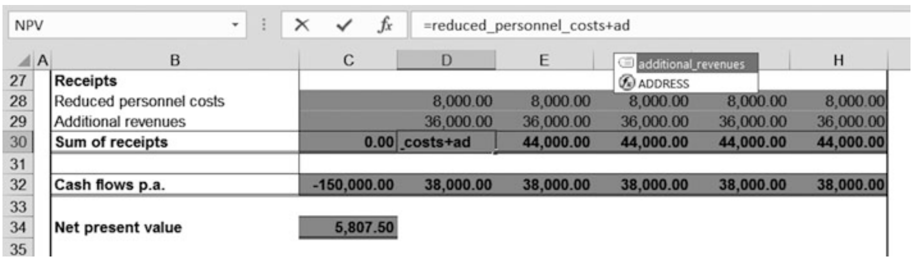


Fig. 5.11 Working comfortably with *Names* (Excel File Workshop Excel_2, Worksheet *Names_Final*)

36		
37	**Names**	
38	acquisition_costs	=Names!$C$7
39	additional_revenues	=Names!$C$12
40	disclaimer	=Menu_and_Docu!$D$81
41	employee_training	=Names!$C$10
42	energy_costs	=Names!$C$8
43	interest_rate	=Names!$C$13
44	maintenance	=Names!$C$9
45	net_present_value	=Names!$C$34
46	reduced_personnel_costs	=Names!$C$11
47	starting_date	=Names!$C$14
48		

Fig. 5.12 List of names (Excel File Workshop Excel_2, Worksheet *Names_Final*)

1. Once you have entered – as in this example – the letters “Ad,”
2. You are provided with a selection, from which the term *Additional Revenues* can be selected.

Inserting the list of Names.

For the documentation, you can create a list of the *Names* used (Fig. 5.12): *Formulas* ➲ *Defined Names* ➲ *Use in Formula* ➲ *Paste Names* ➲ *Paste List*.

3.6 Comments

Comments are an additional possibility to document financial models. They can be used to directly place information in the financial model. They are not entered into cells but instead written directly into a comment field (small yellow fields).

Inserting *Comments* in Excel (Fig. 5.13):

An exercise: Excel File Workshop_2, Worksheet Comments.

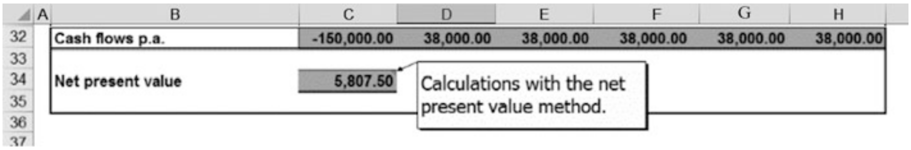


Fig. 5.13 *Comments* in the applied example (Excel File Workshop Excel_2, Worksheet *Comments*)

1. Right-click with the mouse on the cell where you want to insert a *Comment*.
2. Select from the context menu *Insert Comment*.
3. Write the desired text.

Cells with *Comments* can be recognized by the small red triangle in the upper right corner. The text of the comment is displayed only if the mouse points to a comment cell. It disappears as soon as the mouse is moved away. If you want to show all comments permanently, you need to activate the display of *comments* for the entire worksheet with *Review* ➲ *Comments* ➲ *Show All Comments*.

Practical Tip

Inserting a Picture into a *Comment*

Comments need not only contain text. You can also add pictures to the comment fields, in order to improve the clarity of the explanations.

Follows these steps:

1. Mark a cell which includes a *Comment* by right-clicking the mouse.
2. Select *Edit Comment* from the context menu.
3. Right-click on the border of the *Comment* in order to get to the dialog box *Format Comment* (Fig. 5.14).
4. Go to the tab *Colors and Lines*.
5. Click on the dropdown-menu *Color*.
6. Select *Fill Effects*.

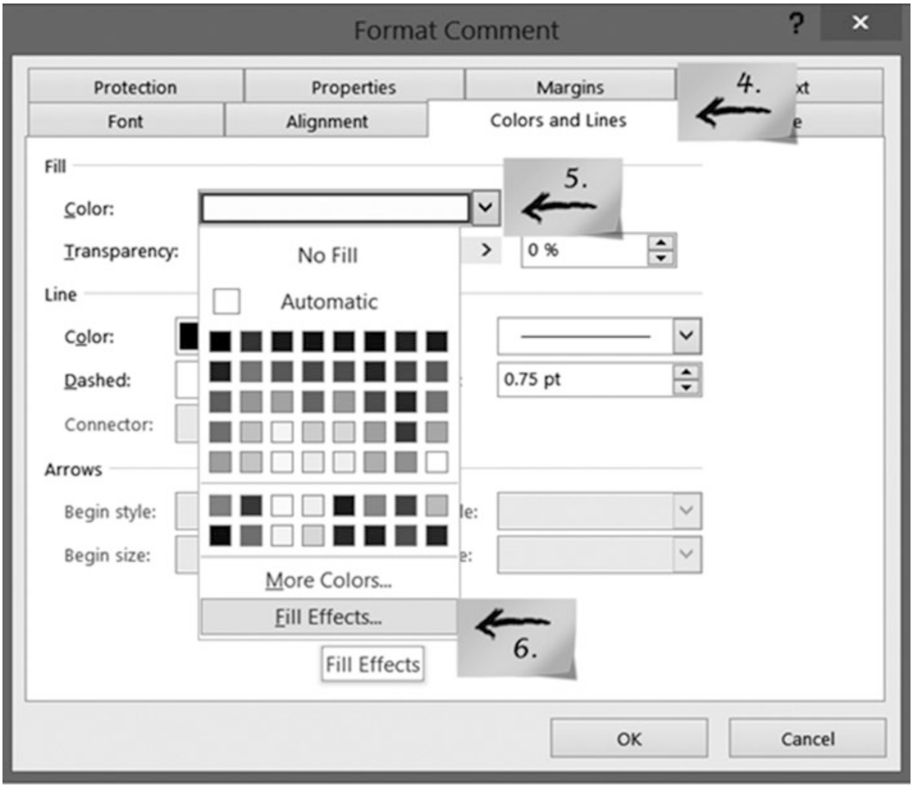


Fig. 5.14 Inserting a picture into a *Comment*

7. From the dialogue field *Fill effect* switch to the tab *Picture* (Fig. 5.15).
8. Click on the button *Select Picture*.
9. Select a picture in the newly opened dialogue box *Insert Pictures*.

Printing comments.

The standard settings of Excel do not include the possibility to print out *Comments*. This can be changed as follows (Fig. 5.16):

1. Go to the tab *Page Layout*.

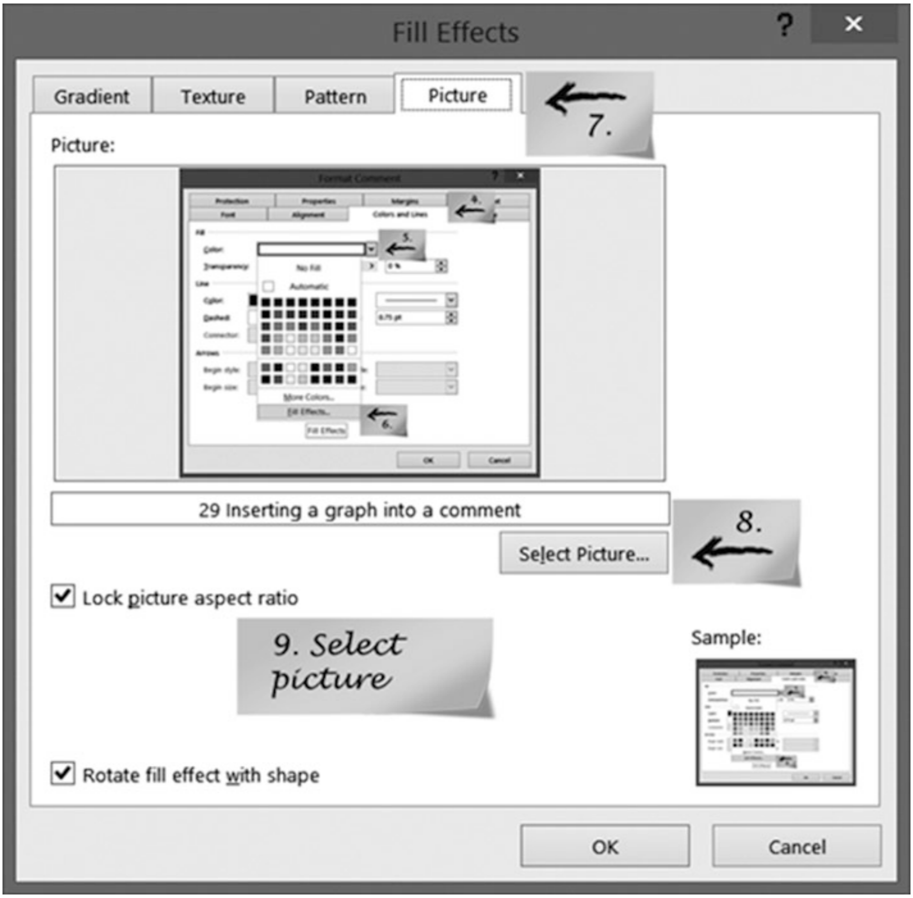


Fig. 5.15 Selecting a picture for a *Comment*

2. Click on the small triangle (dialog box launcher) on the right side in the group *Page Setup*.
3. The dialog box *Page Setup* appears.
4. Go to the tab *Sheet*.
5. Change the settings for *Comments*.

You have the option of printing comments *At the end of sheet* or *As displayed on sheet*.

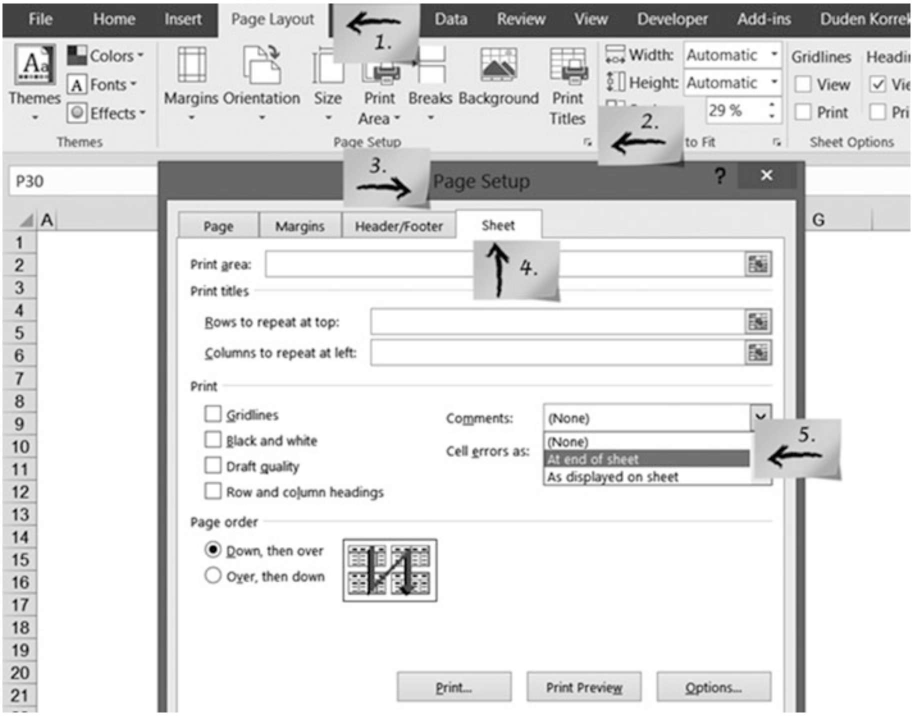


Fig. 5.16 Changing the settings for printing the *Comments*

4 Sending Signals to the Management

Financial Models differ from data repositories in the quick and direct availability of relevant information for the user. Two instruments are available in Excel for that purpose: *Conditional Formatting* and the command *Text*, which can be used to generate current messages.

4.1 Signaling with Colors: Conditional Formatting to Create Information

The management of Supplier Inc. mainly wants to know whether the investment should be made or not. *Conditional Formatting* in the management summary can be helpful to show this directly. *Conditional Formatting* allows the formatting of cells in line with the cell contents.

When is an investment favorable? If the net present value is

- positive (> 0), the investment is favorable (it should be made),
- = 0, the investment can still be done, since the minimum rate of return is just achieved (can still be made),
- negative (< 0), the investment is unfavorable and should not be made.

Implementing *Conditional Formatting* in Excel, which shows whether the investment is favorable:

An exercise: Excel File Workshop Excel_2, Worksheet Color_Signals.

1. Mark cell `H7` (Fig. 5.17).
2. Go to tab *Home* ➲ *Styles* ➲ *Conditional Formatting*.
3. Select *Highlight Cells Rules*.
4. Click on the first selection *Greater than ...*
5. The dialogue box in Fig. 5.18 appears. Enter a value of 0 into the left input field.
6. In the right input field, you can select a color.
7. Confirm with *OK*.

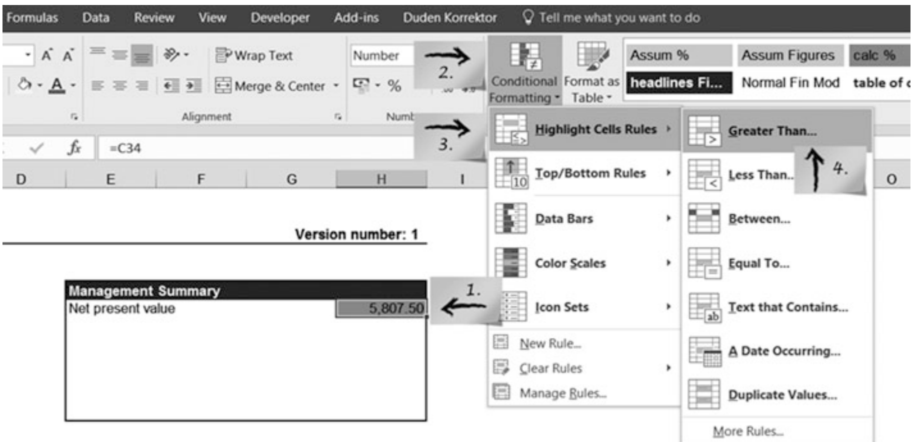


Fig. 5.17 Signals for the management decision using *Conditional Formatting* (Excel File Workshop Excel_2, Worksheet Color_Signals)

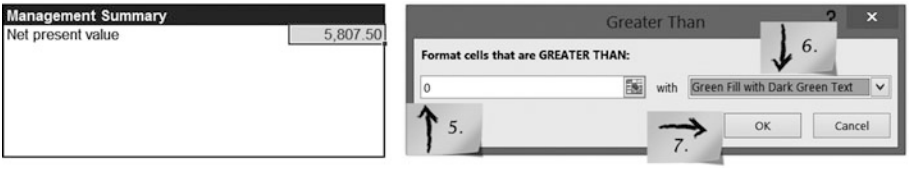


Fig. 5.18 Input for the value and the reference of the *Conditional Formatting* (Excel File Workshop Excel_2, Worksheet Color_Signals)

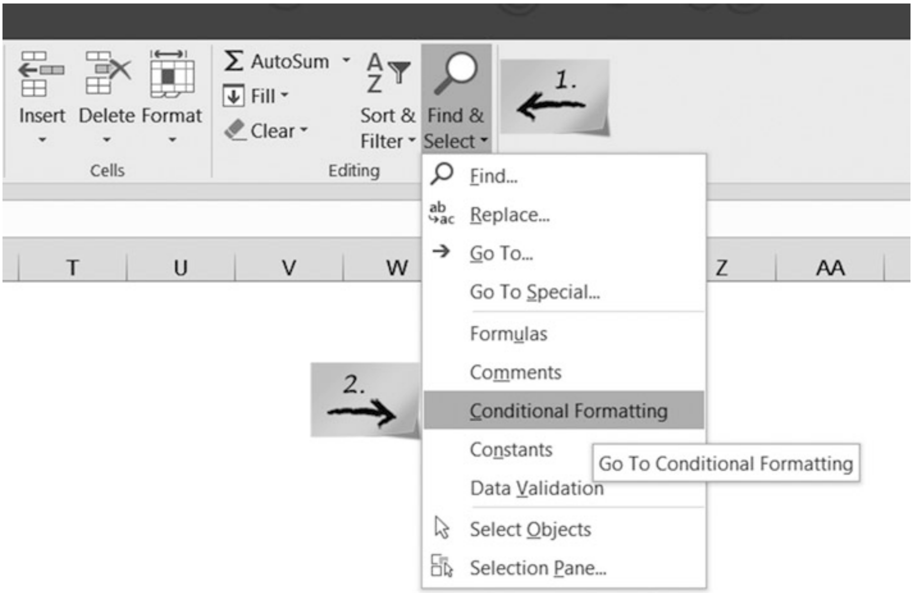


Fig. 5.19 Searching for *Conditional Formatting*

If *Conditional Formatting* is used regularly,it is possible to lose track of all the places where it was used (Fig. 5.19):

1. Go via tab *Home* to ➲ *Find &Select*.
2. Select *Conditional Formatting*. All relevant cells are shown.

4.2 Text as Signal: Providing Informative Messages

A simple management information tool was implemented with the help of *Conditional Formatting*. The change in color signals whether

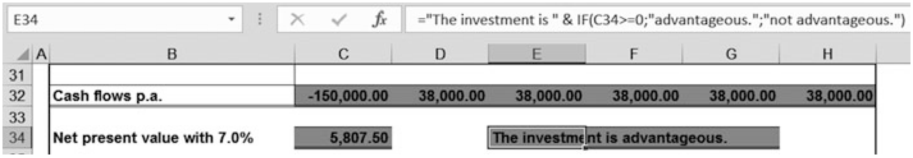


Fig. 5.20 Text as management signal (Excel File Workshop Excel_2, Worksheet Text_Signals)

an investment is favorable or not. Figure 5.20 presents two improvements:

- The interest rate is shown directly next to the net present value.
- The user is provided with a text message which evaluates the net present value of the investment: "The investment is advantageous/not advantageous." This involves the use of an *If/Then-Formula* which uses the condition that the investment is advantageous if the net present value is ≥ 0.

This is the approach:

An exercise: Excel File Workshop Excel_2, Worksheet Text_Signals.

1. In cell `B34` provide the following information: `="Net Present value with "&TEXT(C13;"0.0%")`
2. In cell `E34` provide the following information: `="The investment is " & IF(C34≥0;"advantageous.";"not advantageous.")`

5 Data Collection

In all likelihood, financial models und financial assessments are created under significant time pressure. In such an environment, the financial modeler will usually not be able to conduct a data search himself. Here you will learn how to securely get data from third parties and external sources.

5.1 Secure Data Gathering

If a financial model is used by several persons, the data should be screened during the input process in order to prevent invalid data entries. The financial modeler has two options:

- The Excel function *Data Validation* and
- the more challenging, but significantly more comfortable dynamic checking.

5.1.1 The Simple Excel Function Data Validation

The Excel function *Data Validation* allows the definition of data input rules. For the investment analysis it is advisable to protect the entire module *Assumptions* against faulty data input:

Assumptions	Criteria
Acquisition costs	Input $\geq$ 0
Energy costs	Input $\geq$ 0
Maintenance	Input $\geq$ 0
Employee training	Input $\geq$ 0
Reduced personnel costs	Input $\geq$ 0
Additional revenues	Input $\geq$ 0
Interest rate	Between 0 and 0.2, in other words 0-20 %

In the following example, the Excel function *Data Validation* is implemented using the example of the item *Acquisition costs*.

> An exercise: Excel File Workshop Excel_3, Worksheet Data_Validation.

1. Mark cell C7.
2. Via *Data* ➲ *Data Tools* ➲ *Data Validation* you get to the dialog box of the function.
3. Open the tab *Settings* and follow the sample in Fig. 5.21.
4. For the upper field *Allow* select the option *Decimal*.
5. For the field *Data* select the option *greater than or equal to*.

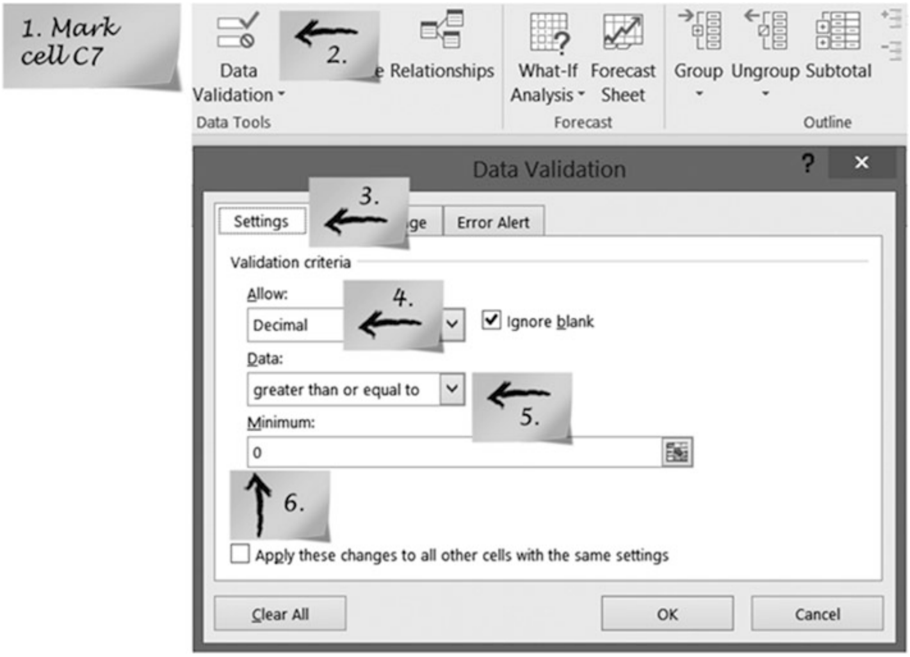


Fig. 5.21 Settings for the *Data Validation* (Excel File Workshop Excel_3, Worksheet Data_Validation)

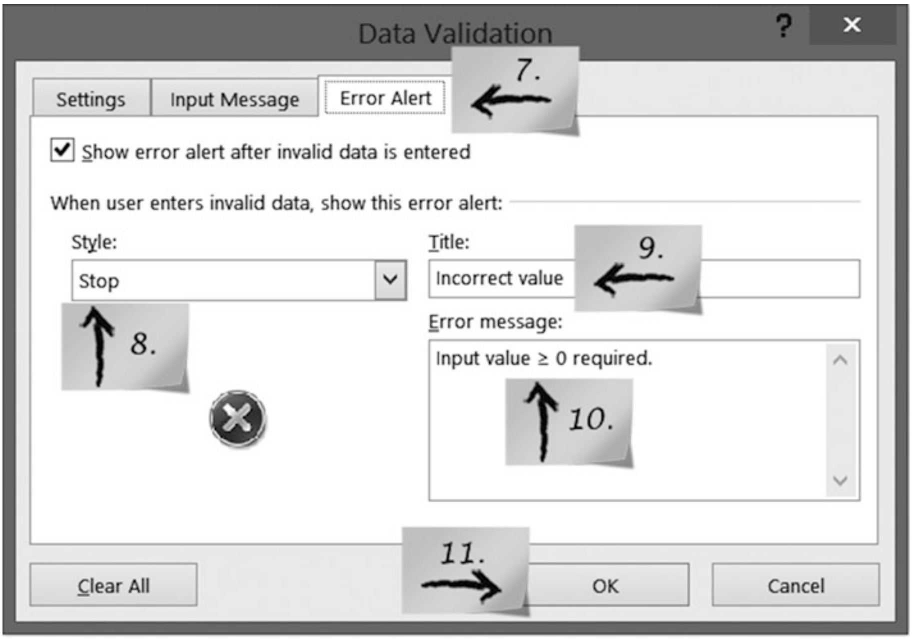


Fig. 5.22 Error message for the Data Validation (Excel File Workshop Excel_3, Worksheet *Data_Validation*)

1. In the text field *Minimum* enter `0`.
2. Open the tab *Error Alert* and use the input from Fig. 5.22.
3. In the field *Style*, select *Stop*.
4. In the field *Title* enter the text "Incorrect value"
5. In the text field *Error message* enter the text: "Input value $\geq$ 0 required."
6. Complete the input with *OK*.

In line with the definition of the data entry rules for the acquisition costs, the interest rate can also be protected against invalid entries (Fig. 5.23):

1. For the field *Allow* select the option *Decimal*.
2. For the field *Data* select the option *between*.
3. As minimum enter 0.
4. As maximum enter 0.2.
5. Go to the tab *Error Alert* and proceed as shown in Fig. 5.22.

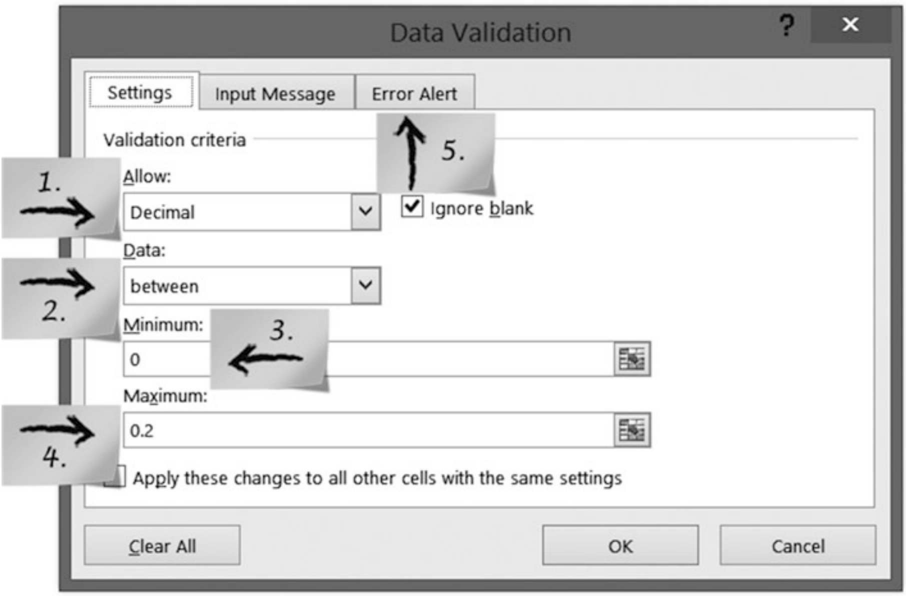


Fig. 5.23 Data Validation for the interest rate (Excel File Workshop Excel_3, Worksheet *Data_Validation*)

6. In the field *Error message* enter the text: "Enter percentages as decimals. Only values between 0 and 0.2 are allowed."

Implementation of the *Data Validation* for the remaining variable is more simple, since the rules are identical for all the other assumptions (with the exception of the interest rate). They can be copied using a simple trick, which is demonstrated using the example of energy costs:

1. Copy cell C7 (acquisition costs).
2. Insert the copied cell in C8 with *Home* ➲ *Paste* ➲ *Paste Special* ➲ *Validation* (Fig. 5.24).
3. Do the same with the other assumptions.

Test the new functionality of your financial model and enter an interest rate greater than 20%. The error message in Fig. 5.25 appears if the data validation has been set up correctly.

Next we show a method which can be programmed easily, assures greater stability of the financial model and facilitates its use.

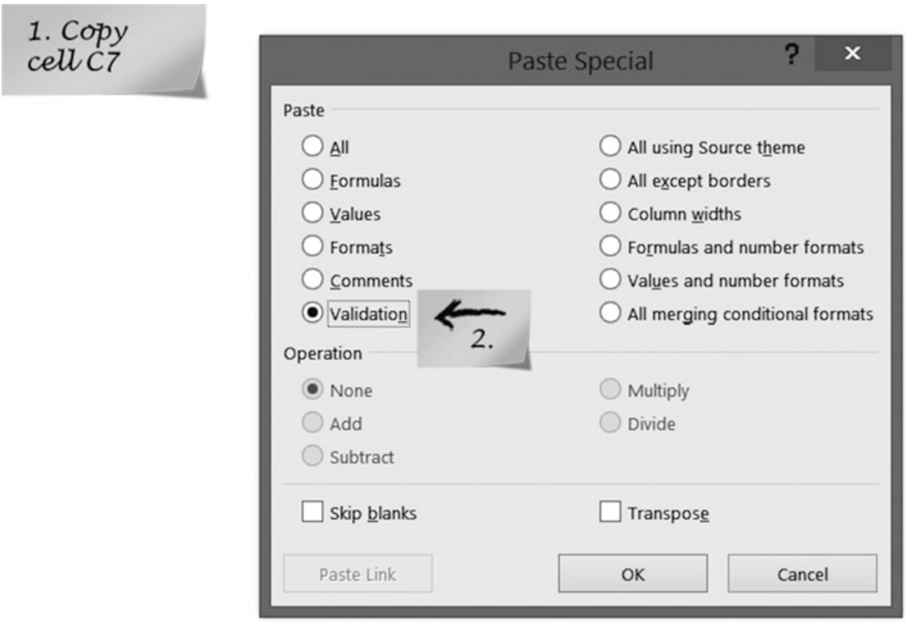


Fig. 5.24 Quick progress with *Insert Contents*

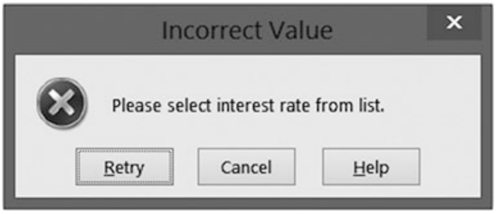


Fig. 5.25 Error message if an incorrect value has been entered for the interest rate

5.1.2 Dynamic Data Validation

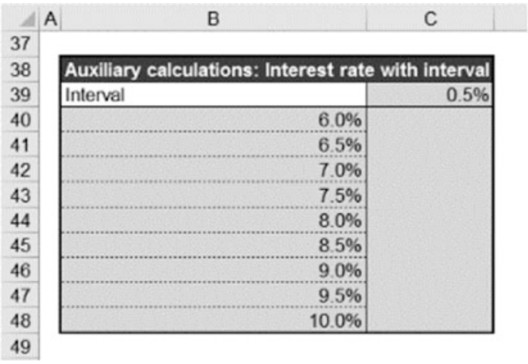
With the function *Data Validation* it is not possible to define all types of data input intervals. Looking at interest rates, for example, it is not possible to restrict the range from 6% to 10% to steps of 0.5%.

An auxiliary calculation is required to achieve this aim.

> An exercise: Excel File Workshop Excel_3, Worksheet Data_Validation_Dynamic.

1. Enter a new auxiliary calculation below the module *Calculations* in the range `B38:C48`.
2. Take Fig. 5.26 as an example for entering the formulas.

The result is a table with an interval beginning at 6%, which increases in steps of 0.5%. The steps are set in cell `C39`.



	A	B	C
37			
38		Auxiliary calculations: Interest rate with interval	
39		Interval	0.5%
40		6.0%	
41		6.5%	
42		7.0%	
43		7.5%	
44		8.0%	
45		8.5%	
46		9.0%	
47		9.5%	
48		10.0%	
49			

Fig. 5.26 The auxiliary calculations for the interest rate with intervals in the formula view (Excel File Workshop Excel_3, Worksheet Data_Validation_Dynamic)

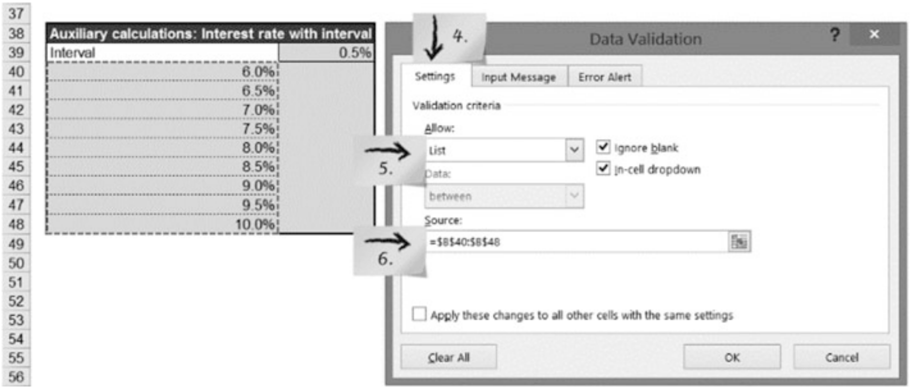


Fig. 5.27 Data Validation with a list (Excel File Workshop Excel_3, Worksheet Data_Validation_Dynamic)

With the auxiliary calculations it is possible to set up a dynamic *Data Validation* with an interval (Fig. 5.27):

3. Insert a *Data Validation* in cell `C13`: *Data* ➲ *Data Tools* ➲ *Data Validation*.
4. Go to *Settings*.
5. Under *Validation Criteria* select *Admit: List*
6. In the field *Source* enter: `=$B$40:$B$48` (range of the values from the auxiliary calculation "interest rate with intervals")
7. Confirm with *OK*.

5.2 Importing Internal Data

Up to this point, we have manually transferred data from the module *Assumptions* with the help of simple cell references or with *Names* to the module *Calculations* (Fig. 5.28). Now assume that we do not only have six, but several dozen assumptions which all span several years. It would require a huge effort to manually link the cells and at the same time, the likelihood of errors would go up.

In order to facilitate your work in the future, you will now learn how to import data with Excel. For that purpose, we present the Excel function *VLookup* and alternatively the combination of *Index* and *Match*.

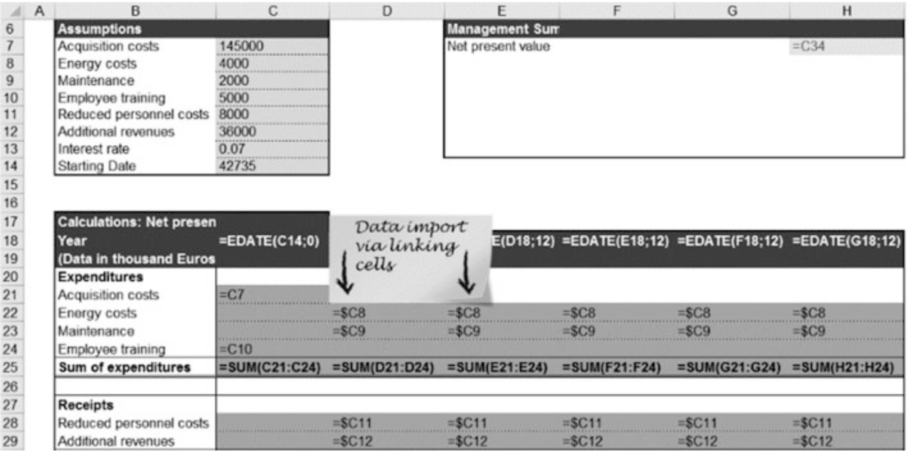


Fig. 5.28 Data import which relies on cell references (Excel File Workshop Excel_3, Worksheet Data_Validation_Dynamic)

5.2.1 Importing Data with VLookup

The use of the function *VLookup* is demonstrated using the example of the acquisition costs (Fig. 5.29).

An exercise: Excel File Workshop Excel_3, Worksheet Data_Import_VLookup.

1. In cell `C21` insert the function *VLookup*: `=VLookup`
2. Activate *Insert Function* (small symbol *fx* next to the input field). You can now see the function arguments for *VLookup* (Fig. 5.29).
3. The *Lookup_value* criterion here is acquisition costs. For that reason, provide the cell `$B21`.
4. The *Table_array* is the range from which the data needs to be imported: cells `$B$7:$C$14`
5. The *Col_index_num* indicates the column of the matrix, from which the data needs to be imported. Here it is the second column of the matrix. In step 4, we defined the columns B and C as *Table_array*. And the data is contained in column C (`C7:C14`).

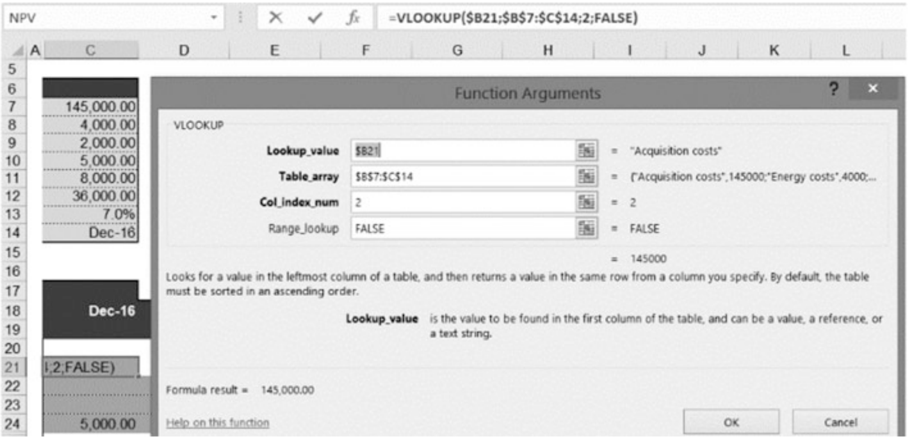


Fig. 5.29 Data import with *VLookup* (Excel File Workshop Excel_3, Worksheet Data_Import_VLookup)

6. In the last field, Excel asks for the so-called *Range_lookup*. A simple function hides behind this complicated term: should the values in question (see *Lookup_value* from step 3) be precisely (*FALSE*) or only approximately (*TRUE*) equal to the values in the *Table_array*.

The same approach can be used to import the remaining assumptions via *VLookup* into the module *Calculations*.

5.2.2 An Alternative: Index/Match

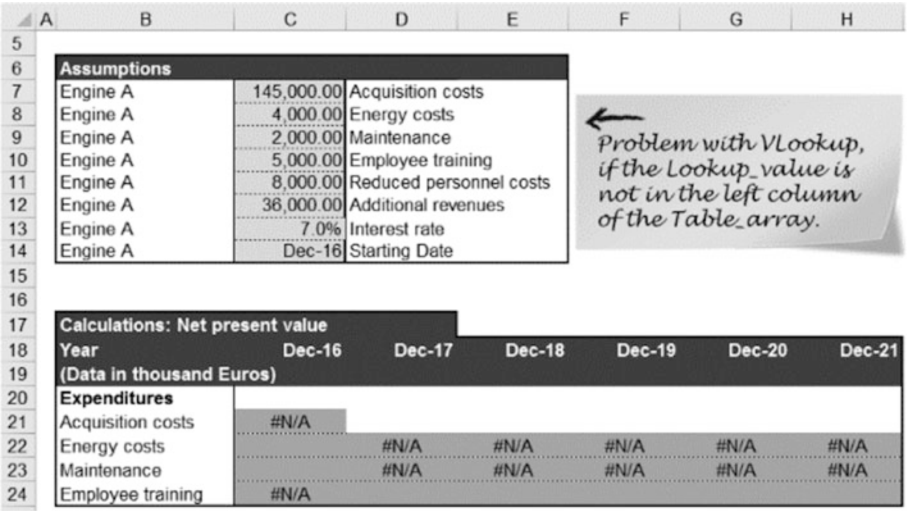
What if the relevant column (assumptions) was placed in the middle of a table and you wanted to select a column for the *VLookup* that is placed before the column with the selection criteria?

Figure 5.30 demonstrates the problem. The search for "acquisition costs" will fail (error message: *#NA*), since the values (*Table_array*) are found to the left of the search term (*Lookup_value).*

The function *VLookup* has one disadvantage: It is only possible to search to the right of the search column. Data to the left of the search column cannot be found.

Problem with VLookup, if the *Lookup_value is not in the left column of the Table_array.*

There are two ways to fix this problem:



	A	B	C	D	E	F	G	H
5								
6		Assumptions						
7		Engine A	145,000.00	Acquisition costs				
8		Engine A	4,000.00	Energy costs				
9		Engine A	2,000.00	Maintenance				
10		Engine A	5,000.00	Employee training				
11		Engine A	8,000.00	Reduced personnel costs				
12		Engine A	36,000.00	Additional revenues				
13		Engine A	7.0%	Interest rate				
14		Engine A	Dec-16	Starting Date				
15								
16								
17		Calculations: Net present value						
18		Year	Dec-16	Dec-17	Dec-18	Dec-19	Dec-20	Dec-21
19		(Data in thousand Euros)						
20		Expenditures						
21		Acquisition costs	#N/A					
22		Energy costs		#N/A	#N/A	#N/A	#N/A	#N/A
23		Maintenance		#N/A	#N/A	#N/A	#N/A	#N/A
24		Employee training	#N/A					

Fig. 5.30 A possible problem when importing data with *VLookup* (Excel File Workshop Excel_3, Worksheet Data_Import_*VLookup*)

1. You structure the module in such a way that the data is placed correctly (to the right of the search criteria) or
2. You work with an alternative to *VLookup* — the combination of the functions *Index* and *Match*.

Solution number 1 can generally be implemented quickly. You only need to move the columns to the correct place. But there are situations where no changes to the modules are desired. Solution 2 should be utilized in this case.

These are the steps needed to import data with the functions *Index* and *Match*:

> An exercise: Excel File Workshop Excel_3, Worksheet Data_Import_Index_Match.

1. First you need the function *Index* (Fig. 5.31). Place the pointer on cell `C21` and write: `=Index(`
2. Activate the Excel input help (small symbol *fx* next to the input field). You can now see the function arguments for *Index*.
3. Mark this function *(array;row_num;column_num)* and confirm with *OK* (Fig. 5.32).

Fig. 5.31 Starting the function assistant

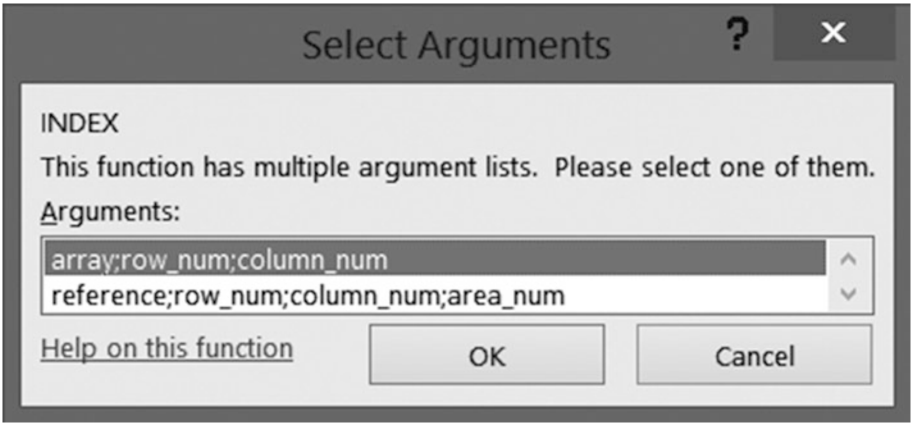


Fig. 5.32 Selecting the arguments for *Index*

Fig. 5.33 The combination Index/Match

4. The *Array* – as in our previous example with *VLookup* – again covers the area of the module *Assumptions* (Fig. 5.33): `$C$7:$C$14`
5. In the field *Row_num* you enter the function *Match*: `MATCH($B21;$B$7:$B$14;)`
6. Confirm with *OK*.
7. Copy the formula to other cells of the module *Calculations*.

5.3 Importing External Data: Working with Security Prices from the Internet in Excel

As will be seen later in numerous examples in the chapters on derivatives and portfolio management, financial models regularly analyze listed securities. Professional providers such as Bloomberg, Reuters and VWD provide access to data from global trading places. However, these are fee-based offerings which in some cases require specific hardware. For practitioners who occasionally need a price quote for their models, this approach is not necessarily suitable.

An alternative is the download of limited amounts of data from the internet, which can be exported directly to Excel. The information content is sufficient for simple applications.

Financial portals such as Yahoo Finance, Google Finance and Finanztreff.de as well as several online banks (CortalConsors, Comdirect Bank and others) offer share prices that can be downloaded and used in Excel.

Using the example of Yahoo Finance, we demonstrate how price data of Siemens AG can be imported to Excel from the internet:

An exercise: Excel File Workshop Excel_3, Worksheet Share_Prices_Raw_Data.

1. Use an internet browser to go to Yahoo Finance (Fig. 5.34): https://finance.yahoo.com
2. In the search field entre the name of the company you are looking for: *Siemens*
3. You get a list of hits from which you select the appropriate security and trading venue.
4. Click on *Historical Prices*.
5. You get to the following overview (Fig. 5.35). Select time period and time interval (daily, weekly or annually).
6. Confirm with *Get Prices*.
7. Click on the link *Download to Spreadsheet*.
8. A menu appears, which can be used to open the file. The question "What should be done with the file?" is answered by selecting the option *Open with Microsoft Office Excel (Standard)*.

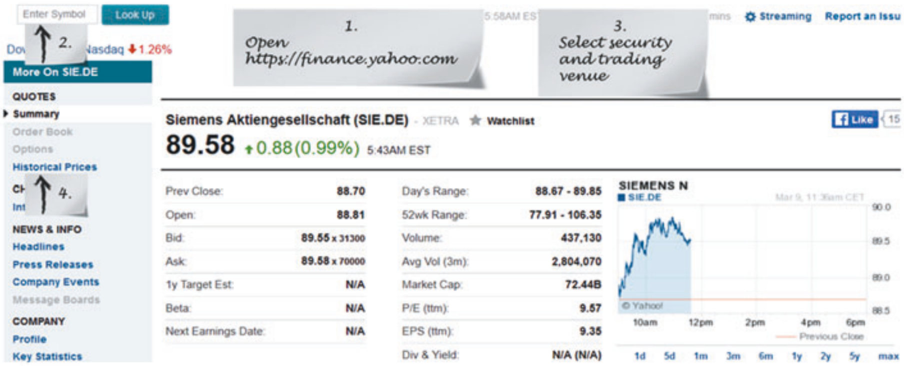


Fig. 5.34 Stock market information about Siemens shares

9. The download of the prices is inserted as raw data into a worksheet (Fig. 5.36). For their future use, the data needs to be modified, since it is currently stringed together without any separators.
10. In case you are unable to download the data, please use the data provided in the worksheet Share_Prices_Raw_Data. The share prices in their raw form are available there.

> An exercise: Excel File Workshop Excel_3, Worksheet Share_Prices_Raw_Data.

1. To improve the structure of the presentation, select the fields `A3:A25`, which contain the price data. Please note that all data is exclusively contained in Column `A` – even though it might appear that the following columns also contain data. If you also mark Column `B` or `C`, conflicts with the text conversion assistant will arise.

> Attention, only mark Column A

Set Date Range

5.

Start Date: Feb 1 2016 Eg. Jan 1, 2010

End Date: Mar 1 2016

- (•) Daily
- ( ) Weekly
- ( ) Monthly
- ( ) Dividends Only

Get Prices

6.

First | Previous | Next | Last

Prices

Date	Open	High	Low	Close	Volume	Adj Close*
Mar 1, 2016	85.51	87.16	85.26	87.16	2,196,200	87.16
Feb 29, 2016	85.52	85.70	84.43	85.46	2,506,500	85.46
Feb 26, 2016	85.20	86.93	85.05	86.31	2,671,300	86.31
Feb 25, 2016	83.70	84.98	83.08	84.12	2,175,400	84.12
Feb 24, 2016	85.11	85.18	82.09	82.49	2,822,900	82.49
Feb 23, 2016	85.87	86.37	85.01	85.01	1,784,600	85.01
Feb 22, 2016	85.08	86.58	85.00	86.43	1,814,500	86.43
Feb 19, 2016	85.34	85.53	83.95	84.55	2,667,800	84.55
Feb 18, 2016	84.86	85.68	84.19	84.89	2,345,600	84.89
Feb 17, 2016	82.61	84.72	82.50	84.48	2,356,500	84.48
Feb 16, 2016	82.51	83.09	81.78	82.15	2,099,900	82.15
Feb 15, 2016	81.78	82.77	81.00	82.23	2,548,900	82.23
Feb 12, 2016	80.00	80.67	79.74	80.65	2,849,200	80.65
Feb 11, 2016	81.09	81.15	79.23	79.23	3,779,800	79.23
Feb 10, 2016	82.56	83.80	81.97	82.25	2,757,200	82.25
Feb 9, 2016	82.83	83.47	81.24	81.99	4,020,300	81.99
Feb 8, 2016	84.71	85.37	81.92	82.55	3,588,700	82.55
Feb 5, 2016	85.04	85.95	84.17	84.55	3,018,000	84.55
Feb 4, 2016	85.99	86.23	83.99	85.14	3,379,000	85.14
Feb 3, 2016	85.60	86.00	83.84	84.81	3,080,700	84.81
Feb 2, 2016	87.11	87.65	85.21	85.99	2,835,700	85.99
Feb 1, 2016	88.80	89.06	86.47	87.45	2,134,400	87.45

* Close price adjusted for dividends and splits.

First | Previous | Next | Last

Download to Spreadsheet 7.

Currency in EUR.

Fig. 5.35 Historical share prices as presented by Yahoo Finance

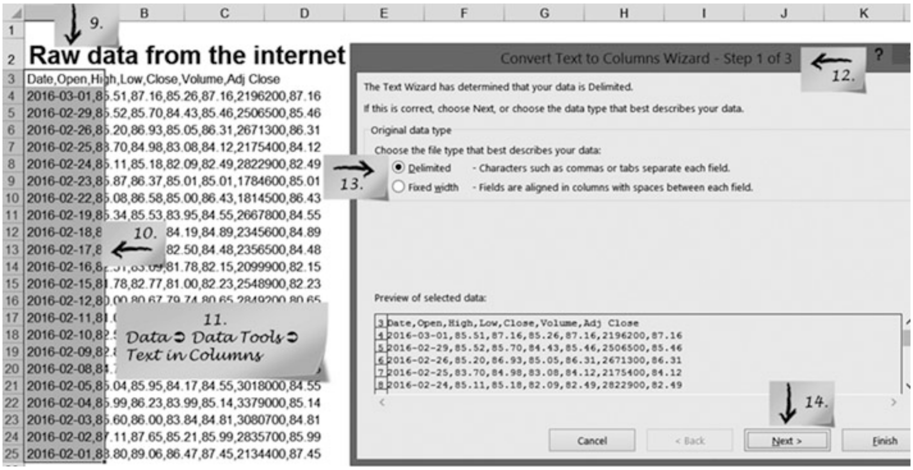


Fig. 5.36 Imported raw data from the internet and the *text conversion assistant* (Excel File Workshop Excel_3, Worksheet Share_Prices_Raw_Data)

11. Go to *Data* ➲ *Data Tools* ➲ *Text to Columns.*
12. The *Convert Text to Columns Wizard* (Fig. 5.37) opens up.
13. Select *Delimited*.
14. Press *Next*.
15. In the following dialogue box (step 2 of 3 in the *Convert Text to Columns Wizard)* you set the comma as *delimiter* (Fig. 5.37).
16. Confirm the process with *Next*.
17. In the third step of the *wizard* (Fig. 5.38) retain the provided data format for the column (standard).
18. Give the target area as `=$F$3`.
19. Click on *Finish*.

The result which you obtain after the conversion is already a huge improvement compared to the confusing heap of data that was imported from the internet. But it is still not in line with the demands of an effective financial model. As a future financial modeler, you can now utilize your fresh knowledge on the topic of formatting and apply it to the data. Use colors, borders, data formats and separators, change the alignment and the headers to improve the presentation of the data in the worksheet.

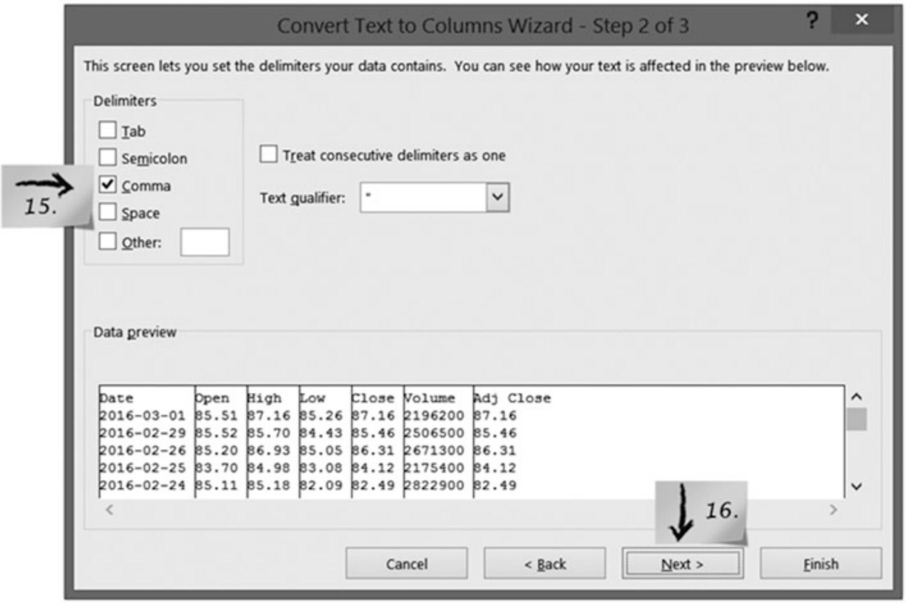


Fig. 5.37 Step 2 of 3 by Convert Text to *Columns Wizard*

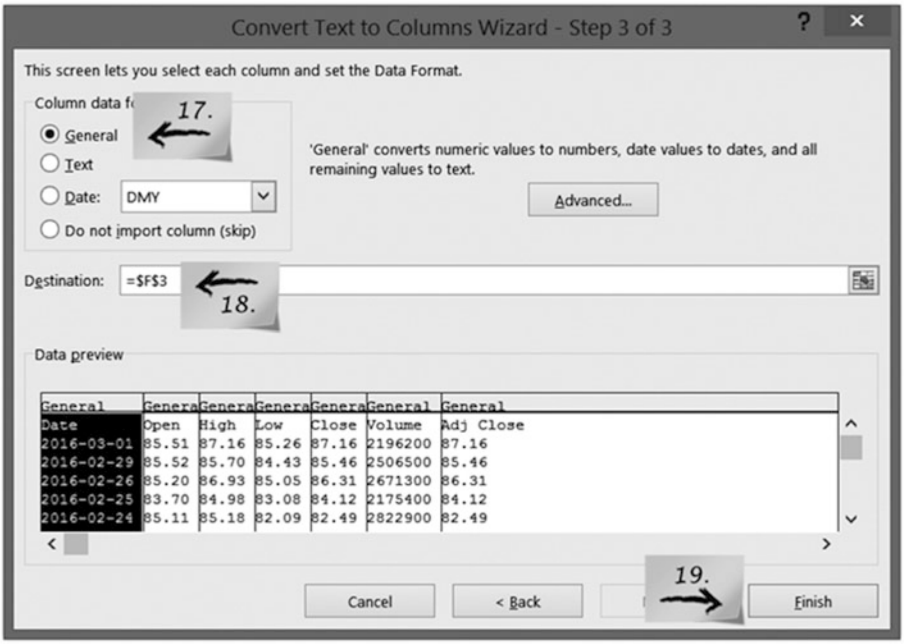


Fig. 5.38 Step 3 of 3 by the text conversion assistant

After text conversion

Date	Open	High	Low	Close	Volume	Adj Close
01.03.2016	85.51	87.16	85.26	87.16	2196200	87.16
29.02.2016	85.52	85.7	84.43	85.46	2506500	85.46
26.02.2016	85.2	86.93	85.05	86.31	2671300	86.31
25.02.2016	83.7	84.98	83.08	84.12	2175400	84.12
24.02.2016	85.11	85.18	82.09	82.49	2822900	82.49
23.02.2016	85.87	86.37	85.01	85.01	1784600	85.01
22.02.2016	85.08	86.58	85	86.43	1814500	86.43
19.02.2016	85.34	85.53	83.95	84.55	2667800	84.55
18.02.2016	84.86	85.68	84.19	84.89	2345600	84.89
17.02.2016	82.61	84.72	82.5	84.48	2356500	84.48
16.02.2016	82.51	83.09	81.78	82.15	2099900	82.15
15.02.2016	81.78	82.77	81	82.23	2548900	82.23
12.02.2016	80	80.67	79.74	80.65	2849200	80.65
11.02.2016	81.09	81.15	79.23	79.23	3779800	79.23
10.02.2016	82.56	83.8	81.97	82.25	2757200	82.25
09.02.2016	82.83	83.47	81.24	81.99	4020300	81.99
08.02.2016	84.71	85.37	81.92	82.55	3588700	82.55
05.02.2016	85.04	85.95	84.17	84.55	3018000	84.55
04.02.2016	85.99	86.23	83.99	85.14	3379000	85.14
03.02.2016	85.6	86	83.84	84.81	3080700	84.81
02.02.2016	87.11	87.65	85.21	85.99	2835700	85.99
01.02.2016	88.8	89.06	86.47	87.45	2134400	87.45

After formatting

Date	Open	High	Low	Close	Volume	Adj Close
01.03.16	85.51	87.16	85.26	87.16	2,196,200	87.16
29.02.16	85.52	85.70	84.43	85.46	2,506,500	85.46
26.02.16	85.20	86.93	85.05	86.31	2,671,300	86.31
25.02.16	83.70	84.98	83.08	84.12	2,175,400	84.12
24.02.16	85.11	85.18	82.09	82.49	2,822,900	82.49
23.02.16	85.87	86.37	85.01	85.01	1,784,600	85.01
22.02.16	85.08	86.58	85.00	86.43	1,814,500	86.43
19.02.16	85.34	85.53	83.95	84.55	2,667,800	84.55
18.02.16	84.86	85.68	84.19	84.89	2,345,600	84.89
17.02.16	82.61	84.72	82.50	84.48	2,356,500	84.48
16.02.16	82.51	83.09	81.78	82.15	2,099,900	82.15
15.02.16	81.78	82.77	81.00	82.23	2,548,900	82.23
12.02.16	80.00	80.67	79.74	80.65	2,849,200	80.65
11.02.16	81.09	81.15	79.23	79.23	3,779,800	79.23
10.02.16	82.56	83.80	81.97	82.25	2,757,200	82.25
09.02.16	82.83	83.47	81.24	81.99	4,020,300	81.99
08.02.16	84.71	85.37	81.92	82.55	3,588,700	82.55
05.02.16	85.04	85.95	84.17	84.55	3,018,000	84.55
04.02.16	85.99	86.23	83.99	85.14	3,379,000	85.14
03.02.16	85.60	86.00	83.84	84.81	3,080,700	84.81
02.02.16	87.11	87.65	85.21	85.99	2,835,700	85.99
01.02.16	88.80	89.06	86.47	87.45	2,134,400	87.45

Fig. 5.39 Imported price data: following text conversion and formatting (Excel File Workshop Excel_3, Worksheet Share_Prices_Formatted)

Here is one suggestion for the final look of the worksheet following the formatting (Fig. 5.39).

6 Analysis Stage: Sensitivity and Scenarios

Complex tasks are unlikely to have a unique and simple solution. Instead, the financial modeler faces the challenge of capturing an unfamiliar situation and drawing conclusions about linkages and possible effects.

Here we provide tools which help in assessing the results of a financial model. The following Excel functions provide support in this regard:

- Sensitivity analysis using *Data Tables*
- Scenarios using the *Scenario Manager*
- *Goal Seek*
- *Solver*

6.1 Sensitivity Analysis Using Data Tables

Gaining insights from the sensitivity analysis.

In most cases, the exact parameters of the model are not known and the modeler must make reasonable assumptions. These assumptions can be verified by varying one or more of them in a structured manner.

> Sensitivity analysis using Excel Data Table.

The *Data Table* of Excel are a useful instrument to assess the effect of a change in an input parameter on the result of a formula.

You want to practice on you own to build up the auxiliary calculations for sensitivity analysis? Then open Excel File Workshop Excel_4, Worksheet Sensitivity_1. Once you have completed your own exercise, compare the results with those in Excel File Workshop Excel_4, Worksheet Sensitivity_Final.

> Exercising: Excel File Workshop Excel_4, Worksheet Sensitivity_1
>
> The complete auxiliary calculations: Excel File Workshop Excel_4, Worksheet Sensitivity_Final.

Setting up a *Data Table* in Excel:

1. In this case it also makes sense to start a fresh module (range `B38:H42`).
2. Insert in rows `38-42` the contents and calculations from Fig. 5.40. Please make sure that the cells `C41:H41` remain empty.

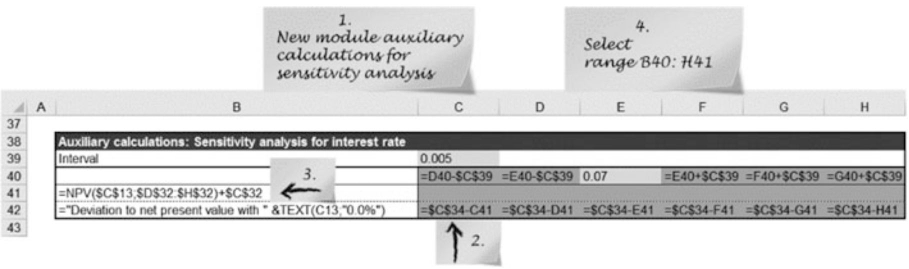


Fig. 5.40 Formulas for the sensitivity analysis with *Data Table* (Excel File Workshop Excel_4, Worksheet Sensitivity_1)

3. The formula for the net present value from cell C34 is entered in cell B41. The function *Data Table* will use the formula to calculate the value based on the interest rate (row 41).
4. Mark the range B40:H41.
5. Go to the function *Data Table* (Fig. 5.41) via *Data* ➲ *Forecast*[1] ➲ *What-If-Analysis* ➲ *Data Table*.
6. In the dialogue box *Raw input cell* add the cell for the interest rate $C$13.

The output is a table with two variables (light gray input fields: in C39 length of the interval, in E40 starting interest rate), which can be used to assess the implications for the final result if the interest rates are varied in a systematic fashion.

The interval (here: 0.5%) can be varied for the analysis in the upper row of Fig. 5.42. In the second row, the starting interest rate (here: 7.0 %) is specified. The values in the third row are determined via the *Data Table* function and reflect the net present value of the interest rate in the row above. The fourth row determines the deviation relative to the net present value of the baseline, which is shown in cell B41.

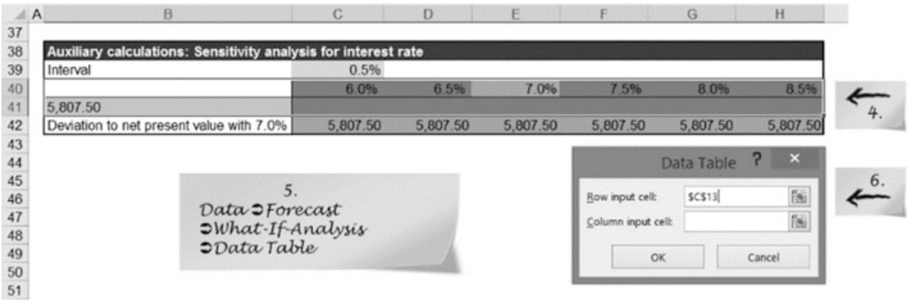


Fig. 5.41 Inserting the function Data Table for a sensitivity (Excel File Workshop Excel_4, Worksheet Sensitivity_1)

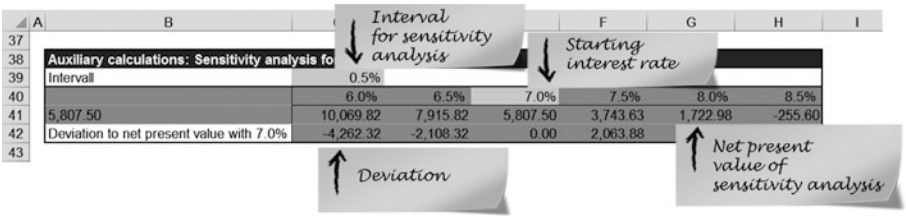


Fig. 5.42 Result of the sensitivity analysis with the *Data Table* (Excel File Workshop Excel_4, Worksheet Sensitivity_Final)

6.2 Scenarios with the Scenario Manager

The quality of a financial model can be enhanced further by supporting the sensitivity analysis with a scenario analysis. This method critically assesses the entire approach, as it allows the consideration of future opportunities and risks and facilitates an appropriate assessment of an uncertain environment.

Applied Example

Scenarios for the Investment Analysis
The net present value of the investments which serves as a basis for the decision of Supplier Inc. can be assessed for plausibility by incorporating different scenarios.

- What if the expected annual output is exceeded?
- What if the cost of maintenance is significantly higher?
- What would be the effect of a sizeable increase in interest rates?
- What if the machine life is shorter than planned?

Scenario Manager

The *Scenario Manager* of Excel allows the archiving of cell ranges in the form of scenarios, which can be accessed again if needed or summarized in reports.

Saving the initial value in scenarios, before the value drivers are changed.

The characteristics of the *Scenario Manager*:

- The scenarios are saved in a worksheet and can be enlarged to capture additional scenarios.
- It is recommended to start with a base case and then to include variations (such as worst case, best case, profit scenario, loss scenario) by employing different values.
- The *Scenario Manager* allows any number of parameters.

- The deviations among the various scenarios allow insights about the problem.

Towards scenarios in Excel:

Useful preliminary work: preparing auxiliary calculations and assigning names.

The *Scenario Manager* works with *Changing cells* (=variables) and result cells. For the *Changing cells* only cells are accepted which contain text, numbers or *Names* – formulas and links to calculations are not allowed. For that reason it is recommended to work with auxiliary calculations (Fig. 5.43), which are used to manually capture the input data.

You want to practice on you own to build up the auxiliary calculations for the scenario manager? Then open Excel File Workshop Excel 4, Worksheet Scenario_1. Once you have completed your own exercise, compare the results with those in Excel File Workshop Excel_5, Worksheet Scenario_Final.

Exercise: Excel File Workshop Excel_4, Worksheet Scenario_1 The complete auxiliary calculations: Excel File Workshop Excel_5, Worksheet Scenario_Final.

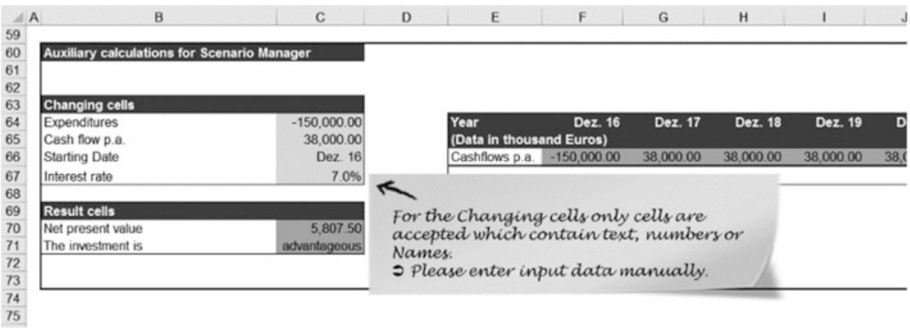


Fig. 5.43 Auxiliary calculations for the *Scenario Manager* (Excel File Workshop Excel_5, Worksheet Scenario_Final)

In the cell for the result, the net present value of the investment (cell `C70`) is calculated with the following function: `=NPV(C67;G66:K66)+C64`

For the *Scenario Report* the minimum investment amount is presented in the following way:

- In cell `B71` enter the text “The investment is”
- In cell `C71` add the formula: `=IF(C70≥0;"advantageous";" not advantageous")`

To maintain structure in the scenario manager, assign Names first.

Assign a *Name* to the adjustable cells and the result cells in order to obtain meaningful information when setting up the scenarios and the scenario reports. Without *Names* only the cell references are reported (such as `$C$64`). *Names* are assigned via *Formulas* ➲ *Name Manager* ➲ *New* (more details are found in the section Using Names to Improve Clarity of the Formulas).

Assign *Names* for the adjustable cells:

- Expenditures (`scenario_expenditures`)
- Cash flow p. a. (`scenario_cashflows`)
- Starting date (`scenario_starting_date`)
- Interest rate (`scenario_interest_rate`)
- Net present value (`scenario_NPV`)
- Investment threshold (`scenario_threshold`)

1. Via *Data* ➲ *Forecast*[2] ➲ *What-if-Analysis* ➲ go to the *Scenario Manager*.
2. In order to define a scenario, press *Add*.
3. The dialog box *Add Scenarios* opens up (Fig. 5.44).
4. Assign a name in the input field *Scenario name* (here: Base Case).
5. Activate the input field *Changing cells*. Mark the desired range with the mouse (here `$C$64:$C$67`).
6. If desired, you can add a comment to the comment field *Comment*, which describes the scenario.

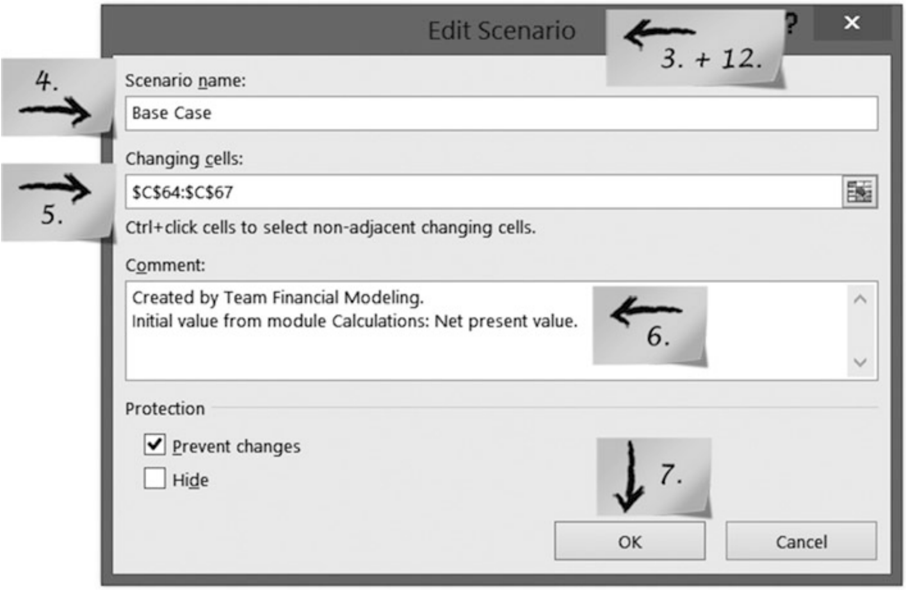


Fig. 5.44 Menu Edit Scenarios

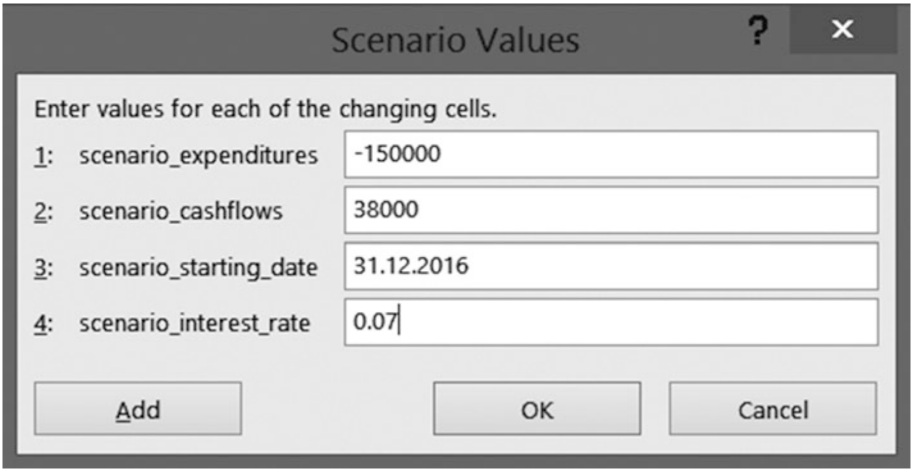


Fig. 5.45 Scenario values

7. Finish the input by hitting *OK*.
8. The dialogue *Scenario Values* opens up (Fig. 5.45).
9. The current numerical values have already been entered into the input fields. For the base case scenario, the inputs are kept and confirmed with *OK*.

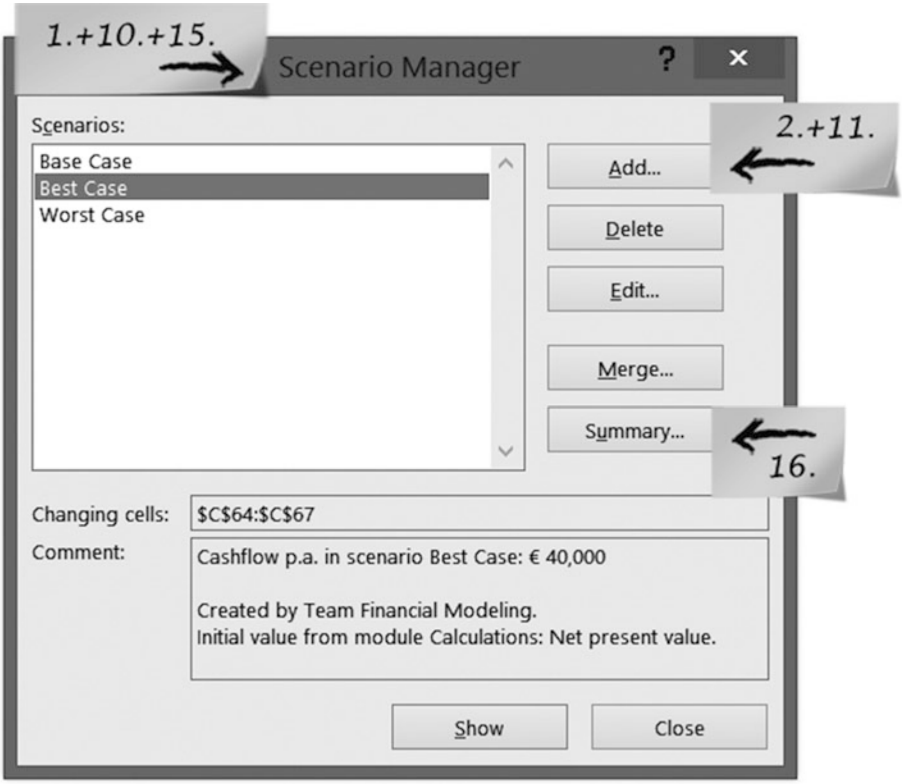


Fig. 5.46 Scenario Manager

10. You are now again in the dialog box *Scenario Manager* (Fig. 5.46).
11. With *Add* you can model additional scenarios (Best Case and Worst Case).
12. The field *Edit Scenarios* again appears (Fig. 5.44).
13. Repeat steps 4–8.
14. Vary the information concerning cash flow during the time of operation (Best Case 40,000, Worst Case 33,000) for the scenarios (Fig. 5.45).
15. Once the input is completed you again return to the menu *Scenario Manager* (Fig. 5.46).
16. Click on *Summary*, to receive the *Scenario Report*.
17. Enter into the field *Results Cells* the range `C70:C71` (Fig. 5.47).
18. The *Scenario Summary* is created on a separate worksheet (Fig. 5.48).

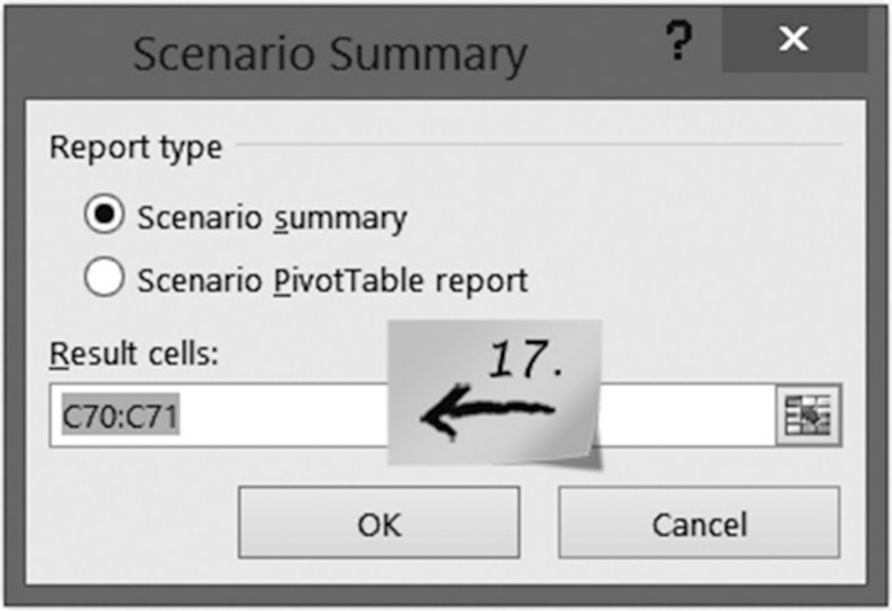
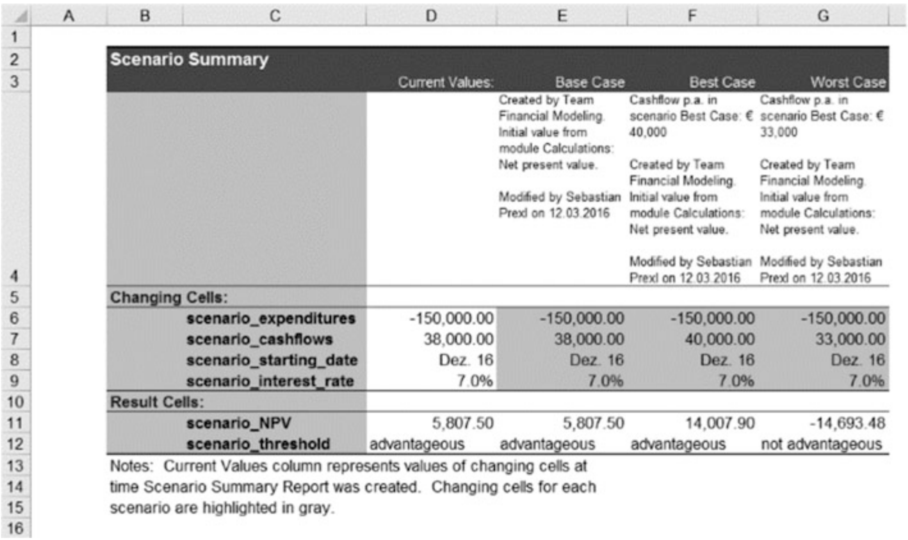


Fig. 5.47 Menu scenario report



Scenario Summary					
		Current Values:	Base Case	Best Case	Worst Case
			Created by Team Financial Modeling. Initial value from module Calculations: Net present value. Modified by Sebastian Prexl on 12.03.2016	Cashflow p.a. in scenario Best Case: € 40,000 Created by Team Financial Modeling. Initial value from module Calculations: Net present value. Modified by Sebastian Prexl on 12.03.2016	Cashflow p.a. in scenario Best Case: € 33,000 Created by Team Financial Modeling. Initial value from module Calculations: Net present value. Modified by Sebastian Prexl on 12.03.2016
Changing Cells:					
	scenario_expenditures	-150,000.00	-150,000.00	-150,000.00	-150,000.00
	scenario_cashflows	38,000.00	38,000.00	40,000.00	33,000.00
	scenario_starting_date	Dez. 16	Dez. 16	Dez. 16	Dez. 16
	scenario_interest_rate	7.0%	7.0%	7.0%	7.0%
Result Cells:					
	scenario_NPV	5,807.50	5,807.50	14,007.90	-14,693.48
	scenario_threshold	advantageous	advantageous	advantageous	not advantageous

Notes: Current Values column represents values of changing cells at time Scenario Summary Report was created. Changing cells for each scenario are highlighted in gray.

Fig. 5.48 The *scenario summary* for the investment assessment (Excel File Workshop Excel_5, Worksheet Scenario_Summary)

The complete auxiliary calculations for the scenario manager: Excel File Workshop Excel_5, Worksheet Scenario_Final.

6.3 Goal Seek

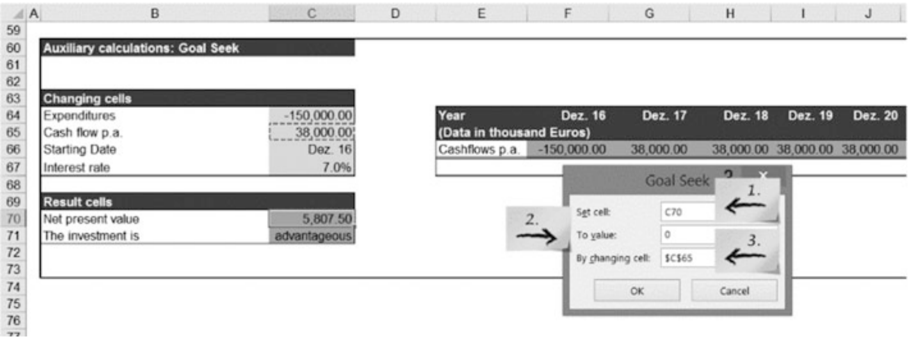


Fig. 5.49 Auxiliary calculations for Goal Seek (Excel File Workshop Excel_5, Worksheet Goal_Seek_1)

The management assistant wants to know the cash flow which just leads to a profitable investment. This means that the net present value needs to be at least zero.

He uses the so-called *Goal Seek* function of Excel: *Data* ➲ *Data Tools* ➲ *What-if-Analysis* ➲ *Goal Seek*. *Goal Seek* is an instrument in Excel suitable to solve linear equations with one unknown.

The following information is required in the input fields of the *Goal Seek* function (Fig. 5.49):

An exercise: Excel File Workshop Excel_5, Worksheet Goal_Seek_1.

1. Target cell (*Set cell*): Net present value (cell: `C70`)
2. Target value (*To value*): 0
3. Changing cell (*By changing cell*): Cash flow p.a. (cell: `$C$65`)

Goal Seek determines that the annual cash flow cannot fall below €36,583.60. Up to this amount, the investment is still profitable (net present value ≥ 0) and the required return is achieved.

> The results of Goal Seek: Excel File Workshop Excel_5, Worksheet Goal_Seek_Final.

6.4 Solver – Goal Seek for Challenging Tasks

> Solves what-if-scenarios with several unknowns and constraints.

Goal Seek allows the calculation of an individual value on the basis of the desired final result. For tasks where the result in question depends on several variables, the so-called *Solver* is utilized. It can be used to determine the optimum value for a formula.

Its approach is similar to that of *Goal Seek* – but the functionality is significantly larger. It also offers the potential to include calculations with constraints by setting maximum and minimum values. The *Solver* adjusts the unknown variables until the target value is reached.

> Activating the Add-in Solver.

The *Solver*, just as the already familiar function *Edate*, is a so-called *Add-in*. *Add-ins* are not automatically activated when installing Excel. The installation of such additional functions is described in the section "Activating *Add-ins*."

After the assistant presented the results derived with the help of *Goal Seek*, the management team wants to know whether the minimum return of the investments (net present value ≥ 0) is possible under the following conditions:

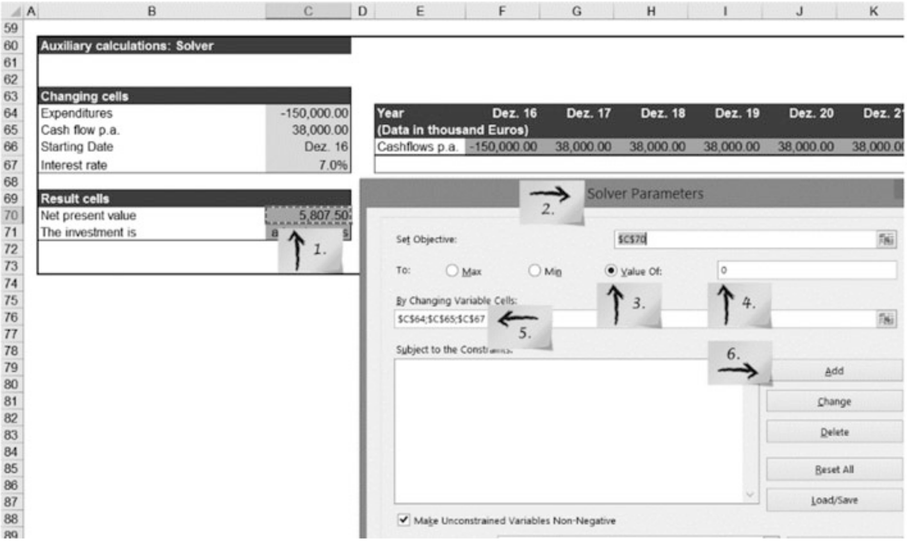


Fig. 5.50 *Solver Parameter* (Excel File Workshop Excel_5, Worksheet Solver_1)

- Acquisition costs plus the cost of employee training are to stay below €155,000.
- The cash flow p.a. during operations can take on a maximum value of €39,000.
- The interest rate cannot exceed or be equal to 8%.

To solve this task, the assistant again uses the auxiliary calculation which he already utilized for the *Scenario Manager* and *Goal Seek*. Working with the *Solver* (Fig. 5.50):

An exercise: Excel File Workshop Excel_5, Worksheet Solver_1.

1. Place the pointer on cell `C70` (net present value).
2. Open the *Solver* via *Data* ➲ *Analyze* ➲ *Solver*. You get to the dialog box *Solver Parameters*.

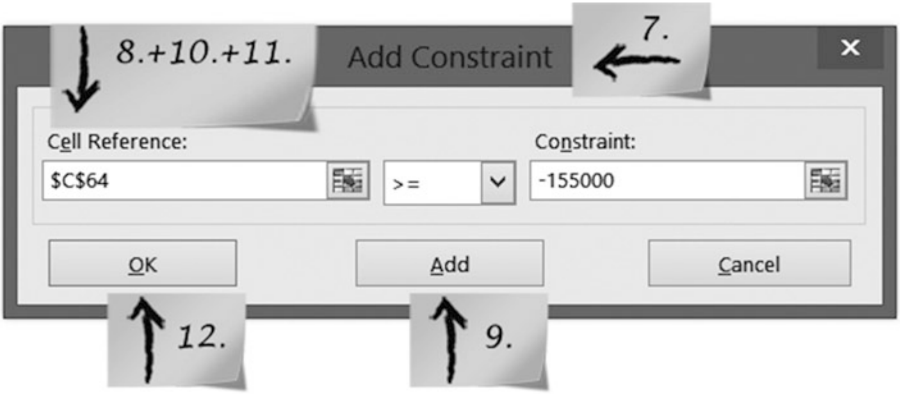


Fig. 5.51 Required input: adding constraints

3. Activate the option `Value of`.
4. Enter a value: *0*.
5. Place the cursor into the box *By Changing Variable Cells* and insert the range `$C$64;$C$65;$C$67`
6. To define the constraints, press *Add*.
7. The dialog box *Ad Constraint* appears (Fig. 5.51).
8. In the box *Cell Reference* enter `$C$64` (Expenditures), as *Operator* the $\geq$ symbol and as *Constraint* the value *–155,000*.
9. Press *Add*.
10. Repeat the process (steps 7—9) for the second unknown variable cash flow p.a.): *Cell Reference* `$C$65`, *Operator* $\leqslant$, *Constraint 39,000*.
11. Once again repeat the process (steps 7–9) for the third constraint (interest rate): *Cell reference* `$C$67`, *Operator* $\geq$, *Constraint 8%*.
12. Confirm with *OK*. You are now in the menu *Solver Parameter*.
13. Choose *Solve* (Fig. 5.52). The *Solver* starts the calculations.
14. Excel informs you in the dialog box *Solver Results* whether a solution has been found (Fig. 5.53).
15. Activate the option *Restore Original Values*.
16. In the box *Reports* select the option *Answer*.

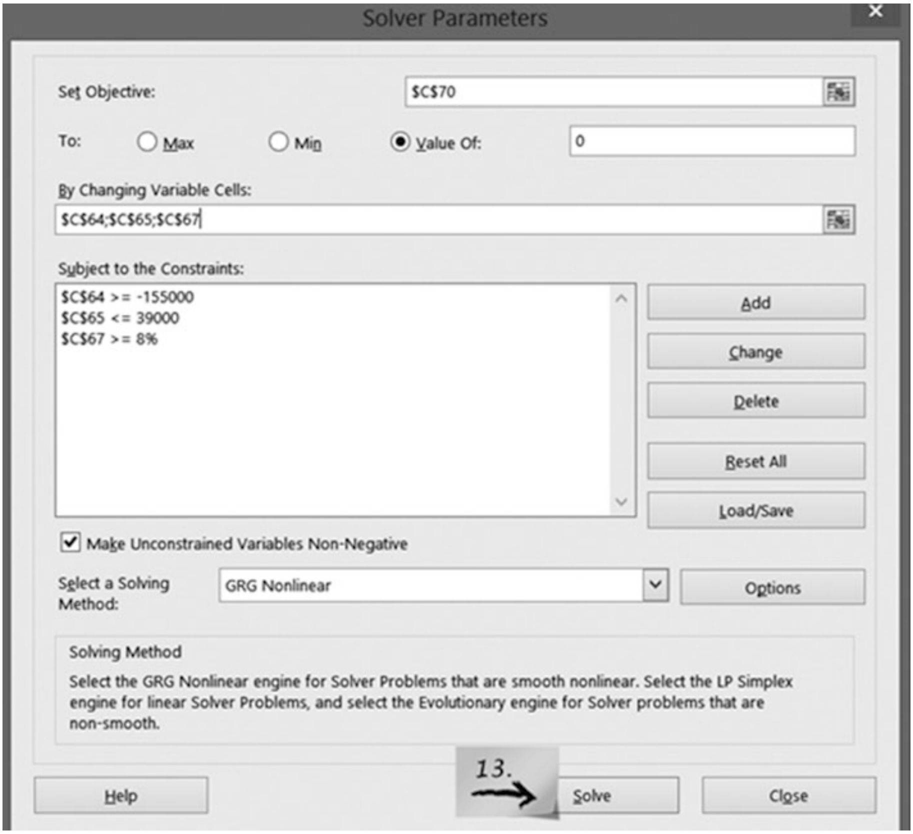


Fig. 5.52 Solver

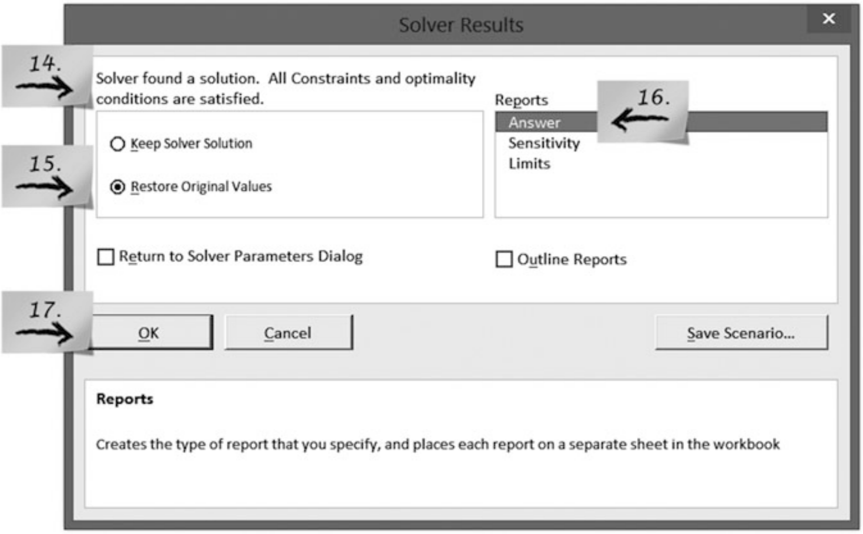


Fig. 5.53 Menu result of the *Solver*

Objective Cell (Value Of)

Cell	Name	Original Value	Final Value
$C$70	Net present value	5,807.50	0.00

Variable Cells

Cell	Name	Original Value	Final Value	Integer
$C$64	Expenditures	-150,000.00	-150,851.65	Contin
$C$65	Cash flow p.a.	38,000.00	37,781.77	Contin
$C$67	Interest rate	7.0%	8.0%	Contin

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
$C$70	Net present value	0.00	$C$70=0	Binding	0
$C$64	Expenditures	-150,851.65	$C$64>=-155000	Not Binding	4,148.35
$C$65	Cash flow p.a.	37,781.77	$C$65<=39000	Not Binding	1218.230072
$C$67	Interest rate	8.0%	$C$67>=0.08	Binding	0.0%

Fig. 5.54 Answer Report of the *Solver* (Excel File Workshop Excel_6, Worksheet Solver_Report)

17. Confirm with *OK*.
18. Once all calculations have been completed, a separate worksheet with a report summarizing all results is provided (Fig. 5.54).

The report of the Solver: Excel File Workshop Excel_6, Worksheet Solver_Report.

As a result of the optimization process, the *Solver* confirms that the constraints set by management can be satisfied.

7 Testing the Performance of a Financial Model

The systematic evaluation of a financial model is required to assure that it contains no calculation errors and that all information is flowing appropriately. The testing phase is a critical and frequently neglected step in the process. The resources spent on the task will usually be minor compared to potential consequences of faulty decisions, especially if they have financial repercussions.

Excel offers three effective instruments for the identification of errors and their causes:

- Formula auditing,
- Error checking and
- Formula evaluation.

7.1 Formula Auditing: Checking the Flow of Data and Formulas

It is possible to display linkages between cells in a transparent manner in the *Formula Auditing* mode. Tracer arrows are used by Excel to show the flow of data and formulas in a worksheet. This helps to recognize *Precedents* (cells which relate to a formula) or *Dependents* (cells which relate to other cells). The arrows help to detect errors and are also helpful during the programming process.

> Tracer arrows help to gain an overview.
> An exercise: Excel File Workshop Excel_7, Worksheet Test_Precedents.

In order to find out the links to other cells or formulas that are relevant for a specific cell,

1. Mark the cell (cell `C34`) which you want to analyze (Fig. 5.55).
2. Go to Tab *Formulas* and then to *Formula Auditing*.
3. Here you find the tracer arrows under *Trace Precedents* and *Trace Dependents*.
4. With *Remove Arrows* the traces are deleted again.

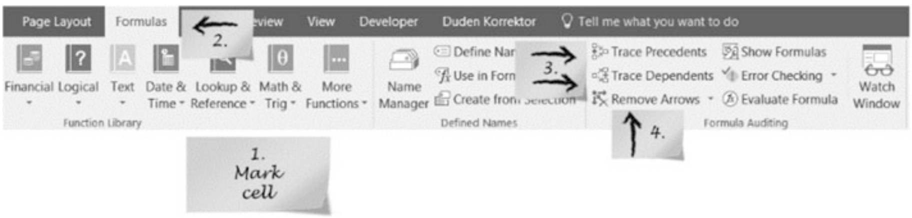
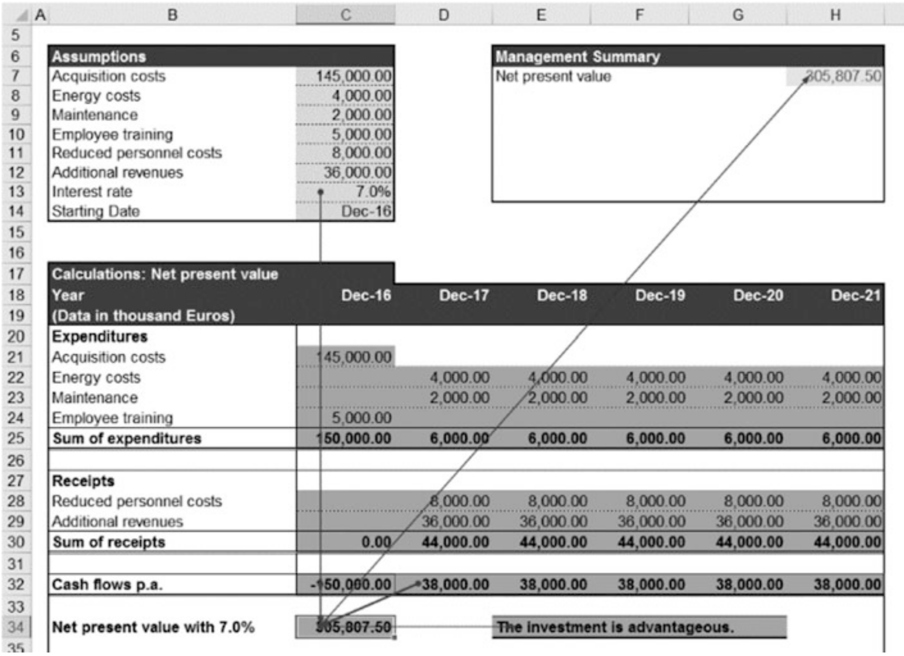


Fig. 5.55 Formula Auditing in the tab Formulas



Assumptions	
Acquisition costs	145,000.00
Energy costs	4,000.00
Maintenance	2,000.00
Employee training	5,000.00
Reduced personnel costs	8,000.00
Additional revenues	36,000.00
Interest rate	7.0%
Starting Date	Dec-16

Management Summary	
Net present value	305,807.50

Calculations: Net present value						
Year	Dec-16	Dec-17	Dec-18	Dec-19	Dec-20	Dec-21
(Data in thousand Euros)						
Expenditures						
Acquisition costs	145,000.00					
Energy costs		4,000.00	4,000.00	4,000.00	4,000.00	4,000.00
Maintenance		2,000.00	2,000.00	2,000.00	2,000.00	2,000.00
Employee training	5,000.00					
Sum of expenditures	150,000.00	6,000.00	6,000.00	6,000.00	6,000.00	6,000.00
Receipts						
Reduced personnel costs		8,000.00	8,000.00	8,000.00	8,000.00	8,000.00
Additional revenues		36,000.00	36,000.00	36,000.00	36,000.00	36,000.00
Sum of receipts	0.00	44,000.00	44,000.00	44,000.00	44,000.00	44,000.00
Cash flows p.a.	-150,000.00	38,000.00	38,000.00	38,000.00	38,000.00	38,000.00
Net present value with 7.0%	305,807.50		**The investment is advantageous.**			

Fig. 5.56 Trace to *Precedents/Dependents* (Excel File Workshop Excel_7, Worksheet Test_Precedents)

In Fig. 5.56 you can see how the net present value in cell C34 is linked with other cells in the worksheet.

7.2 Support from Error Checking

Occasionally a financial modeler is faced with the problem that a financial model does not provide the expected calculation results. *Error Checking* supports you in the search for errors.

There is apparently a mistake in the calculation of the sum of the expenditures in Fig. 5.57: The result in cell E25 deviates from the other two results by €2.000, even though positions in rows 22 to 23 are in line. Excel has identified the error as signaled by the green error indicator in the upper left corner of cell E25.

Correcting the error with *Error Checking*:

An exercise: Excel File Workshop Excel_7, Worksheet Test_Error_Checking.

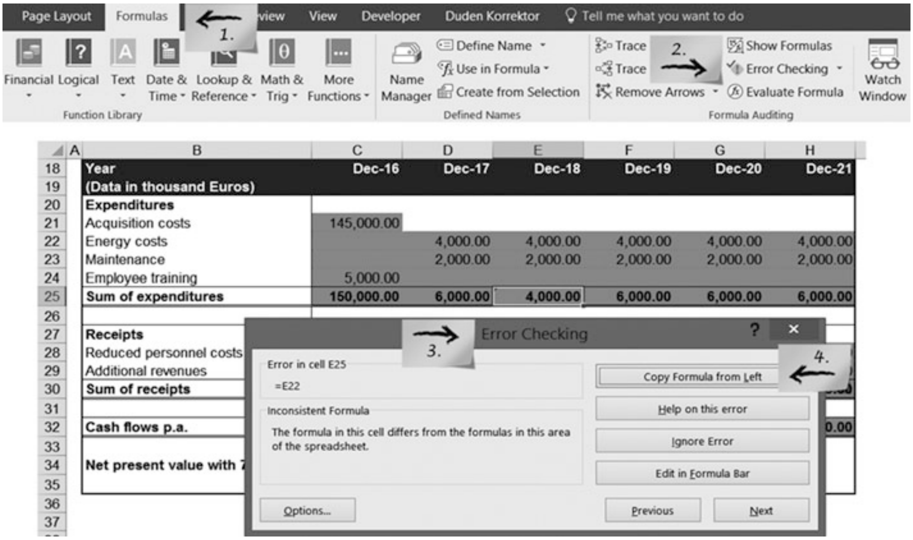


Fig. 5.57 Support from *Error Checking* (Excel File Workshop Excel_7, Worksheet Test_Error_Checking)

1. Mark the faulty cell `E25` and access *Error Checking* via tab *Formulas* ➲ *Formula Auditing*.
2. Click on *Error Checking*.
3. The dialogue box *Error Checking* appears, in which potential sources of error are named and a solution is outlined.
4. Select the first option *Copy Formula from Left* and Excel automatically corrects the cause as explained in the dialogue message.

The error was apparently caused by the fact that the sum of the expenditures in cell `E25` did not consider the item Maintenance (cell `E23`).

7.3 Formula Evaluation: Formula Assessment Step by Step

The Excel function *Evaluate Formula* is a helpful testing procedure for hard to identify shortcomings of a financial model, which might be caused specifically by conceptual errors. Excel shows the individual calculations in a cell step by step (argument for argument):

An exercise: Excel File Workshop Excel_7, Worksheet Test_Evaluate_Formula.

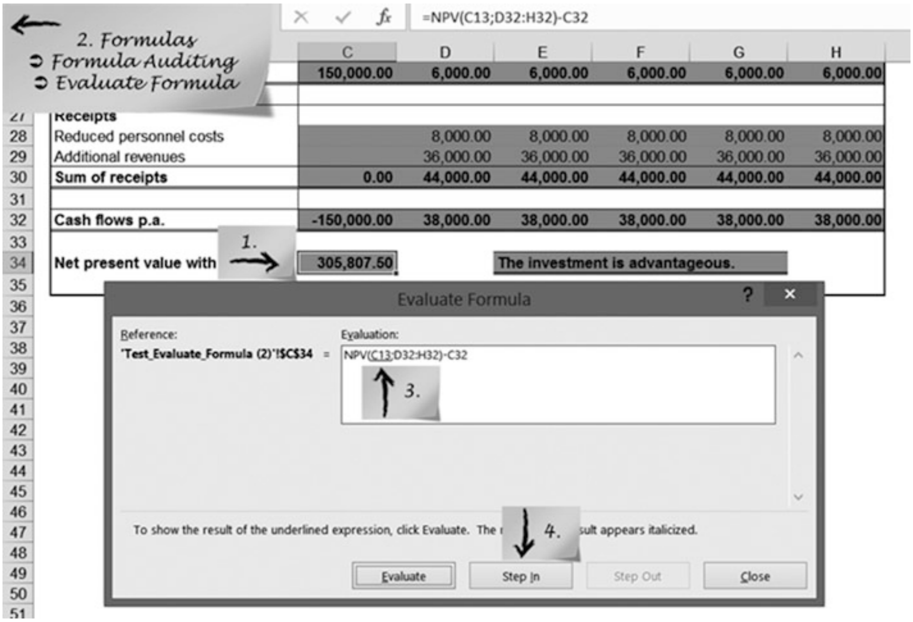


Fig. 5.58 Formula evaluation (Excel File Workshop Excel_7, Worksheet Test_Evaluate_Formula)

1. Put the mouse pointer on cell C34 which potentially contains an error (Fig. 5.58).
2. Activate *Formula Evaluation* via tab *Formulas* ➲ *Formula Auditing* ➲ *Evaluate Formula*.
3. The formula is shown in the analysis window and the first part of the formula is marked.
4. In order to calculate the various components of the formula separately, select *Step In*. The underlined part of the formula is calculated and the result of this part of the calculation is shown in the window.

The value of the net present value is apparently too high at €305,808.50 in Fig. 5.58. The stepwise function *Evaluate Formula* supports to identify of errors. At the end of the formula, the sum of expenditures was subtracted -C32 instead of added. The error is corrected by replacing the minus sign with a plus sign.

8 Summary

The Financial Modeler Acquired the Following Skills in this Workshop:

Financial modeling in Excel:

- Efficient modeling requires a structured and thoughtful approach and thorough preparation.
- There are only very few cases where the result for a complex topic can be derived directly.
- In applied work, the approach of developing a series of increasingly complex and improved prototypes has shown its effectiveness (iterative approach).

1. Using key combinations and the ribbon to work with Excel:
   - Every user of Excel has this problem. The computer mouse and the touchpad of a laptop are inefficient and hinder the workflow.
   - Key combinations or sequences and the *Ribbon* are suitable methods to improve productivity.
2. Creating prototypes and sending signals to the management:
   - A so-called spreadsheet is used to transfer the considerations and partly qualitative information into an Excel application.
   - The skilled use of Excel tools such as *Names*, *Comments*, functions and conditional formatting are important abilities of the financial modeler.
   - Knowledge about functions such as *Data Validation*, dynamic lists and *Add-Ins* are valuable additions.
3. Data collection:
   - Financial modelers are regularly confronted with the challenge of collecting data. They are rarely in the possession of all relevant information.
   - The financial modeler knows how to collect data in a secure manner so that input errors can be prevented.
   - Internal and external data can be imported in Excel. The most important function is *VLookup* and alternatively the combination *Index* and *Match*.

4. Analysis stage - sensitivity and scenarios:
   - A simple and numerically unique solution can rarely be expected for complex tasks.
   - Instead, it is the task of the financial modeler to capture an unknown situation and to draw conclusions about possible effects.
   - The results are assessed for their reliability and meaning with the methods of sensitivity analysis and scenarios.
   - In Excel, the *Scenario Manager*, *Goal Seek* and the *Solver* are used.
5. Testing the performance of a financial model:
   - The systematic assessment of a financial model is required to assure that no arithmetic errors are left and that the flow of information is correct.

Notes

1. In Excel 2016 the group was renamed in *Forecast* – in previous versions of Excel it used to be *Data Tools*.
2. In Excel 2016 the group was renamed in *Forecast* – in previous versions of Excel it used to be *Data Tools*.

Further Reading

Benninga, S. (2014) *Financial Modeling*, 4th edn (Cambridge, MA and London: The MIT Press).

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6
Workshop Excel Part III

1 Executive Summary

In this chapter, the financial modeler acquires the skills needed to develop Excel software solutions.

In the Workshop Excel Part III, the financial modeler studies how best to present the results and recommendations of the financial model to management or clients using Excel. This step is of major importance, since the financial modeler is not just a number cruncher who leaves the presentation to colleagues who are closer to the market. Instead the professional financial modeler can utilize Excel in a way that clearly distinguishes him from the "Powerpoint competition." In contrast to Powerpoint, diagrams can be of a dynamic nature in order to show the implications of changing constraints via time series comparisons, ranking order comparisons, structural comparisons, frequency comparisons and comparisons of correlations.

2 Introduction, Structure, Learning Outcomes and Case Study

Structure

The workshop serves as an introduction to financial modeling and answers the following questions:

- How are the insights from financial models presented?

J. Häcker and D. Ernst, *Financial Modeling*,
Global Financial Markets, DOI 10.1057/978-1-137-42658-1_6

Learning Outcomes

The workshop uses a case study to demonstrate how to build financial models in Excel in a structured manner.

The financial modeler

- Possesses the basic presentation skills necessary to effectively convey the results of the financial modeling process, which are primarily quantitative in nature, to his target audience.

Case Study

Suggestions for use of the book and the download offering:
Learning will be most successful if the insights are directly applied. The examples provided in the download offering (folder Workshop Excel) allow you to deepen your knowledge from the book by applying it to the case study.

Use the workbooks of the workshop as you go through the text. The individual learning steps are contained in small units on separate worksheets in eight workbooks. They can be used in two different ways:

> The contents of the download offering complements the text and supports active learning

1. Open a new workbook and recreate the financial model from the case study step by step by your own. This is the most challenging approach which also promises the greatest reward. Start with `Create Menus` and continue all the way to the `Diagrams`. In that way, you get to know all the steps needed to create a financial model.
2. Or you can use the workbook in the folder of the `Workshop Excel` to directly tackle individual issues of particular importance to you. The different topics in the individual worksheets can be used independently of each other.

Excel Software Version
Workshop Excel was prepared with the latest desktop version of Excel (Excel 2016 for Windows, 32-bit). In general, the information also

applies to Excel 2013 and Excel 2010. If you use these earlier versions, in exceptional circumstances menus and commands can deviate from the demonstration here.

Security

- Security is an important topic when using macros and VBA. VBA programs are deactivated in the standard settings of Excel. Therefore, all security settings need to be changed in order to work with the applied examples (*disable all macros with notification*).
- Once you open the workbook from the download offering, Excel will provide a security warning below the ribbon.
- With the button *Options* followed by *Activate this contents* you allow running of the macro.

More information is found in the Workshop VBA in the Section Correct setting of Virus Protection – Activating Macros.

3 Presenting Insights and Recommendations

Finally, the numerical results from the modeling process are translated into conclusions and recommendations. The predominantly numerical results from the financial model must be presented in a way that is understandable and useful for decision makers. For that reason, assumptions, model contents, results and insights are put into a presentation. A successful transfer requires a combination of quantitative and qualitative abilities combined with a certain degree of creativity.

Practical Tip

Principles for presenting a financial model
The main aspects of each presentation are appropriate messages and adequate packaging:

- A presentation should tell a story.
- It should provide insight and not recount the analysis process.
- It should be to the point – less is more.

- Charts are preferred over words. But if the content is not relevant, even colors will not make it more interesting.

The audience loses interest because of the wrong contents and not the optical layout.

3.1 Recommendations for the Presentation of Charts

Charts allow the audience to digest information more quickly compared to lists of numbers in the form of tables, as long as simple design principles are followed. The financial modeler of Supplier Inc. remembers his training and his first presentation. The presentation was flawed for a number of reasons (Fig. 6.1). It did not have headlines with key messages and too many details that distracted from the main message. Additionally, too many different colors were included.

A unified layout for the presentation of a financial model increases the recognition factor, saves time during production and avoids errors.

1. First of all, formulate the key message for the title of the chart:

   A message should be conveyed and not just numbers. The reader should understand the story behind the results. The importance of

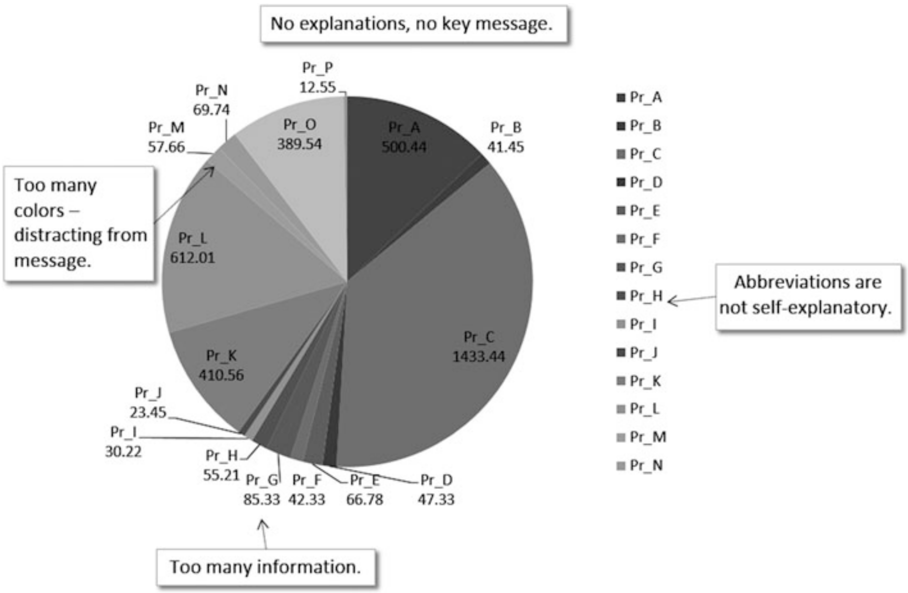

Fig. 6.1 Example of a poor chart

the title can be compared to the heading of an article in the yellow press.

The title of the chart needs to fulfill two conditions:

- It needs to be precise and concise.
- It needs to summarize what the reader will learn.

In the example the title is “Product C has the highest sales volume.” The next steps of creating the chart follow this key message.

> Use succinct titles.

2. Provide additional supporting information in a *Text box* (see Practical Tip: Adding a *Text Box* to a chart in Excel) to draw the attention of the reader to specific features. This increases the explanatory power of the chart. In the example, it would make sense to provide reasons why Product C is of outstanding relevance. “The new marketing approach is paying off: Today Product C is the number 1.”
3. Next, summarize the less relevant facts, so that the chart is not overloaded with information. If the amount of data becomes too large, the processing time of the observer increases and the structure is lost. The maximum of information depends on the type of chart selected:
   - Pie charts: maximum of six elements.
   - Stacked bar charts: maximum of four elements.
   - Line charts: maximum of four lines.

   Details with less relevance can be relegated to the category “Others”
4. Do not present numerical results with unnecessary precision. For example, do not give the exact amount of cents for values in the millions such as € 1,303,284.38. Better is € 1.3 million. It is generally recommended to report a maximum of four digits for numbers and to work with abbreviations such as th. (thousands) or mn. (million).
5. Only use abbreviations that are self-explanatory and avoid redundancies. It is not necessary, for example, to report the year or the

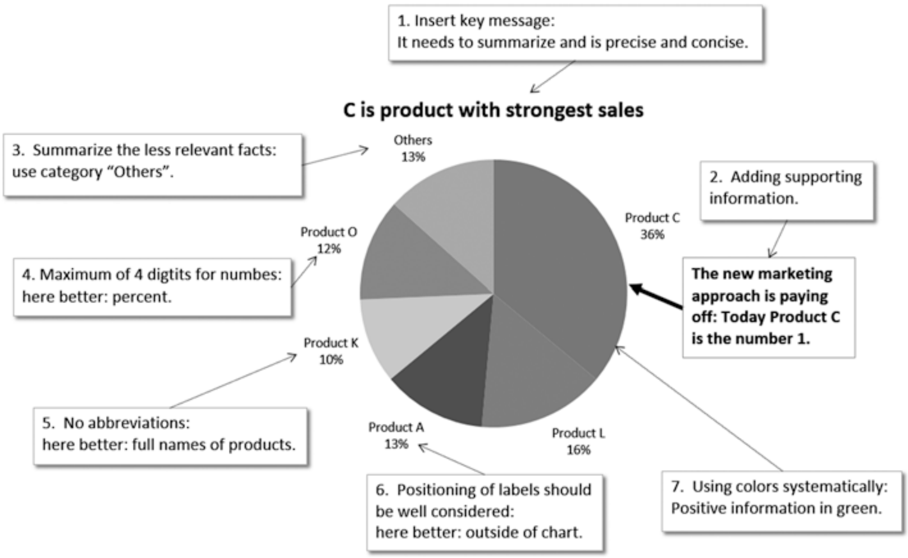

Fig. 6.2 Example for a successful pie chart

currency unit for every data label. This information can be recorded in a separate text field.

6. The labeling of the individual data elements should be well considered. In contrast to the first draft, the data labels in Fig. 6.2 were positioned outside of the pie chart.
7. Use colors systematically and with purpose in order to highlight the information that is most important in the chart. When assigning colors, anticipate the result of a printout on a laser printer which works with shades of gray.

Practical Tip

Adding a *Text Box* to a chart in Excel

1. Mark the chart by clicking on it with the mouse (Fig. 6.3).
2. Go to tab *Insert*.
3. Go to group *Text* and click on *Text Box.*

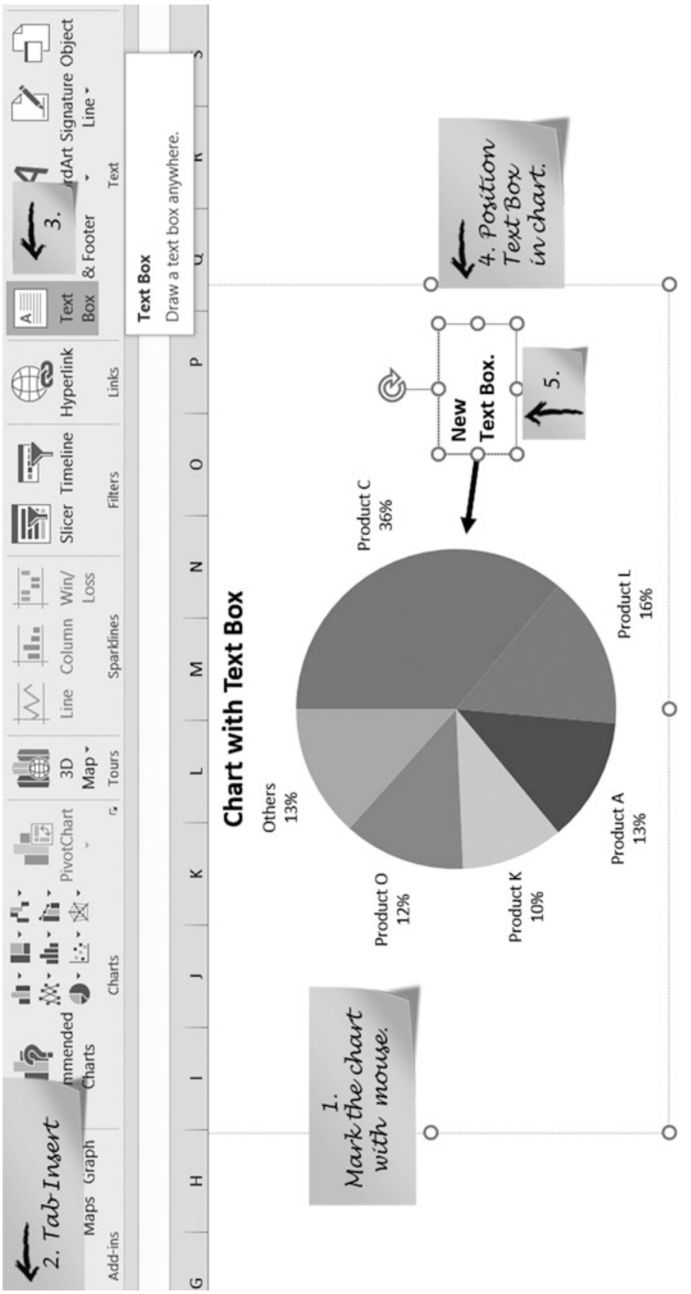

Fig. 6.3 Inserting a *Text Box*

4. Click with the mouse on the position in the chart where you want to insert the *Text Box* and drag it to the desired size.
5. You can enter the text with the blinking cursor.

3.2 Creating Simple Charts in Excel

A comfortable way to create simple charts in Excel involves the use of the chart assistant. As an example, the graphical display of the annual cash flows is in a chart is constructed as follows:

An exercise: Excel File Workshop Excel_8, Worksheet Chart_Simple.

1. Mark the area `B32:H32`.
2. Go to tab *Insert.*
3. Select *Column* as displayed in Fig. 6.4.
4. Click on *2-D Column* (*Clustered Column*).
5. Go to *Chart Tools* ➲ *Design*.
6. Click on *Select Data.*
7. Click on *Edit* in the box *Horizontal (Category) Axis Label* (Fig. 6.5).
8. Provide the range `C18:H18` in the dialogue field.
9. Complete the dialogue with *OK*.

The result is shown in Fig. 6.6.

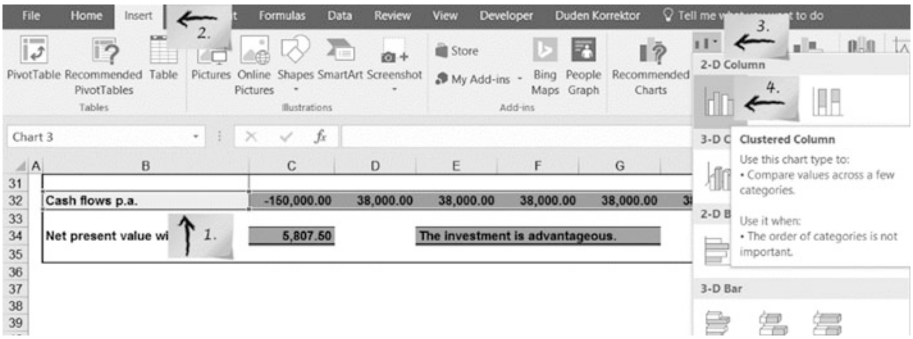

Fig. 6.4 Select chart type (Excel File Workshop Excel_8, Worksheet Chart_Simple_1)

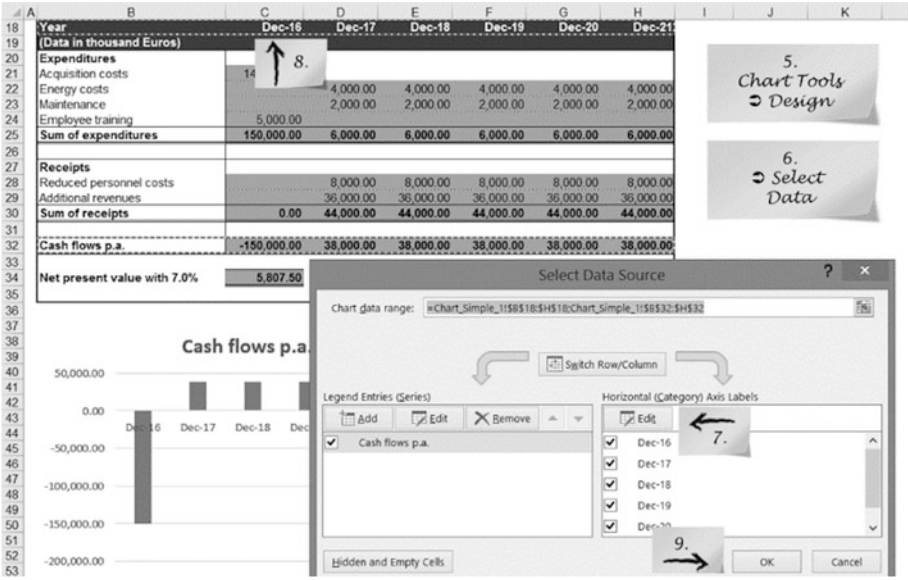

Fig. 6.5 Design of chart (Excel File Workshop Excel_8, Worksheet Chart_Simple_Final)

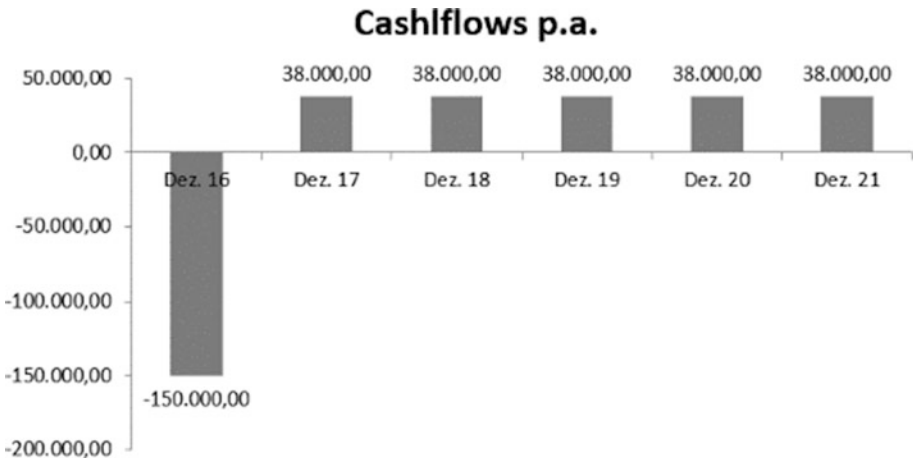

Fig. 6.6 Presenting the annual cash flows in a bar chart (Excel File Workshop Excel_8, Worksheet Chart_Simple_Final)

3.3 Dynamic Charts

The previous presentation is suitable for many occasions, but difficult to adjust if there are data changes. Dynamic charts open up the possibility to display several value drivers in a chart at the touch of a button.

Creating dynamic charts in Excel:

An exercise: Excel File Workshop Excel_8, Worksheet Chart_Dynamic_1.

1. Create a new auxiliary calculation as a new module *Dynamic chart*. Use the cell range `B38:H44`.
2. The necessary calculations for the rows `39` to `41` are found in Fig. 6.7.
3. Copy the cells `D39:D41` to cells `E39:H41`.
4. Enter the following formula in cell `B43`
5. `=OFFSET(B$38;$C$44;0)`
6. Copy the formula into the cell range `C43:H43`.
7. The *Index Counter* for the command *Offset* and for the *Control Element* is inserted in cell `C44`.
8. Insert a *Form Control*. This determines the data for the dynamic chart at the touch of a button. Go to *Developer* (Fig. 6.8).
9. Click on *Insert*.
10. Select a *Combo Box.*
11. Place the *Combo Box* above the free cells `C46` and `D46`.
12. Right-click with the mouse on the *Combo Box*.
13. In the context menu, select the command *Format Control*.
14. Go to the tab *Control*.

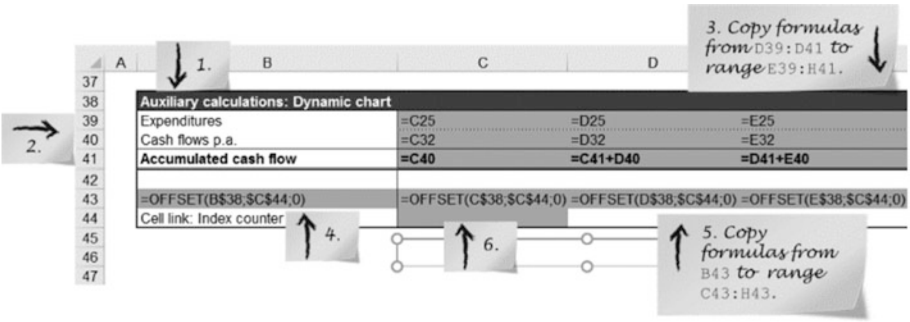

Fig. 6.7 New module auxiliary calculations dynamic chart (Excel File Workshop Excel_8, Worksheet Chart_Dynamic_1)

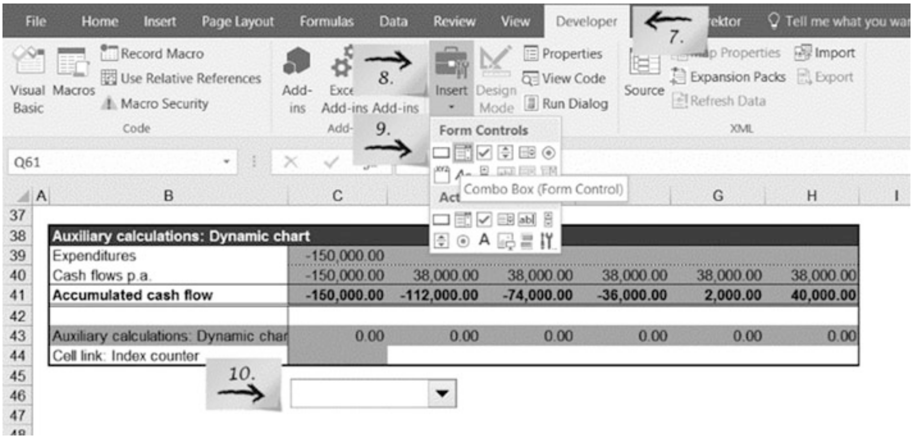

Fig. 6.8 Selecting the Form Control *Combo Box* (Excel File Workshop Excel_8, Worksheet Chart_Dynamic_1)

15. Go to the input field *Input range* and insert the range `$B$39:$B$41`.
16. In the field *Cell link* specify cell `$C$44`.

    This is an index counter, in other words the number which determines the value driver (expenditures, cash flow p.a. or accumulated cash flow) that will later appear in the chart.
17. The field *Drop down lines* can stay at the standard setting *8*.
18. Confirm with *OK* to exit the dialog box.
19. Test the new *Combo Box*.

> The complete auxiliary calculations: Excel File Workshop Excel_8, Worksheet Chart_Dynamic_2.

Now fit the chart in order to make it dynamic. This follows the steps for *Creating simple charts in Excel*. You find the complete auxiliary calculations for the Dynamic Chart in Worksheet Chart_Dynamic_2.

1. Click on the chart with the mouse (Fig. 6.9).
2. Go to *Chart Tools* ➲ *Design*.
3. Click on *Select Data.*

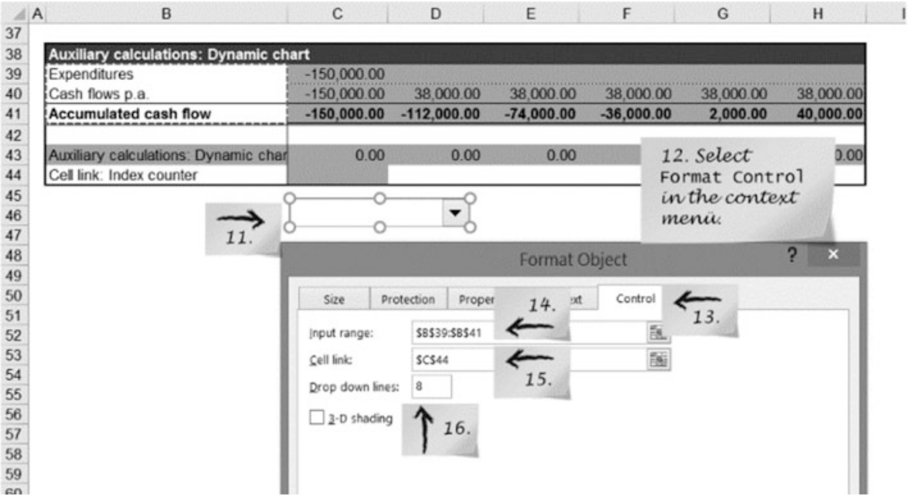

Fig. 6.9 Formatting the *Combo Box* (Excel File Workshop Excel_8, Worksheet Chart_Dynamic_1)

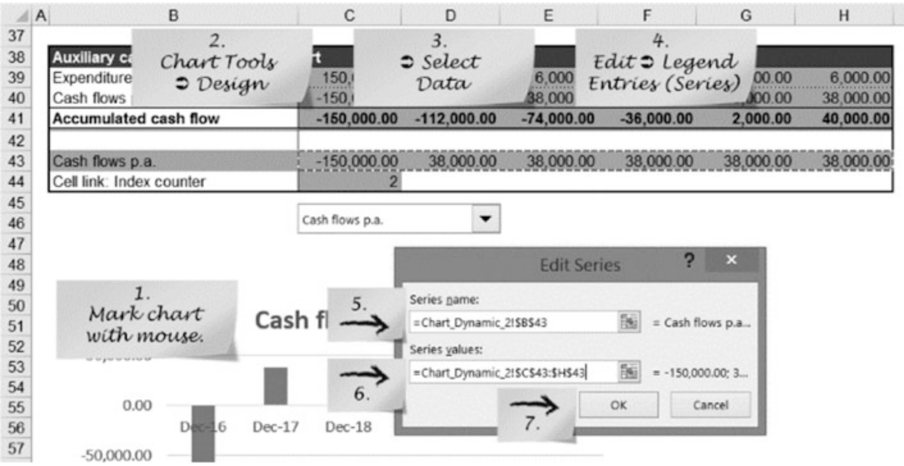

Fig. 6.10 Establishing data series for a dynamic chart (Excel File Workshop Excel_ 8, Worksheet Chart_Dynamic_1)

4. Click on *Edit* in the box *Legend Entries (Series)*.
5. In *Series name* enter: `=Chart_Dynamic_2!$B$43`
6. In *Series values*: `=Chart_Dynamic_2!$C$43:$H$43`
7. Terminate the dialogue with *OK* (Fig. 6.10).

3.4 Selecting a Suitable Chart

In the previous section you obtained the knowledge necessary to create simple and dynamic charts in Excel. But the used column chart presented only a small part of the available options for visualizing figures in Excel. Figure 6.11 provides an overview of the different types of charts that are available in Excel.

Practical Tip

Experiment with chart types in Excel

The range of available chart types in Excel is very comprehensive. But especially managers and staff members in finance frequently

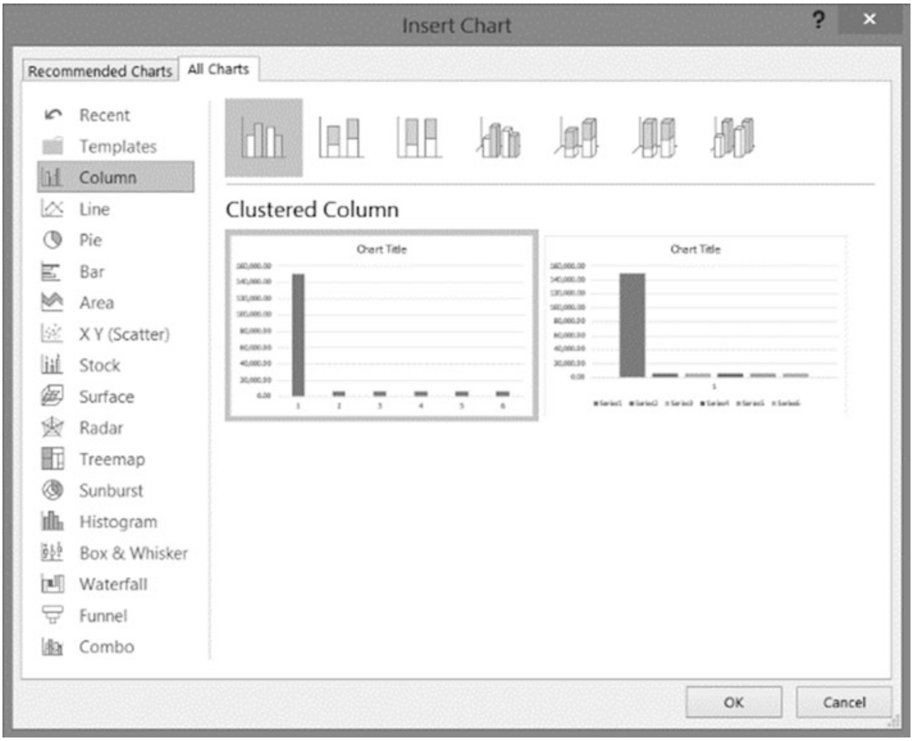

Fig. 6.11 The dialog box *Insert Chart* which gives an overview of the numerous types of charts and their subcategories.

encounter presentations that are only based on the standard tools of Excel. You can stand out from the masses if you give your presentations a stronger and more individual look. Experiment with the chart masters of Excel and utilize individualized ways of presenting the data. Get inspired by the charts (such as waterfall chart and dual bar chart) in this section (see Heimrath, 2009, p. 5 following).

The choice of a suitable type of chart is decisive for the quality of the presentation. Therefore the financial modeler should be clear about purpose and intention of the chart. With a reasoned and correct choice of chart category, the creation of a chart becomes a simple and mechanical task.

Five different categories are mostly used in financial modeling:

- Displaying changes over time (time series comparison).
- Relationships between parts and the complete setup (structural comparisons).
- Comparison and assessment of two or several aspects (ranking comparison).
- Distributions of different classes (frequency comparisons).
- Pointing out relationships between different variables (comparisons of correlations).

3.4.1 Time Series Comparison: How Does a Value Driver Change over Time?

> Time series comparisons show changes over time.

A time series is the most frequently used comparison. It is utilized to support certain key terms in the main message of the chart (such as change, grow, increase, advance, decline, fall and fluctuate). In contrast to a ranking or structural comparison, the aim of a time series comparison is to provide a visual display over a period of time (day, week, quarter, year and so forth).

Applied Example

Typical time series comparison

- The cost of materials has increased slightly in the past quarter.
- The dividend declined strongly in the past year.
- The value of the put option has gone down compared to the previous month.

Time series comparisons are usually supported with bar charts or line charts – occasionally also area charts or waterfall charts.

Column chart

If only a limited amount of information needs to be conveyed, a column chart is recommended.

Creating column charts in Excel ➲ *Insert* ➲ *Charts* ➲ *Column* ➲ *2-D Column*.

Experience shows that the following features for column charts are effective:

- For the main object, which is highlighted in the header, strong colors should be used (in Fig. 6.12 this is the annual result 2016).
- Negative values can also be highlighted in a different color.
- The amounts should be placed above or below the columns.
- For column charts it must be assured that the gaps between the columns are narrower than the columns themselves.

Varying the gap between the columns.

Adjusting the gap between the columns in Excel:

1. Mark the *Data Series* in the chart with the right mouse button.
2. Select *Format Data Series* in the context menu.
3. Go to *Series Options*.
4. You change the *Gap Width* with the lower slide control (here: 28%).

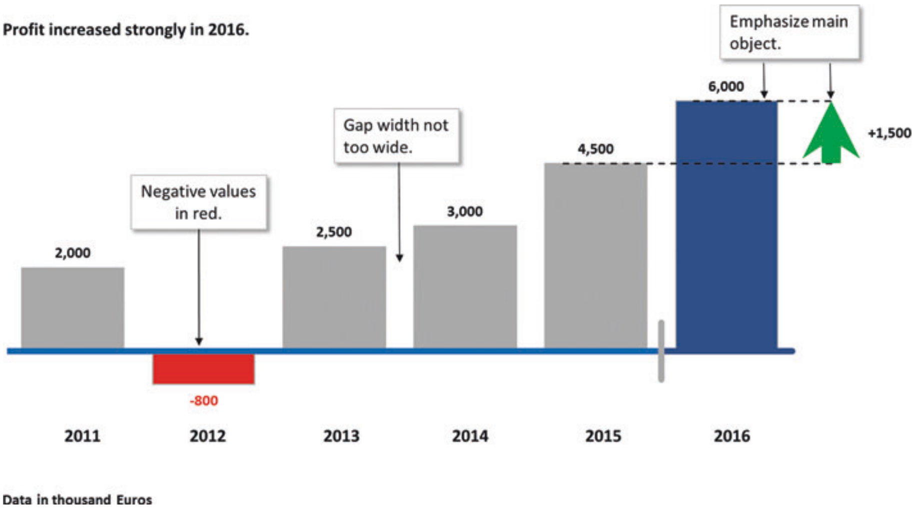

Fig. 6.12 Example for column chart (own presentation following Heimrath (2009))

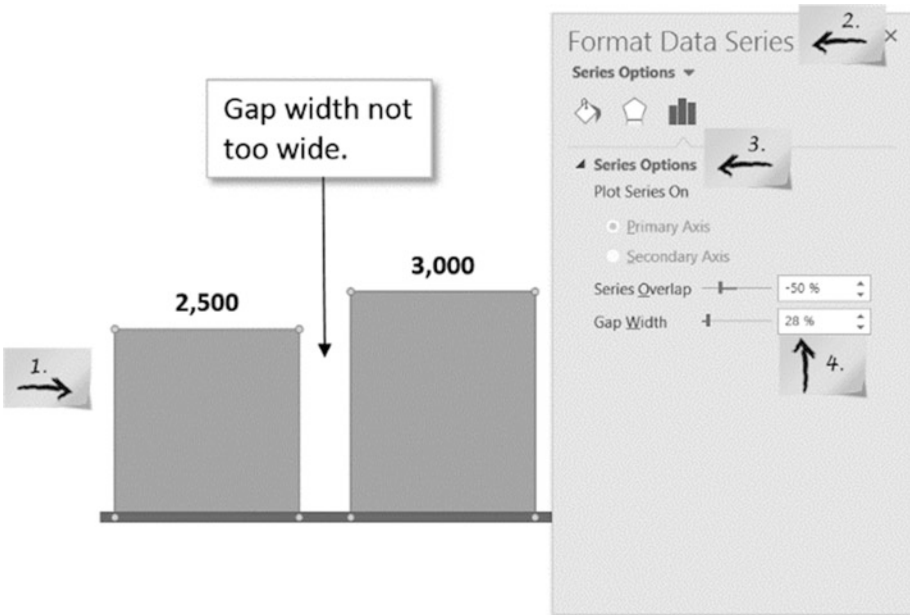

Fig. 6.13 Adjusting the distance between columns

In Fig. 6.13, a negative profit was recorded in year 2012. The corresponding column was highlighted in red to distinguish it from the positive numbers. For this purpose, use the function *Invert* (Fig. 6.14) in Excel:

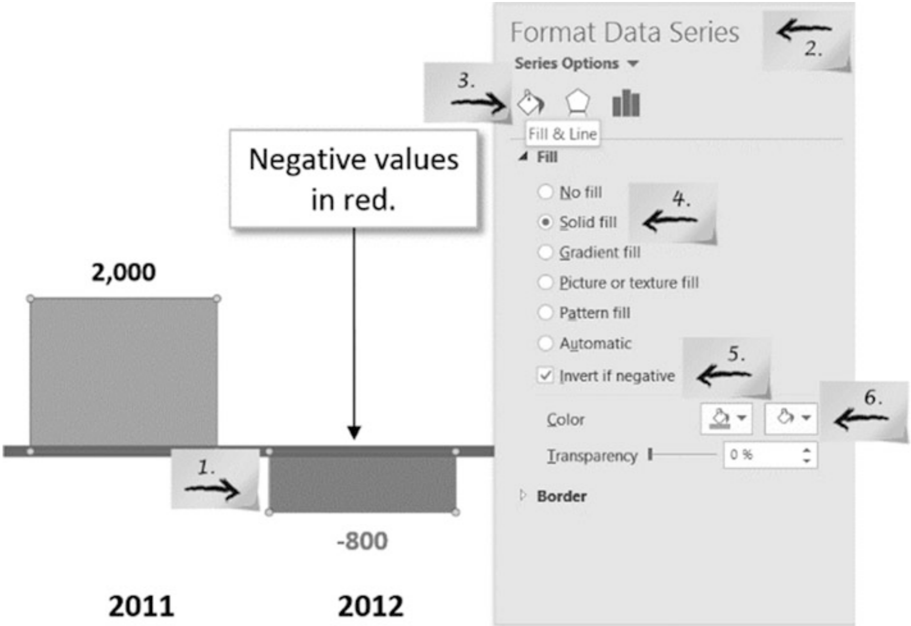

Fig. 6.14 Inverting negative numbers in red

1. Mark the *Data Series* in the chart with the right mouse button.
2. In the context menu, select *Format Data Series*.
3. Click on *Fill & Line*.
4. Activate option *Solid fill*.
5. Activate option *Invert if negative*.
6. Select an *Inverted Fill color* (e.g. red).

Horizontal waterfall chart
Waterfall charts are a version of column or bar charts. They are a powerful tool to show how a beginning value changes over time. Intermediate values, which lead to increases or declines are positioned differently and marked in color:

- An increase is shown above with a green column and
- A decline is shown below with a red column.

Creating horizontal waterfall charts in Excel: ➲ *Insert* ➲ *Charts* ➲ *Scatter* (Fig. 6.15).

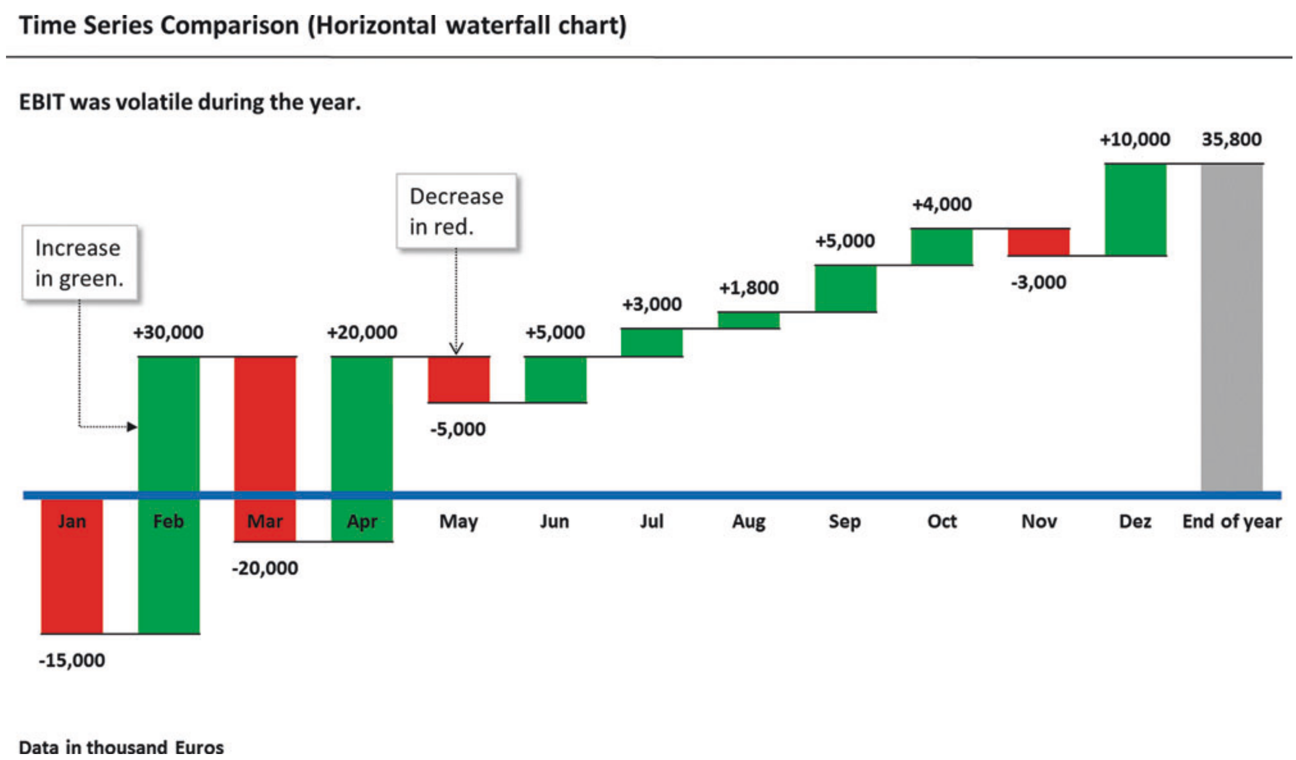

Fig. 6.15 Example of an accomplished horizontal waterfall chart (own presentation following Heimrath (2009))

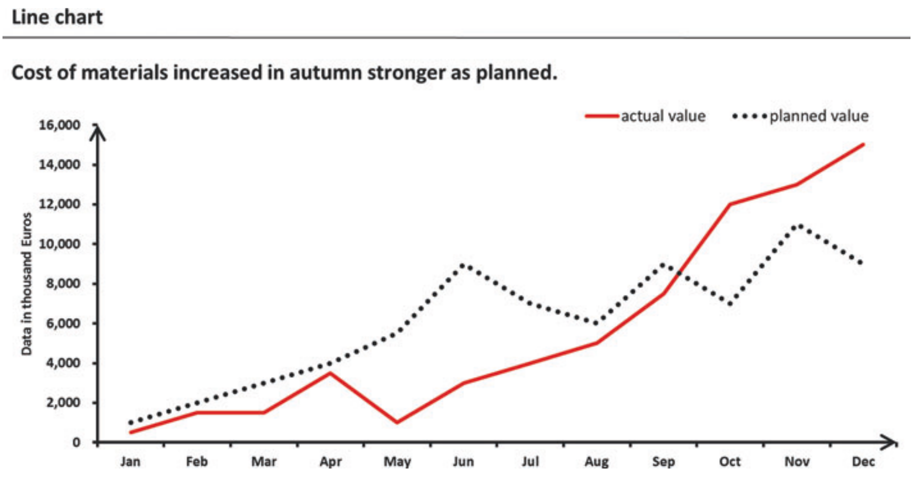

Fig. 6.16 Line chart (own presentation following Heimrath (2009))

Line chart

Line charts are used to display longer time periods (for example greater than one year). They have an advantage over column charts if more than twelve data points are compared, which are close together. With this type of chart, it is especially possible to illustrate trends (such as increase, decline or stagnate).

Creating line charts in Excel: *Insert* ➲ *Charts* ➲ *Line Chart* (Fig. 6.16).

Area chart

Area charts are suitable to graphically show the change of numerical values during a specific time period (especially for monthly comparisons). Suitable applications include the presentation of cash flows, material expenses and EBIT per month. The areas lead to a high visibility of the changes of the variables.

Creating area charts in Excel: *Insert* ➲ *Charts* ➲ *Area* ➲ *2-D Area* (Fig. 6.17).

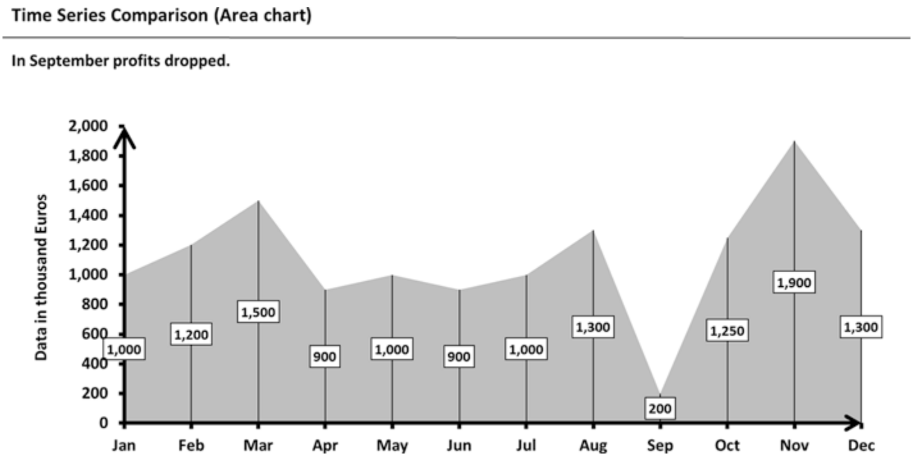

Fig. 6.17 Area chart (own presentation following Heimrath (2009))

3.4.2 Ranking Order Comparison: Which Aspect Is the Most Important, Best or Worst?

Individual aspects at a specific point in time are assessed and compared with a ranking order comparison.

Terms such as greater than, less than or equal indicate a ranking order comparison.

Applied Example

Typical ranking order comparisons

- The dividend is higher than the average of the EUROSTOXX 50.
- The volatility of the call option is lower in comparison to the peer group.
- The cost of materials ratio is the same in all business units.

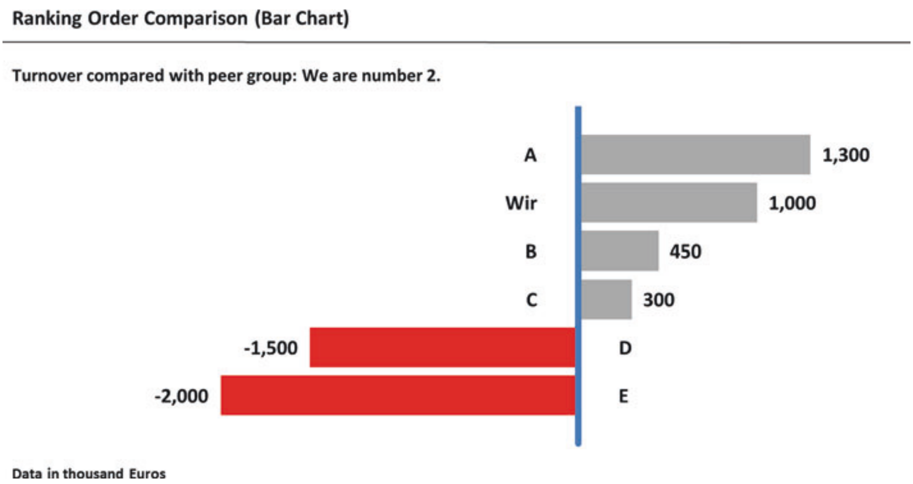

Fig. 6.18 Bar chart (own presentation following Heimrath (2009))

Bar charts are the standard for ranking order comparisons. Due to the numerous possible ways of presenting the data, a broad range of ranking order comparisons can be covered. Waterfall charts are also appropriate in this regard, even though they are used less frequently in applied work. They can be useful especially if the change in the overall value is also important in addition to the ranking.

Bar chart

The same design features are relevant (distance between bars, use of colors) for bar charts and column charts.

Creating bar charts in Excel: *Insert* ➲ *Charts* ➲ *Bar* ➲ *2D-Bar* ➲ *Grouped Bars* (Fig. 6.18).

Vertical waterfall chart

Vertical waterfall charts can be used to implement comparative assessments of various aspects (industries, companies, profit centers and so forth), which provide insights about the total result. Sort the subgroups in ascending or descending order by value. This achieves a separation of the positive from the negative values as well as a ranking.

Creating vertical waterfall charts in Excel: *Insert* ➲ *Charts* ➲ *Scatter* (Fig. 6.19).

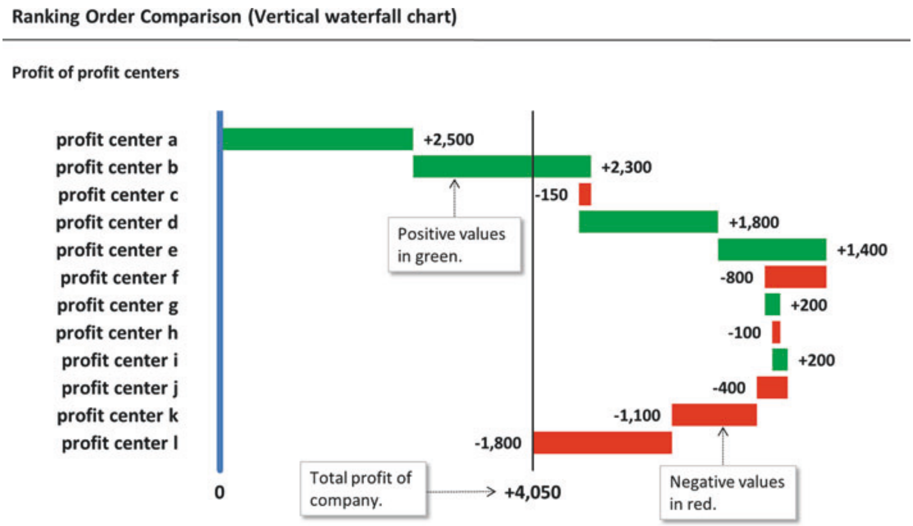

Fig. 6.19 Vertical waterfall chart (own presentation following Heimrath (2009))

3.4.3 Structural Comparison: How Large Is the Share of a Specific Aspect in the Total?

Structural comparisons show the importance of individual components for the total.

Words that are indicative of a structural comparison include share, percentage, X percent, are part of, one third, one half and so on.

Applied Example

Typical structural comparisons

- The equity ratio is 25%.
- One fourth of the portfolio is a long-term investment.
- 40% of all put options expire in 20 days.

Typical representations of structural comparisons are pie charts and stacked column and area charts.

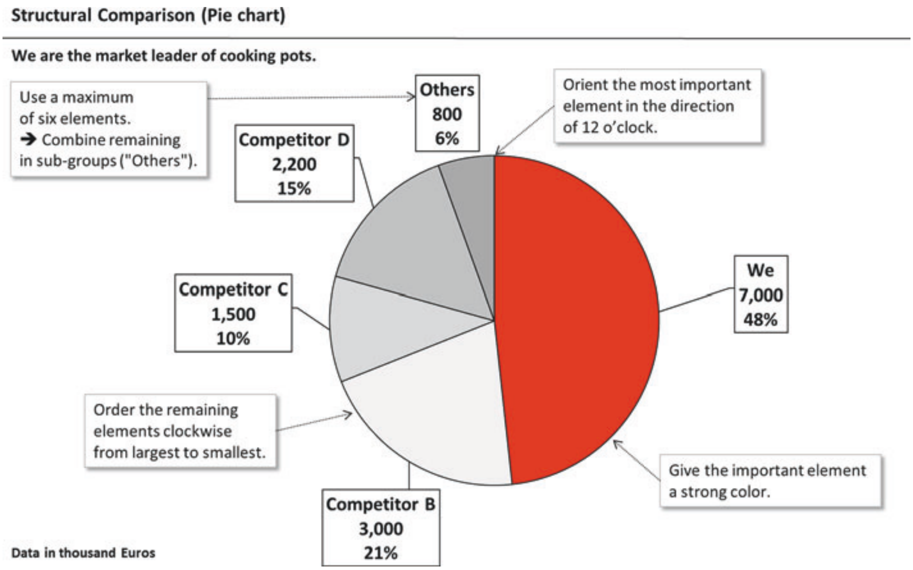

Fig. 6.20 Pie chart (own presentation following Heimrath (2009))

Pie chart

The layout of pie charts was already discussed in the general recommendations for charts. Additional aspects include:

- Use a maximum of six elements.
- Combine the remaining elements in sub-groups (such as "Others").
- Orient the most important element in the direction of 12 o'clock and give it a strong color.
- Order the remaining elements clockwise from largest to smallest.
- The descriptions are positioned inside the pie chart. Thus no key is needed.
- No Y-axis known from column and bar charts is needed for pie charts.

Creating pie charts in Excel: *Insert* ➲ *Charts* ➲ *Pie* ➲ *2-D Pie* (Fig. 6.20).

If the category "Others" is relevant for additional considerations, it can be explained further in a column chart (Fig. 6.21).

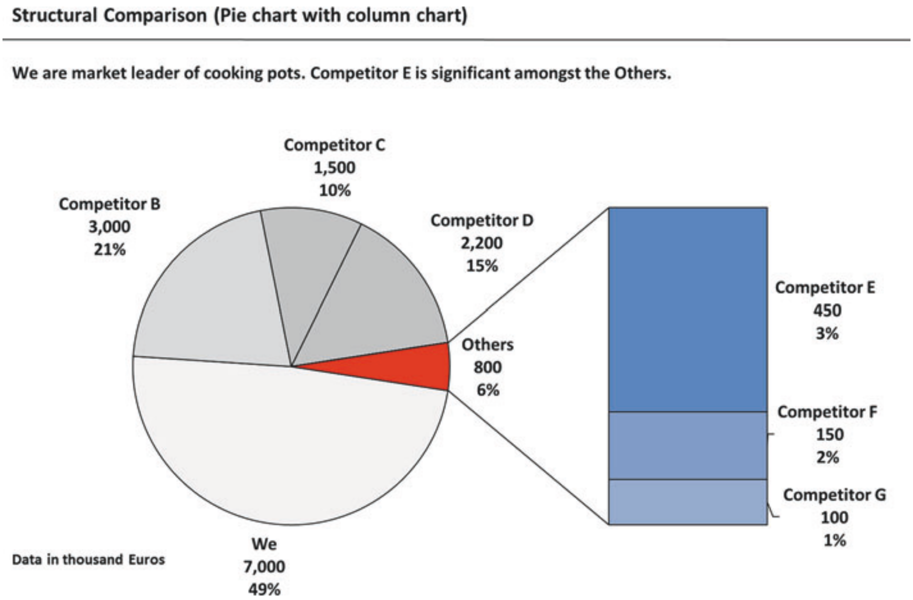

Fig. 6.21 Pie chart with column chart (own presentation following Heimrath (2009))

Stacked area chart

Stacked area and column charts are also suitable to visualize structures. They are preferred over pie charts in the following situations:

- Absolute and not relative (percentages) distributions of individual elements are considered.
- The structures of several elements are compared.
- Different points in time or time periods are relevant (such as monthly or quarterly comparisons).

Creating stacked area charts in Excel: *Insert* ➲ *Charts* ➲ *Stacked Area* (Fig. 6.22).

Stacked column chart

If the structure of more than five elements is to be compared in a chart, the stacked column chart is used instead of the stacked area chart.

Creating stacked column charts in Excel: *Insert* ➲ *Charts* ➲ *Columns* ➲ *2-D Columns* ➲ *Stacked Column* (Fig. 6.23).

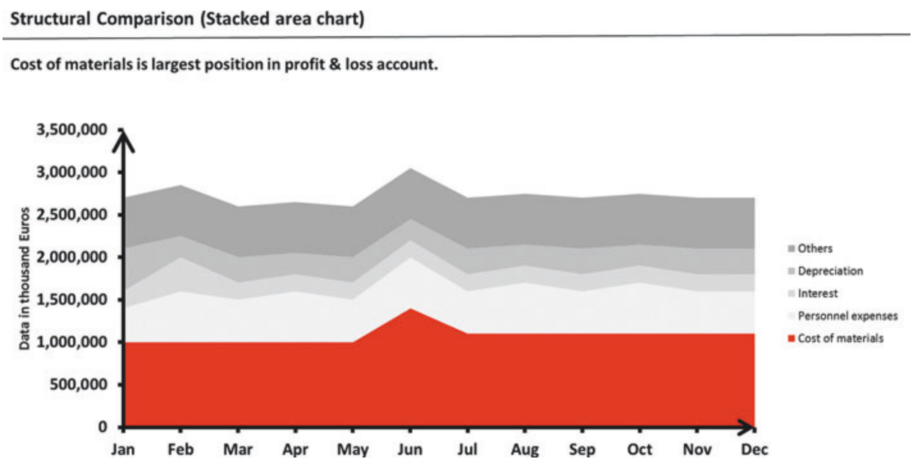

Fig. 6.22 Stacked area chart (own presentation following Heimrath (2009))

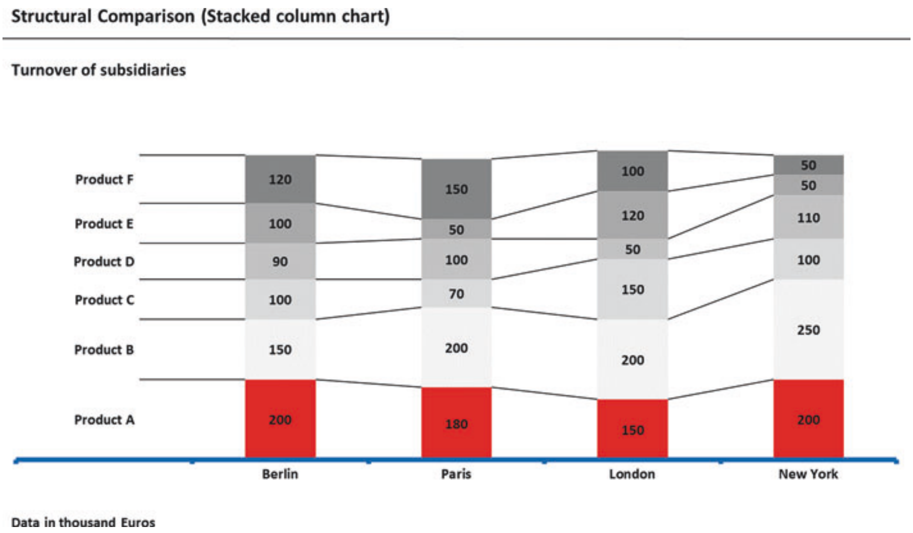

Fig. 6.23 Stacked column chart (own presentation following Heimrath (2009))

3.4.4 Frequency Comparison: What Is the Distribution Across Specific Classes or Intervals?

A frequency comparison shows how often a specific object appears in different consecutive categories.

The presentation of the different categories shows the distribution of the values and forecasts which can be derived based on that information. Additionally, it is possible to display strengths and weaknesses, for example relative to a peer group. Terms such as area x- y, concentration, frequency and distribution are indicative of frequency comparisons.

Applied Example

Typical frequency comparisons

- What is the typical margin range for most individual sales?
- Do dependencies on individual customers or suppliers exist?
- How frequently do customers order depending on the size of the corporation?
- How long does it take to pay bills?

In applied work, histogram, area charts and line charts are widely used or frequency comparisons. Histogram and area charts are used primarily for comparisons with only a few categories or intervals. In the case of larger categories or intervals, line charts are preferred.

Histogram
Creating histograms in Excel: *Insert* ➲ *Charts* ➲ *Columns* ➲ *2-D Columns* ➲ *Stacked Column* (Fig. 6.24).

Area chart
Creating area charts in Excel: *Insert* ➲ *Charts* ➲ *Area* ➲ *2-D Area* (Fig. 6.25).

Line chart
Creating a line chart in Excel: *Insert* ➲ *Charts* ➲ *Line* ➲ *2-D Line* ➲ *Line* (Fig. 6.26).

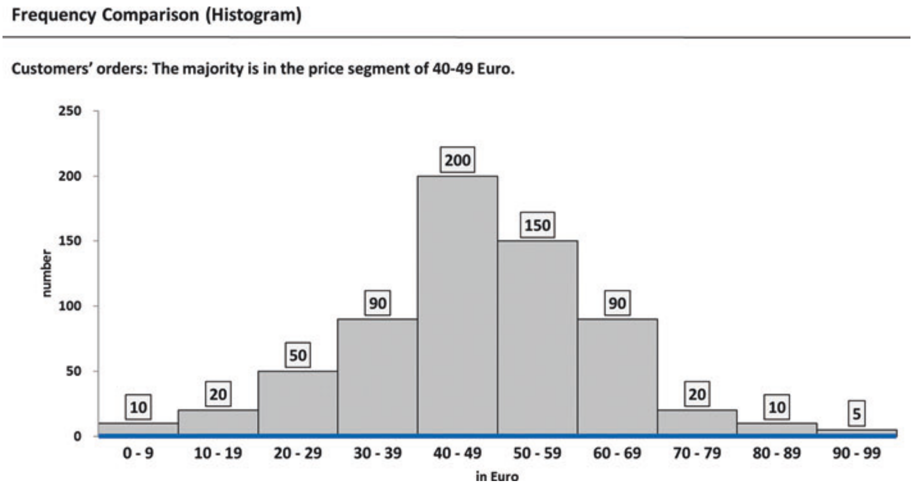

Fig. 6.24 Histogram (own presentation following Heimrath (2009))

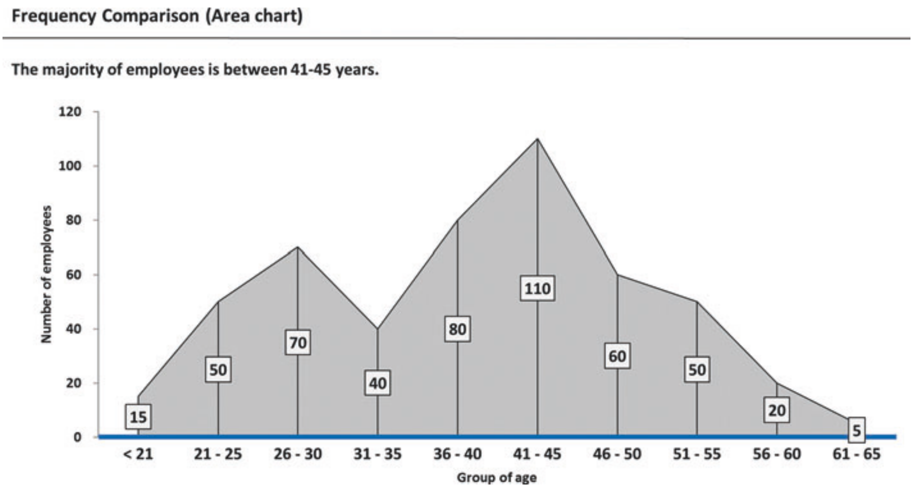

Fig. 6.25 Area chart (own presentation following Heimrath (2009))

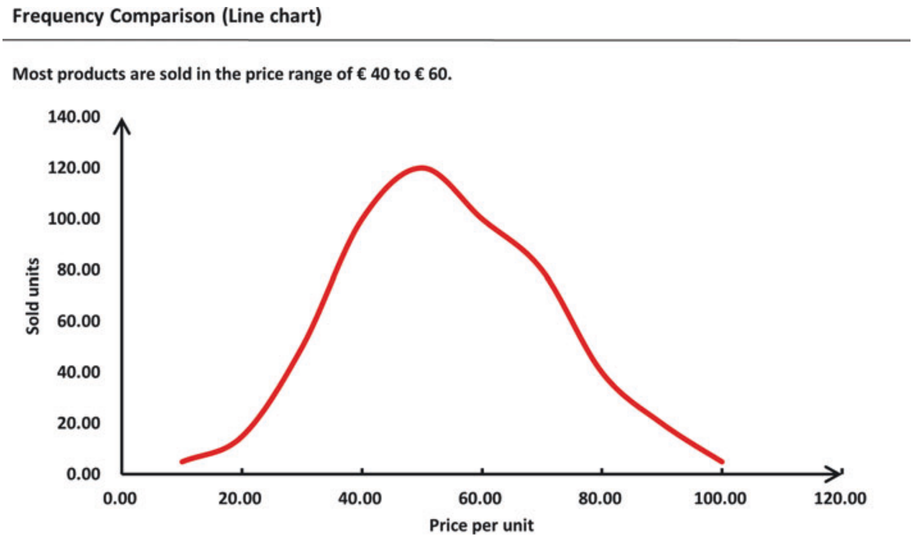

Fig. 6.26 Line chart (own presentation following Heimrath (2009))

3.4.5 Correlation Analysis: What Are the Links between Different Factors?

> Correlation analysis provides information about linkages between variables and shows whether there are patterns among these linkages and dependencies exist.

For statements such as relative . . . , does (not) increase with . . . , does (not) decline with. . . , does (not) change in line with . . . , a correlation analysis will prove valuable.

A distinction is made between positive and negative correlation:

- Positive correlation: the relationship between two variables is characterized by statements such as "one variable goes up and the other also goes up." For example: "An increase in sales also leads to an increase in revenue."
- Negative correlation: Here the relationship is reversed. "As one variable goes up, the other variable goes down." For example: "The higher the price, the lower the units sold."

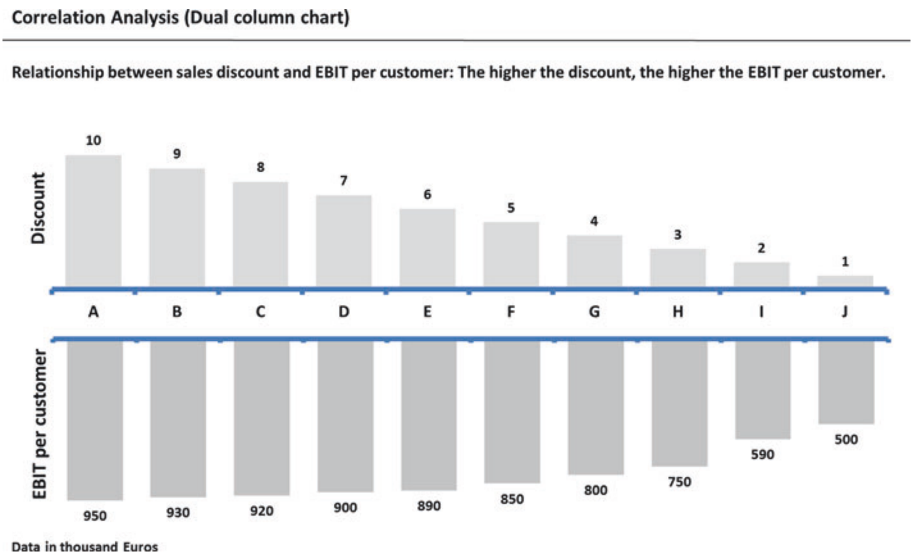

Fig. 6.27 Dual column chart (own presentation following Heimrath (2009))

Applied Example

Typical correlation analysis

- Relationship between the overall economic development and the annual result of a corporation.
- Relationship between EBIT and cost of materials and personnel cost.
- Relationship between securities prices and an index.

Most frequently used for correlation analysis in financial modeling are scatter, dual column chart and dual bar chart. Dual column charts and dual bar charts are used in cases where – in contrast to the scatter – smaller amounts of data are considered. It opens up the possibility to label the data that is being compared and thus to send a clearer message.

Dual column chart

Creating a dual column chart in Excel: *Insert* ➲ *Charts* ➲ *Column* ➲ *2-D Column* (Fig. 6.27).

Dual bar chart

Creating a dual bar chart in Excel: *Insert* ➲ *Charts* ➲ *Bar* ➲ *2-D Bar* (Fig. 6.28).

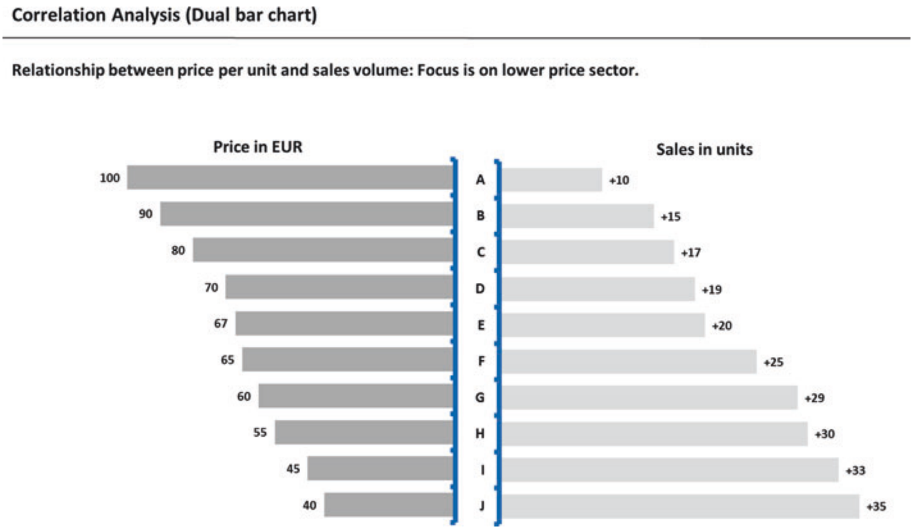

Fig. 6.28 Dual bar chart (own presentation following Heimrath (2009))

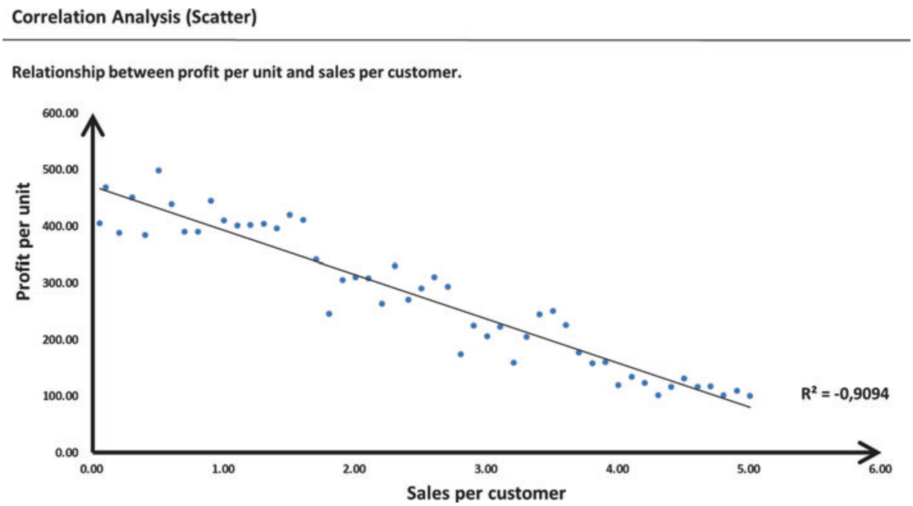

Fig. 6.29 Analysis of a client portfolio with a scatter plot (own presentation following Heimrath (2009))

Scatter

A scatter allows the detection of possible dependencies of a company, for example from customers, products or markets.

Due to the fact that scatters can lack clarity, it is particularly important to thoroughly document the way the chart can be interpreted.

Creating Scatters in Excel: *Insert ➲ Charts ➲ Scatter ➲ Scatter with only Markers* (Fig. 6.29).

Analysis of a client portfolio with a scatter plot (own presentation following Heimrath (2009))

Figure 6.29 illustrates a case of a high correlation between client sales (individual sales of the various clients) and the profitability of the client relationship (contribution margin).

This is the case of a negative correlation. This means,

- the higher the sales per customer,
- the lower is the contribution margin.

This is a typical situation where a major buyer is able to negotiate huge discounts due to his buying power. The opposite constellation is also possible, for example if customers only buy limited quantities from small production series which also leads to a low contribution margin.

Concluding remarks

The comprehensive functionality of Excel makes it possible to also master demanding financial modeling tasks. The steps presented in this workshop lay the foundations for comprehensive analysis, comparative valuation and decision making. If a structured approach is followed, meaningful results can be generated even if time and personnel resources are restricted.

Excel is much more than a simple spreadsheet. The creation of professionally structured financial models absolutely requires familiarity with the most important Excel functions and tools.

Looking ahead

The problem solving skills and the Excel knowledge which were obtained in the workshop Excel are the foundations for the following workshop VBA and the topics in finance. In the chapters on corporate finance, derivatives and portfolio management, the topics discussed here will be applied in Excel using numerous examples from daily business. This gives you a chance to solidify your knowledge about templates, formats, functions and tools (such as names, scenarios, Solver, Goal Seek and so forth). As financial modeler you will be in a position to provide efficient solutions in Excel for tasks in finance.

4 Summary

The financial modeler acquired the following skills in this workshop:
Financial modeling in Excel:

- Efficient modeling requires a structured and thoughtful approach and thorough preparation.
- There are only very few cases where the result for a complex topic can be derived directly.
- In applied work, the approach of developing a series of increasingly complex and improved prototypes has shown its effectiveness (iterative approach).

Presenting the results:

- Finally, conclusions and recommendations are derived from the numerical results.
- An effective presentation is characterized by the ability to translate the complexity of a problem into a form that is adequate for the target audience.
- The choice of suitable types of charts is decisive for the quality of a presentation.

Further Reading

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7
VBA Workshop

1 Executive Summary

In this chapter the financial modeler will study the development of Excel software solutions. He will understand how these can be created with the macro recorder or directly via programming with VBA in the development environment. Almost all Excel operations can be automated. The financial modeler writes commands that are executed by Excel. The use of VBA offers a number of advantages to the financial modeler:

- **Consistency:** Excel will always solve the tasks in identical fashion.
- **Speed:** The task is completed in Excel much faster compared to any manual solution provided by the financial modeler.
- **Quality:** Under the assumption that the financial modeler has mastered VBA and can program error-free macros, Excel will execute the task without any flaw.
- **Transfer:** If the financial modeler has programmed everything correctly, clients or colleagues who have no Excel skills can complete the task correctly and reliably.
- **Multitasking:** The financial modeler is enabled to automate complex and time consuming tasks in Excel. If this is a lengthy process, he can open up a different work file and work on a different project in the meantime.

J. Häcker and D. Ernst, *Financial Modeling*,
Global Financial Markets, DOI 10.1057/978-1-137-42658-1_7

- **No additional cost:** In contrast to numerous different programming languages, the use of VBA involves no additional costs, since VBA is already included in the Microsoft Office packages.
- **Limited degree of complexity:** VBA was derived from the BASIC dialect Visual Basic (VB) developed by Microsoft. The target audience of BASIC at the time were beginning programmers. In that sense, VBA is a language that is relatively easy to master.
- **Huge degree of freedom:** The VBA based programs can be activated as the need arises. Since the programs are contained in Add-Ins, a toolkit of individual solutions can be assembled without any change to the standard applications in Excel.

2 Introduction, Structure and Learning Outcomes

Structure

The workshop provides an introduction to programming of macros with the programming language of Excel (Visual Basic for Applications) and answers the following questions:

- What is Visual Basic for Applications (VBA) and what are its advantages?
- How can individually programmed Excel applications be used?
- How can software solutions be programmed efficiently?
- How can programs be executed?
- What are the most important language elements of VBA?
- How can input and output of data be structured comfortably?
- How can the creation of charts be expedited with VBA?
- How can helpful VBA tools facilitate working with Excel?

Learning Outcomes

The workshop presents the most important programming terms with reference to applied examples. The financial modeler

- Is able to develop Excel software solutions with the various tools of VBA,
- knows how to establish the appropriate settings for programming,

- is familiar with the development environment,
- acquires the necessary knowledge concerning variables and data types,
- is familiar with identifying, avoiding and correcting mistakes,
- can use the most important language elements of VBA,
- learns how to program comfortable input and output fields with user-defined dialogue boxes,
- is able to control programs with the help of decisions, operators and loops,
- can work with cells and ranges,
- has the basic skills needed to produce diagrams in VBA,
- is able to optimize proprietary financial models with the help of suitable Excel tools.

Definition

The term "Visual Basic for Applications" refers to a programing language developed by Microsoft and is abbreviated as VBA. VBA is a programing language but is also occasionally called a macro language. Something that is written in VBA and executed in Excel is frequently called a macro by the Excel help function. In addition to Excel, VBA is also available in additional Microsoft Office programs (such as Word, Access, PowerPoint und Outlook).

VBA is erroneously confused with VB (Visual Basic). While VBA and VB share many similarities, VBA replaced the different and incompatible languages of the Microsoft Office programs in the mid-nineties.

3 Why Study Programming with VBA?

Why study programming with VBA? This question leads to two additional considerations. Why is it useful to master any programming language and why in particular should the choice be Visual Basic for Applications (VBA), given the wide availability of numerous other programming languages?

The answer to the first question is straightforward: complex tasks can be solved efficiently with these programs. A programming language can help for example to set up valuation models that are impossible or very hard to establish with spreadsheets alone.

But why select VBA in particular? With VBA it is possible to enhance the available standard functions to meet personal requirements in all Office Applications (Excel, Word, Access, and so forth). The financial modeler can thus combine the benefits of a programming language with a standard application such as Excel.

The advantages of an individual software solution for Office with the help of VBA are as follows:

- VBA generates significant time savings, since monotonous and repetitive processes as well as manual activities can be automated and accelerated.
- Complex processes can be run at the push of a button. Otherwise their implementation would be very difficult or even impossible.
- VBA helps to eliminate typical sources of error.
- VBA allows the unified presentation of results.
- Complex data sources can be utilized efficiently even by inexperienced users.
- It is not necessary to install an additional driver or to purchase a new programming package. Thus the costs are relatively minor, since all needed components are already integrated into the Office applications.
- It is not necessary to get familiar with a complex solution such as C++. The familiar user surface of the Office application with its intuitive elements is still available. It is possible to comfortably and easily access and use Excel elements such as the construction of tables and diagrams while programming in VBA.
- The software solutions which you develop can be used in your company by all employees without any licensing restrictions. Since you have full access to the source code, all types of adjustments can be implemented by yourself or by others.
- C++ is based on the programming language C and was developed as a multifunctional language that supports several programming paradigms such as object-oriented, generic and procedural programming.

Over the years, VBA has admittedly developed into a rich programming language with a comprehensive volume of commands and

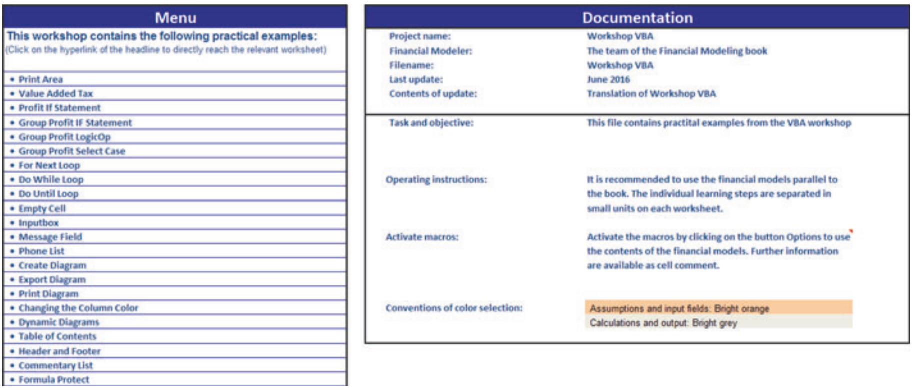

Fig. 7.1 Menu and documentation of the VBA Workshop (Excel File Workshop VBA, Sheet Menu_Doc)

possibilities. Take the time to master VBA. It is a rewarding investment which will amortize quickly due to the huge efficiency gains. The following workshop will support you Fig. 7.1.

4 Generating Excel Software Solutions

Excel software solutions can be generated in two different ways:

1. with the macro recorder and
2. directly by programming with VBA in the development environment.

> Excel software solutions (also called macros, programs, subroutines) are groups of commands and routines based on VBA.

The macro recorder is suitable for the following tasks:

- simple and repetitive routine tasks such as printing lists, turning grid lines on and off or inserting text fields (such as name of the modeler or date).
- Simple sequences of commands without loops that only use simple branches.

- The macro recorder is not as suitable in the following situations, where programming in VBA is preferable:
- If challenging sequences of commands with complex branches or loops are needed.
- In case error handling is needed during a programming run.
- If values only become available while the program is executed or need to be calculated.
- If the structure of tables or queries needs to be modified.

For the VBA beginner, the macro recorder is very helpful. However, only a small fraction of the large array of options of VBA programming can be utilized. For more complex tasks, knowledge of VBA is required.

4.1 Preparing Excel for Macros

Before working with the macro recorder or in the VBA environment, two settings must be established in Excel:

1. Activating the developer tools.
2. Appropriately setting the virus protection.

4.1.1 Activating the Developer Tools

> The developer tools provide support when you are writing macros, execute macros that have been recorded, or write your own VBA programs directly in the development environment.

They are not active in the standard setting and must be activated first Fig. 7.2.

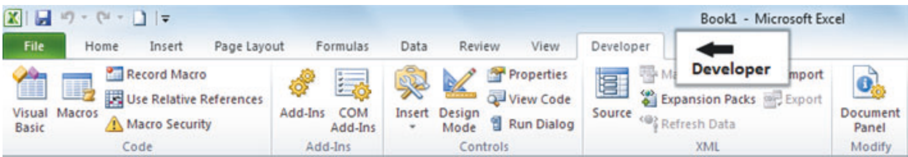

Fig. 7.2 The developer tools

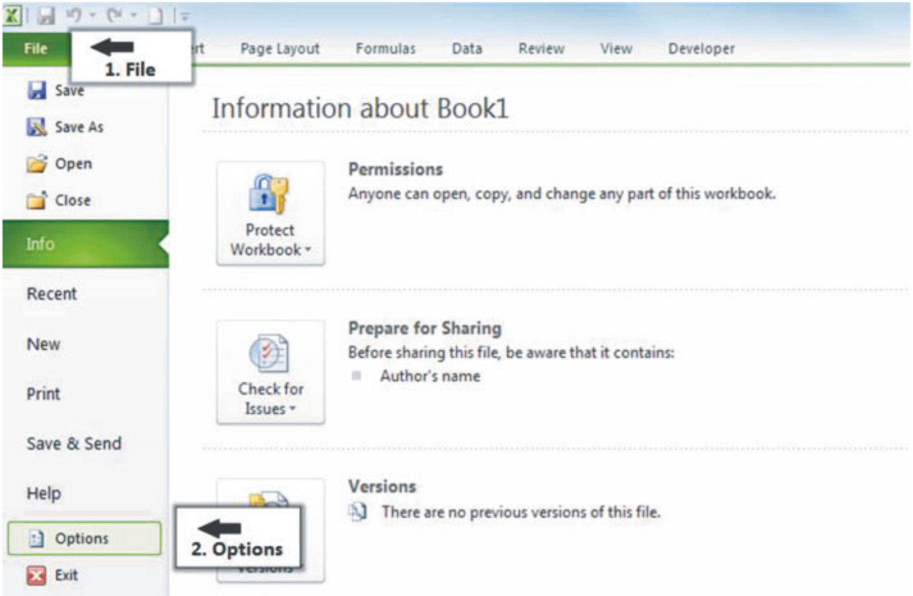

Fig. 7.3 Office button and Excel options

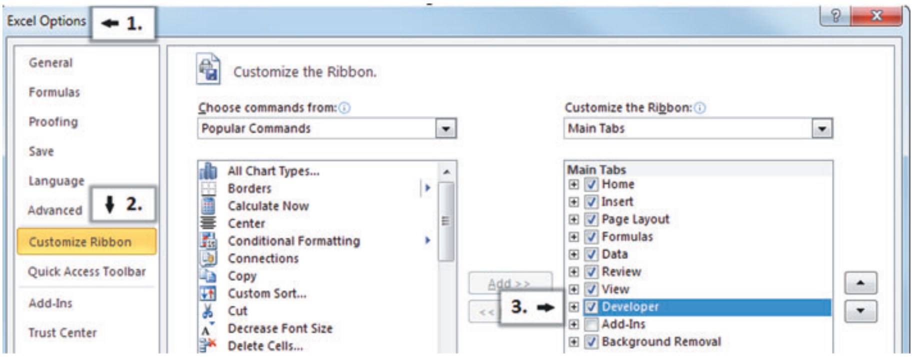

Fig. 7.4 Activating the developer tab

In order to use the developer tools, you need to take the following steps:

3. Click on the *File button* (Fig. 7.3).
4. Choose *Excel Options*.
5. Go the menu *Popular*.
6. Select *Top options for working with Excel*.
7. Activate the control box for *Show Developer tab in the Ribbon* Fig. 7.4.

4.1.2 Appropriate Setting for the Virus Protection — Activating Macros

Security is an important topic when working with macros and VBA. In the initial settings of Office 2007, the VBA programs are deactivated. To enable macros, the security settings must be changed as follows:

8. Follow the same path as before when the developer tools were activated (*File button* ➲ *Excel Options*).
9. Choose the feature *Trust Center* (Fig. 7.5).
10. Go to the field *Trust Center Settings*.
11. Click on *Settings for Macros* (Fig. 7.6).
12. You will be given four choices. Activate *Disable all macros with notification*. This setting is approximately equivalent to the security setting *Medium*, which is familiar from previous versions of Office.

If you now open a file that contains macros, Excel will display a warning message below the ribbon. With the button *Options* followed by *Activate this contents* you allow use of the macro Fig. 7.7.

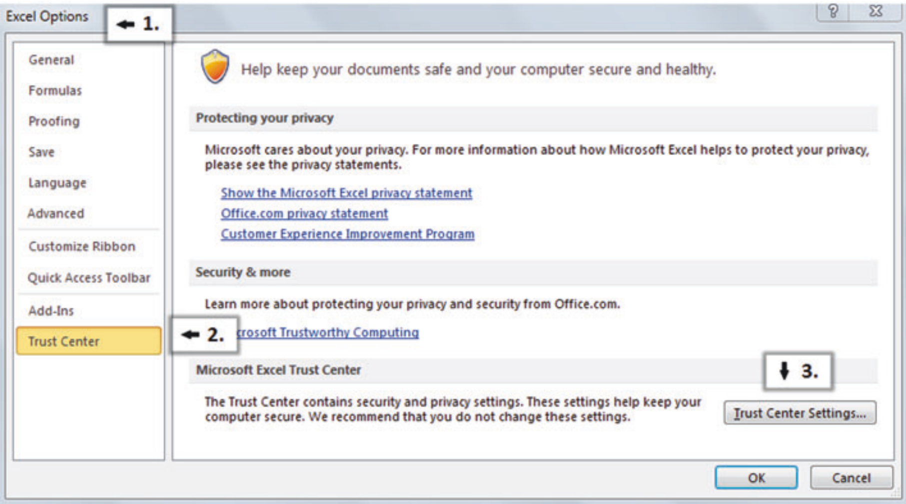

Fig. 7.5 Accessing the security settings

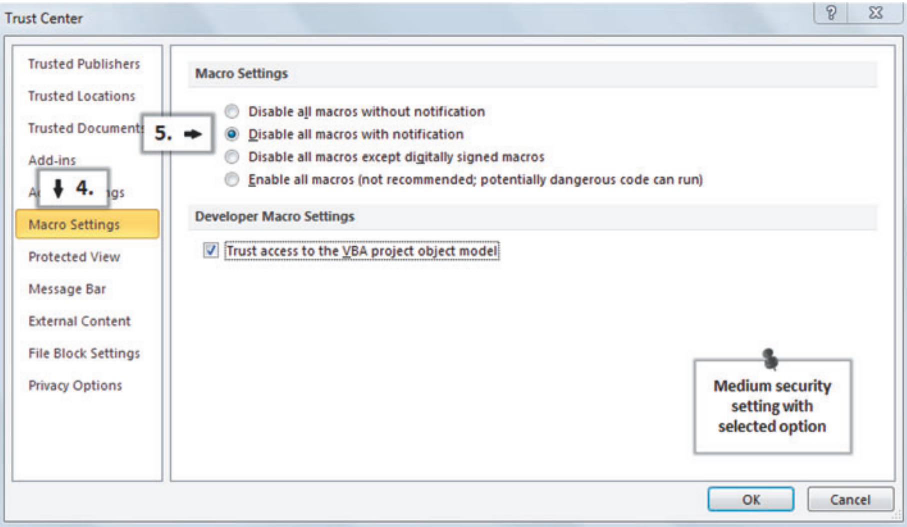

Fig. 7.6 Selecting the appropriate setting for macros

Fig. 7.7 Allowing macros

4.2 Possibility 1: Creating Applications with the Macro Recorder

The macro recorder offers a simple method to establish routines.

> The macro recorder records all activities of the user via mouse or keyboard. This does, however, also include incorrect commands which are very hard to correct.

It records all activities of the user via mouse or keyboard. This does, however, also include incorrect commands which are very hard to correct.

4.2.1 Recording a Macro

In order to record a macro, *View* ➲ *Macros* must be selected. In the dialogue box *Record Macro* a name as well as a combination of key

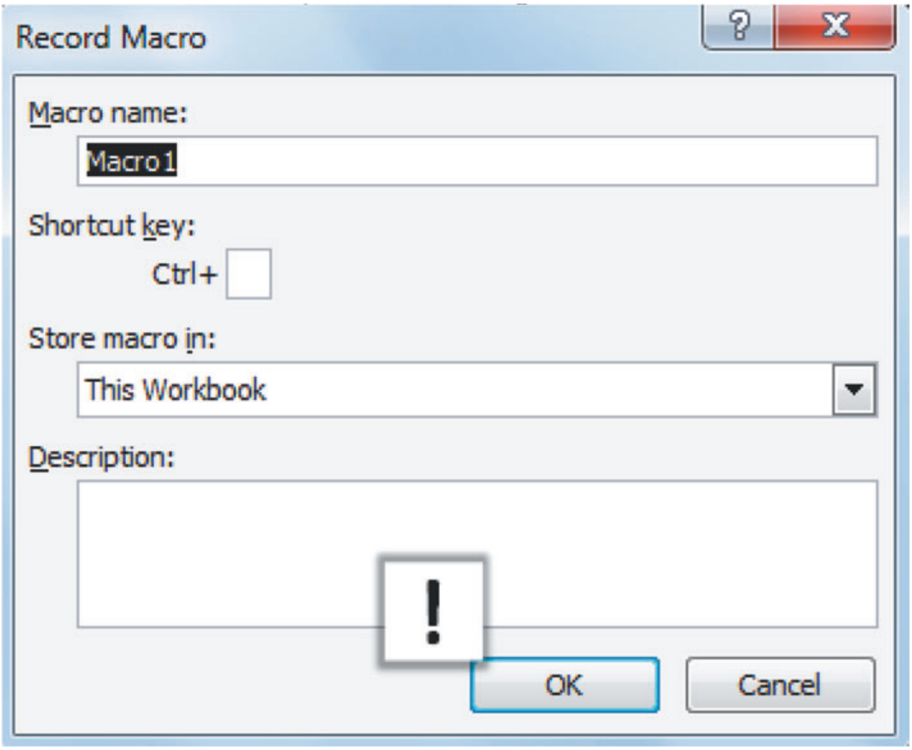

Fig. 7.8 Recording a macro

strokes can be assigned to the macro. Using a combination of key strokes is optional and is needed only in rare cases Fig. 7.8.

The recording is started by pressing the *OK* button. After that, all activities entered via mouse or keyboard will be stored in the macro. In addition, the dialogue box changes from *Record macro* to *End recording*.

As an example, a print range can be established as displayed in Fig. 7.9. Please follow these steps while recording with the *Macro recorder*:

13. Mark the print range `A1:B7`.
14. Set the print range with *Page layout* ➲ *Print range* ➲ *Set print range*.
15. End the recording by using the dialogue box *End recording*.

4.2.2 Viewing the Programming Code of a Macro

In order to view the result of the recording, go to *View* ➲ *Macros* ➲ *Show macros*, select the macro that was just recorded from the list and click on the button *Edit* Fig. 7.9.

During the recording, every single step of the user was captured in chronological order as source code with VBA commands.

Listing 1

Results of the recording with the *macro recorder*

```
Sub Print_Area()
    Range("D6").Select
    Selection.ClearContents
    Range("D12").Select
    Application.Left = 548.5
    Application.Top = 142
    Range("A1:B7").Select 'Selected Print Area
    ActiveSheet.PageSetup.PrintArea = "$A$1:$B$7"
End Sub
```

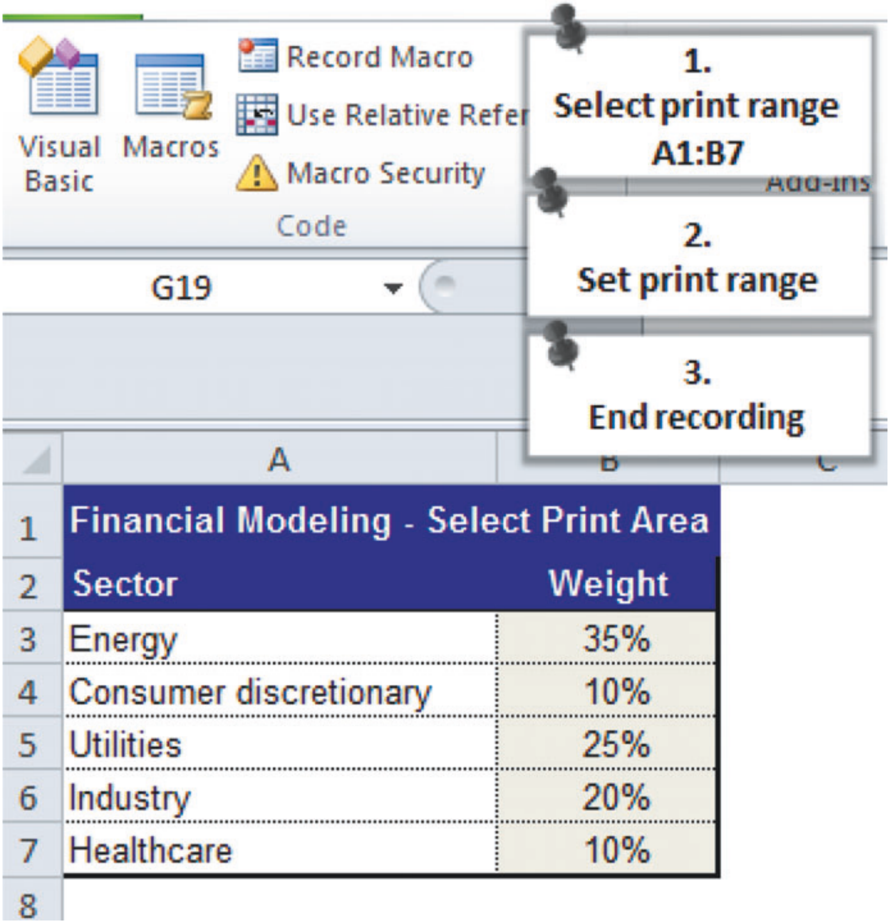

Fig. 7.9 Selecting the print range during the recording

A look at the macro already reveals a few characteristics of VBA:

- The source code is in the English language.
- Macros start with the command *Sub* and end with *End Sub*.
- Following *Sub* is the name of the macro, which can be chosen freely. However, no spaces or special characters can be used. Recommended are names that clearly show the contents and tasks of the macro. Thus the name chosen in the above example is "Print_Range."
- The single quotation mark (') is used for rows that contain comments. Content following the single quotation mark is not executed.

Usually comments contain the name of the macro, the date it was programmed, the macro recorder and any specific features of the program.

The programs compiled with the help of the macro recorder reveal important information concerning the syntax of individual commands. Experience shows that not all commands will be used by the macro recorder and superfluous commands will be recorded. For that reason, the use of the macro recorder is only a first step, since corrections and additions are regularly required. The above example could be improved with regard to the following issues:

- Add an additional comment that describes the macro.
- Delete superfluous programming code (errors made by the user as in the above example).

The corrected macro is now ready for use.

4.2.3 Executing a Macro

There are two possibilities for executing a macro:

1. In the code window, point with the cursor on the first line of the macro and hit the *F5* key.
2. If you have already exited the development environment and are in a spreadsheet, go to *View* ➲ *Show macro*. Select the needed macro and run it using the command *Execute*.

Practical Tip

Testing macros in a new spreadsheet
Please make sure to select the correct cell and spreadsheet. In order to avoid the loss of data or incorrect settings, the user must be aware of the fact that the macro will overwrite all cells which are in the relevant section and change their settings. For that reason it is recommended that the macro is executed in a new spreadsheet Fig. 7.10.

When executing the macro *Set_Print_Area.Print_Area* the previously recorded print range is established.

Use of the *macro recorder* has the advantage that frequently used Excel operations can easily be converted into VBA code, which can

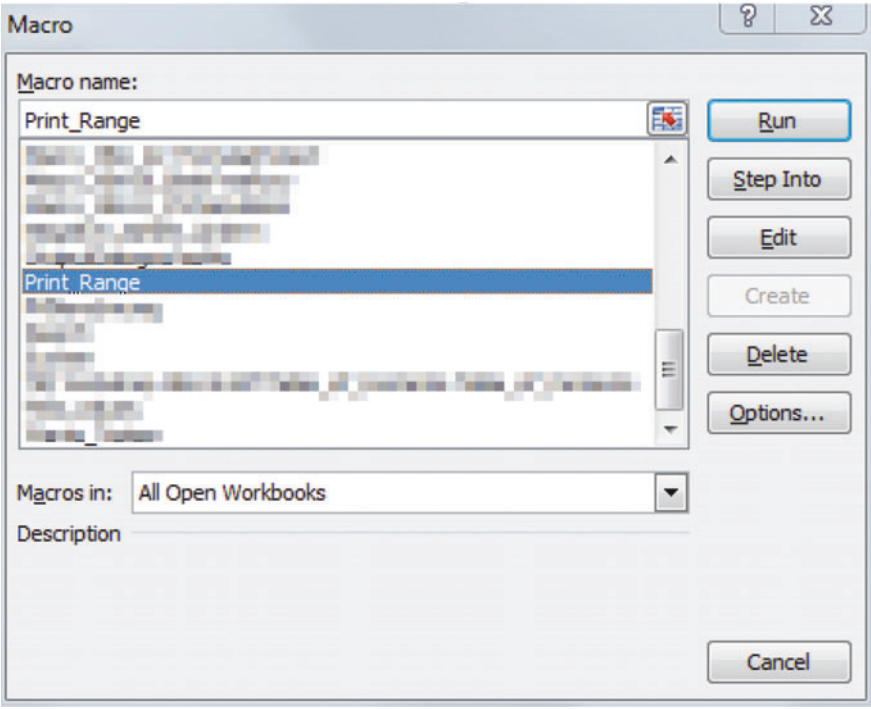

Fig. 7.10 Activating a macro

now be reused as often as desired. However, the *macro recorder* should only be utilized if knowledge of the programing language VBA is limited, since the recorded code

- lacks structure,
- contains unnecessary command lines and
- cannot implement two of the most important elements of programming (loops and branches).

Thus direct programming with the VBA editor is significantly more appropriate.

4.3 Possibility 2: Programming with VBA

Compared to the macro recorder, programming a macro with the VBA editor is the more challenging task. An advantage is the elegance of the applications created.

4.3.1 The Development Environment: Comfortable Creation, Management and Testing of Programs

> The development environment is a surface integrated into Excel, which supports the user in the creation of VBA-based programs.

It does not open automatically and can be accessed in Excel with the key combination *Alt + F11*.

The development environment consists of four windows:

- Project explorer,
- VBA editor,
- Properties window,
- Immediate window.

Additional windows, for example the local window, can be opened via the menu *View* *Fig. 7.11*.

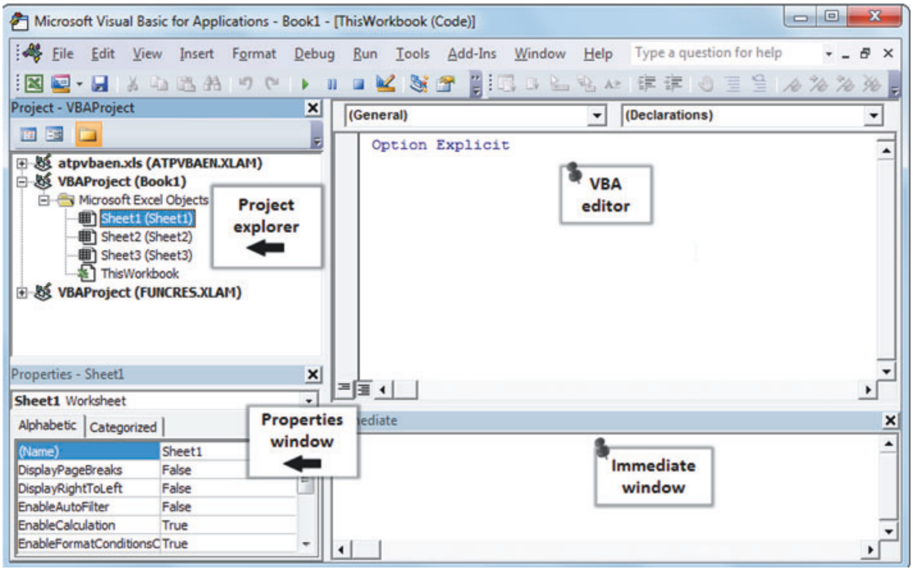

Fig. 7.11 The development environment

The VBA Editor: Programming Environment

The central window of the development environment is the VBA editor (also called code window). It is used for displaying, compiling and editing the programming code and is accessed with the *F7* key.

Project Explorer: The Navigator

The project explorer is located to the left of the development environment. It is responsible for navigating between the individual VBA elements and contains among others the currently opened workbooks, which are shown in a hierarchical list.

Workbooks constitute the top level. Each workbook is considered as an independent project in the VBA development environment. Next in the hierarchy are tables and modules Fig. 7.12.

Modules

The project explorer window is used mainly to create modules. A module is a type of folder for the programming code. For complex programs it is advisable to use several modules, since they give structure to the programming code: They combine programming commands and sequences which belong together. A module is created by right-clicking the mouse in the project explorer ➲ *Insert* ➲ *Create module*.

> A module is a listing of VBA declarations and procedures, which are saved jointly as a unit.

Procedures

Following is the level of procedures. Procedures are the actual programs. Basically two types of procedures can be distinguished:

- Sub procedures and
- Functional procedures (also called functions).

Functions differ from sub procedures in their ability to return values. In Excel spreadsheets you almost certainly already encountered typical Excel functions (*Sum*, *Average*, *Date* and so forth). Functional procedures are functions that have been created by the user.

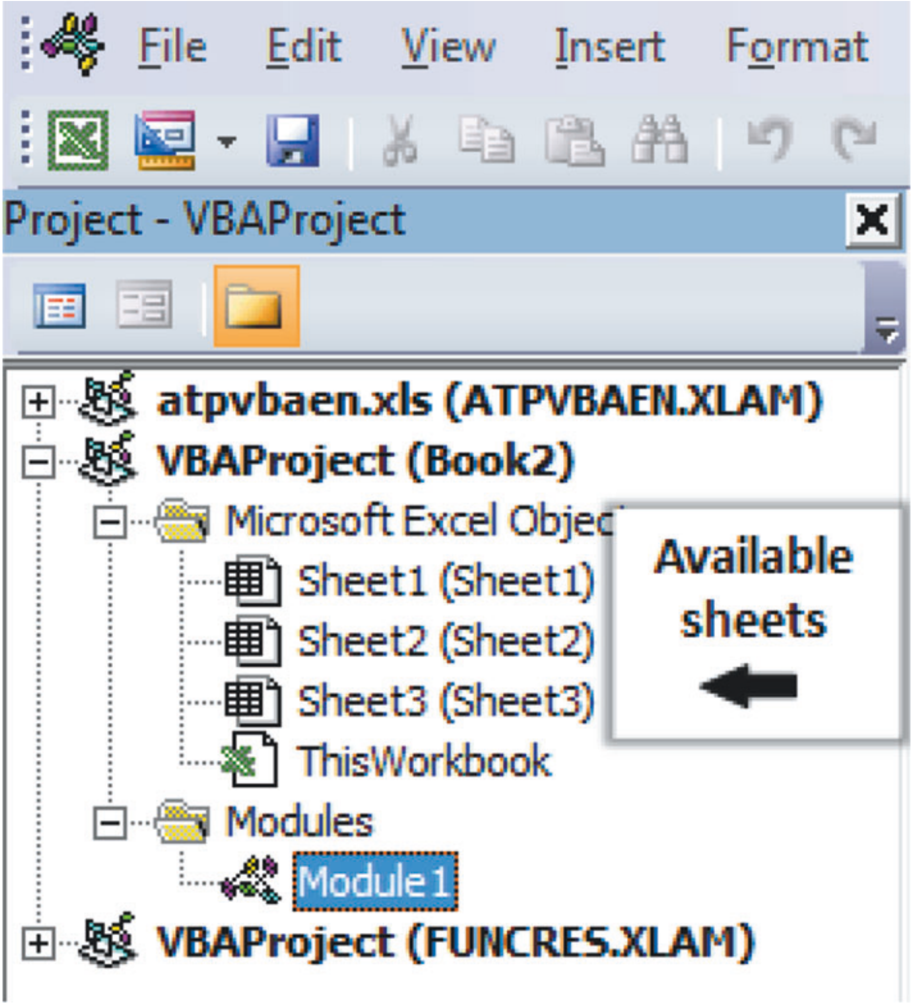

Fig. 7.12 The project explorer

Both types of procedures are structured identically: They start with the procedure head, which contains the name and the list of parameters and the procedure body, which contains the commands that start and end the procedure (see Fig. 7.13).

Element	Sub-Prozedur	Funktion
Procedure head	Sub (Name of the procedure)	`Function NameExa-mpleFunction() as String`
List of parameters	...	`NameExampleFunction = "Test"`
Procedure body	End Sub	`End Function`

Fig. 7.13 The typical structure of a procedure

Digression: Sub Procedures and Functional Procedures in Applied Work

Example of a sub procedure

Generating a sub procedure:

18. Right-click with the mouse in the *Project Explorer*. A context menu appears from which you choose *Insert* ➲ *Module*.
19. Enter the program from Listing 2 into the *VBA Editor*.
20. If you put the cursor on the first line of the program and press the *F5* key, you will receive the message “Hello World” Fig. 7.14.

Listing 2

Programming output

```
Sub MyFirstSubProcedure ()
    MsgBox "Hello World"
End Sub
```

The following example, which calculates the value added tax, exemplifies the structure and use of a *functional procedure*.

Listing 3
Module Value_Added_Tax

Fig. 7.14 The result of my first own sub procedure

Function which calculates the value added tax

```
Public Function ValueAddedTax Value)
     ValueAddedTax = Value * 1.19
End Function
```

In Listing 3, *ValueAdded Tax* is the name of the function, which is also used to save the result of the calculation. The net value, which is needed in the calculation, is declared in brackets after the function name (*Amount*). The parameter list consists of the calculation `ValueAddedTax = Amount * 1.19`. The command *End Function* ends the function *ValueAddedTax*. When running *functional procedures,* Excel will always ask in a separate window for one or several cells which contain the input values. All this must be in place for the program to perform the required calculation.

Applied Example

Running a function that was compiled by the user
Initially enter the three lines of programming code of Listing 3 in the VBA Editor. Go to the worksheet Value_Added_Tax (Excel File Workshop VBA) and add in cell `A6` a net value (such as 200). Mark the cell `B6`, in which the user-defined function *ValueAddedTax* will be performed.

A function which was created in VBA is accessed in the same way as a standard function in Excel (also see Workshop Excel in the Section Use of Formulas):

1. Go to the menu *Formulas* (see Fig. 7.15).
2. Choose *Insert Function*.
3. In the field *Select a category* pick *User Defined*.
4. Choose the previously compiled function *ValueAddedTax*.

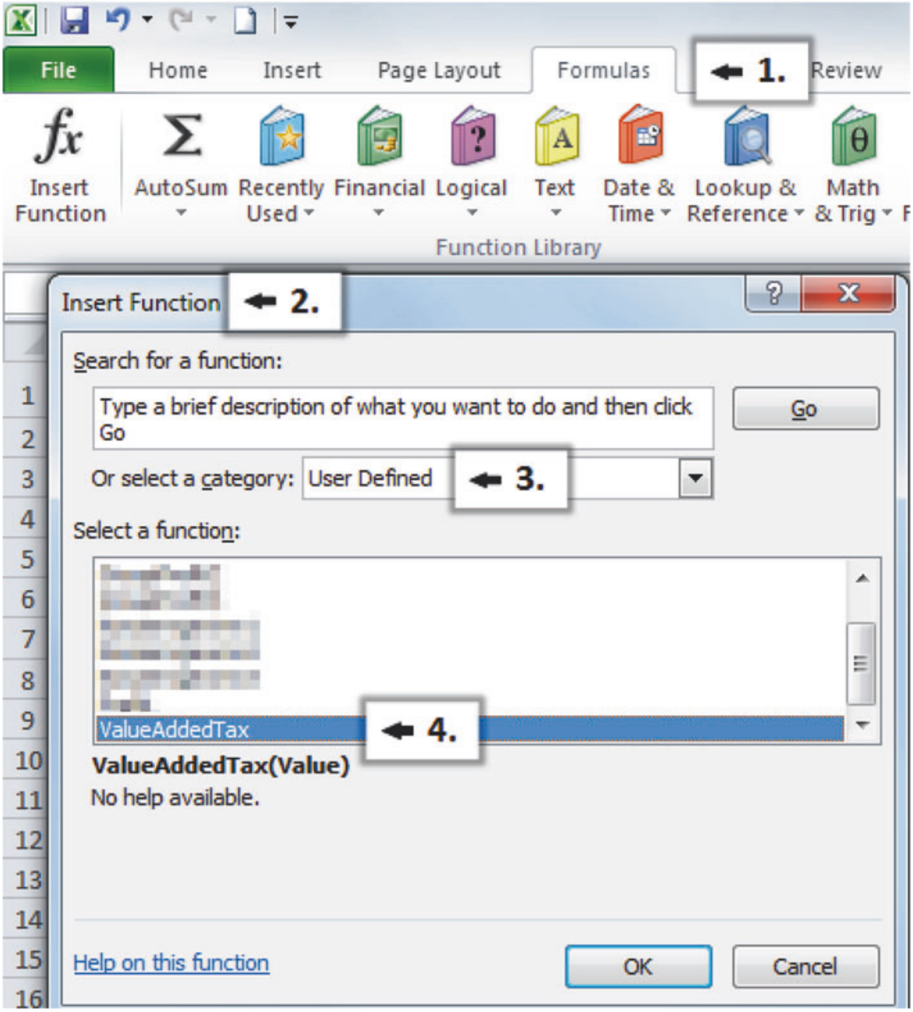

Fig. 7.15 Inserting user defined functions

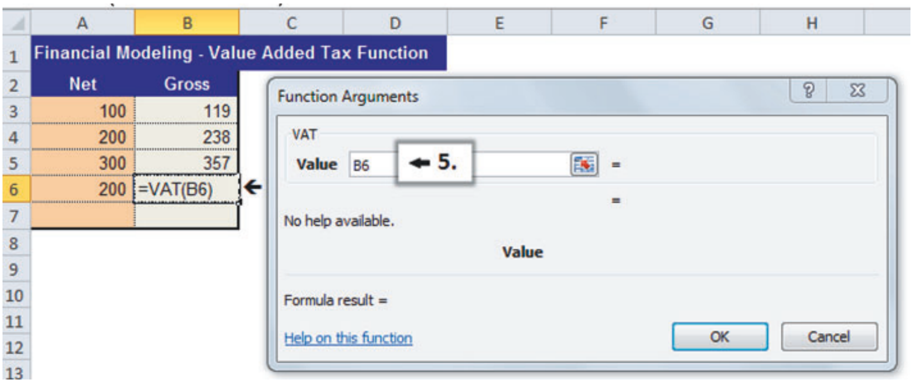

Fig. 7.16 Calculating the value added tax with the help of a user-defined function

5. In the menu *Arguments of the function* (Fig. 7.16) enter the cell for providing the net value (in this case: `A6`) in the field *Amount*.

Properties Window

The properties window shows a list of available properties.

> Properties determine the characteristics of specific objects, which can be changed with so-called methods.

This makes it possible to define the properties of the objects marked in the project explorer. As an example, this is the formatting of an object (Color, name, font). Depending on the active object, different properties are shown. Accordingly, the number of properties displayed differs Fig. 7.17.

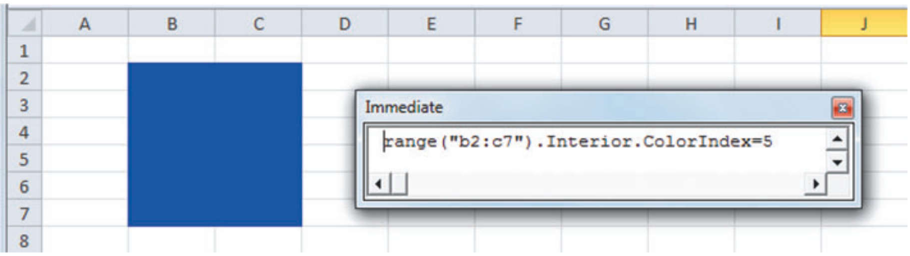

Fig. 7.17 The properties window

In case the properties window is unavailable, it can be displayed via the commands *View* ➲ *Properties* or alternatively with the *F4* key.

4.3.2 The Immediate Window: Directly Viewing the Results

The immediate window is very helpful in various applications (for example when testing programs or when checking for the contents of a variable).

The immediate window is shown via the sequence of commands *View* ➲ *Immediate Window* (alternative key combination *Ctrl* + *G*).

The immediate window is also suitable to quickly ascertain the value obtained with a VBA command:

Start a program, switch into the development environment and enter `?Command` in the immediate window.

With the command `?ActiveWorkbook.Name` you will receive the name of the active workbook as a response in the immediate window.

Asking for the value which is returned in the immediate window Fig. 7.18:

Practical Tip

Following the results of commands directly in the spreadsheet
If you require comprehensive input and changes from the VBA Editor in a spreadsheet, the frequent switching between the editor and the spreadsheet is not very comfortable. A preferred solution is to separate the immediate window:

Fig. 7.18 ActiveWorkbook

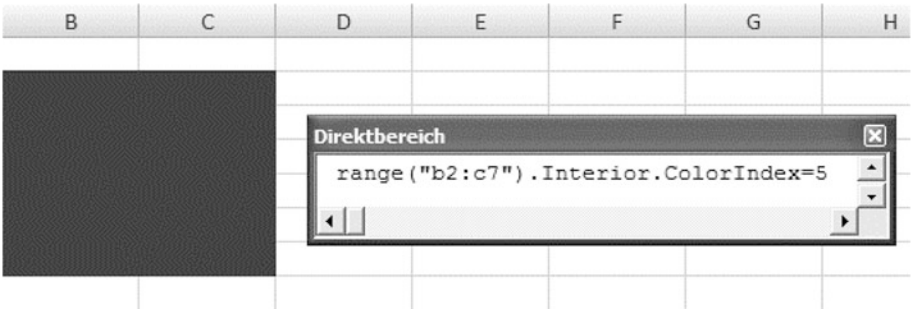

Fig. 7.19 Interior.ColorIndex=5

1. Minimize the size of the development environment in such a way that it comfortably fits on the spreadsheet.
2. Separate the immediate window from the anchoring by holding it at the blue, upper frame (=title bar) and pulling it away by holding down the left mouse button. The immediate window is now floating.
3. Switch to the spreadsheet and once again activate the development environment.

Now all commands that are entered into the immediate window are directly visible in the spreadsheet. Double-clicking the title bar of the immediate window once again anchors the window Fig. 7.19.

In the following figure, the cells in the field `(B2:C7)` are colored blue with the command `Interior.ColorIndex=5`.

4.3.3 Clear Structure for Programs

> As you use more and more programs and as the complexity increases of the tasks that you want to complete with the help of VBA, a structured setup of your source texts gains in importance.

In this regard, the development environment of VBA offers a large range of practical support features. In the following, the different functions of the toolbar *Edit* will be presented Fig. 7.20.

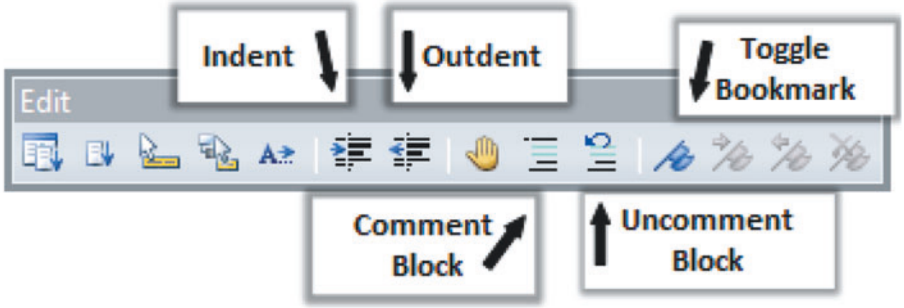

Fig. 7.20 The toolbar Edit

Increase indent or decrease indent: facilitates reading a program
With the function *Increase indent*, a block of lines can be moved to the right. Similarly, the command *Decrease indent* removes the indentation and shifts the lines back to the left. This feature is helpful to create structure and improve readability of the programming code.

Listing 4

Example without indentation

```
If obtnc = false And obtnp = False Then
     MsgBox "Please select call or put option."
End If
```

Listing 5

Example with indentation

```
If obtnc = false And obtnp = False Then
     MsgBox "Please select call or put option."
End If
```

Setting bookmarks: Keeping track of comprehensive source texts

Complex source texts can quickly become rather voluminous and easily cover several pages. In this case, it is not easy to keep track of everything. A helpful feature of the VBA Editor is the *Bookmark*. It allows a direct jump to the position identified by the bookmark.

You find the *Bookmark* in the toolbar *Edit*. Move the cursor to the desired position and press the symbol *Bookmark*. You will recognize the bookmark by the light blue rounded rectangle which is shown in the left bar. In the menu bar *Edit* you can also find the symbols *Next Bookmark* as well as *Previous Bookmark*, which can be used to navigate between the various bookmarks Fig. 7.21.

Documenting the programming code with comments

It is frequently the case that several people work on the same program or that the original programmer resumes his work at a later point in time, for example to add more functions. In those cases, comments are important. They usually consist of explanations about the relevance of the source text and its functioning.

It is recommended to start the source text with a comment that contains the following information:

- Name of the programmer,
- Purpose and task,

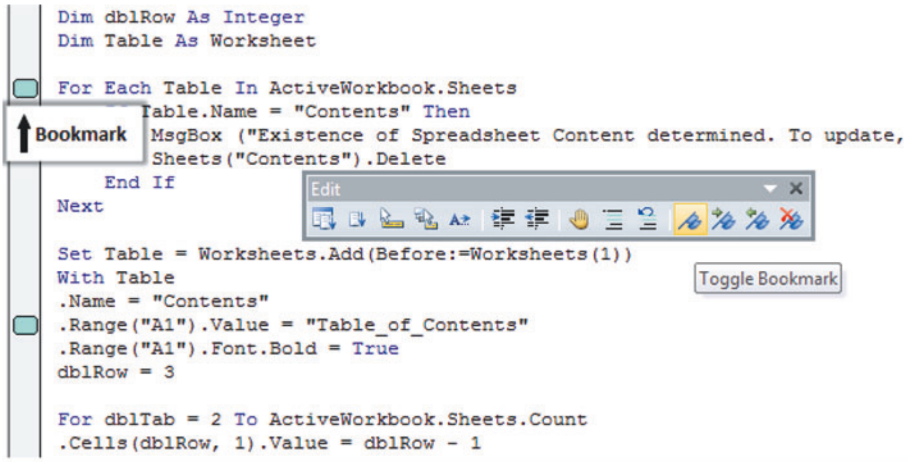

Fig. 7.21 Bookmarks

- Programming date.

For the inexperienced programmer it is also advisable to insert comments about commands and programming steps in order to facilitate an understanding of the various commands.

A comment can be entered into the programing code at any place. It can either consist of an entire row or it can be entered following a command in the same row. A comment begins with a single quotation mark (‘). The VBA Editor ignores the text which is marked as a comment. The color coding function supports this task. Comments are written in green.

The following program shows the use of comments.

Listing 6

Writing comments about a program

```
‘ Created on 7.2.2010 by ABC
‘ Returns Hello World

Sub MyFirstSubProcedure ()
    MsgBox "Hello World" ‘Using a dialogue box to
    return the text
End Sub
```

Practical Tip

Experimenting with the function *Comment Block*

If a programmer wants to test a new approach and for that reason needs to experiment with several versions, one or several lines of text can be deactivated with the comment function. This is better than deleting currently unused lines, since they can be easily reactivated if needed Fig. 7.22.

Fig. 7.22 Comment Block

In order to quickly transform entire blocks of programming into comments, the function *Comment Block* is used. The function is reached via the *Edit* toolbar. The source text can once again be activated with the function *Uncomment Block*.

Writing long commands on several lines
Occasionally commands in VBA become long chains. This has the disadvantage that once they reach a certain length, they no longer fit completely on the screen and it is necessary to scroll to the right. It is better to separate commands on several lines. This requires telling the VBA Editor that the command continues on the next line. Commands can be separated at any position.

In order to continue a command on the next line, the underscore "_"is used as a separator.

Listing 7

Continue command

```
MsgBox "The present value of the following cash flows"
& cf _ "with an interest rate of" & i & " % and a
maturity of " & t_ & "years is:" & pv & "."
```

In this section of the program, a *MsgBox* is used to display specific values. Since the command lines are becoming too long for the programmer, the separator "_" is used to go to the next line.

4.3.4 Efficient Programming Using the Intelligence of the VBA Editor

> Meanwhile VBA has reached a complexity that on occasion can be overwhelming not only for beginners. But the development environment offers support features to facilitate the work, even for experienced programmers.

Intelligent Support by IntelliSense

Excel supports the programmer in various ways (so-called IntelliSenses) when writing the source text. Especially beginners will find this very useful, since Excel takes over tasks from the programmer and helps to prevent mistakes with the automatic syntax check.

Try the following:

1. Enter the command *Workbooks*. Do this in an incomplete fashion (for example *work*).
2. Use the key combination *Ctrl* + *Space bar* and Excel will complete the command and add the missing letters to read *Workbooks*.

This function of completing a command will only work once the command can be uniquely identified by the VBA Editor Fig. 7.23.

The VBA Editor can save you even more typing tasks. The automatic list of elements appears when the object, followed by a

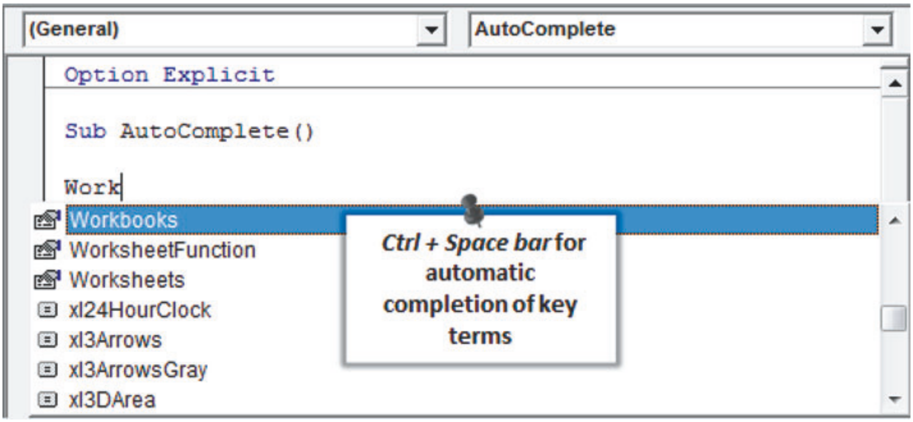

Fig. 7.23 Automatic completion of key terms that were entered only partially

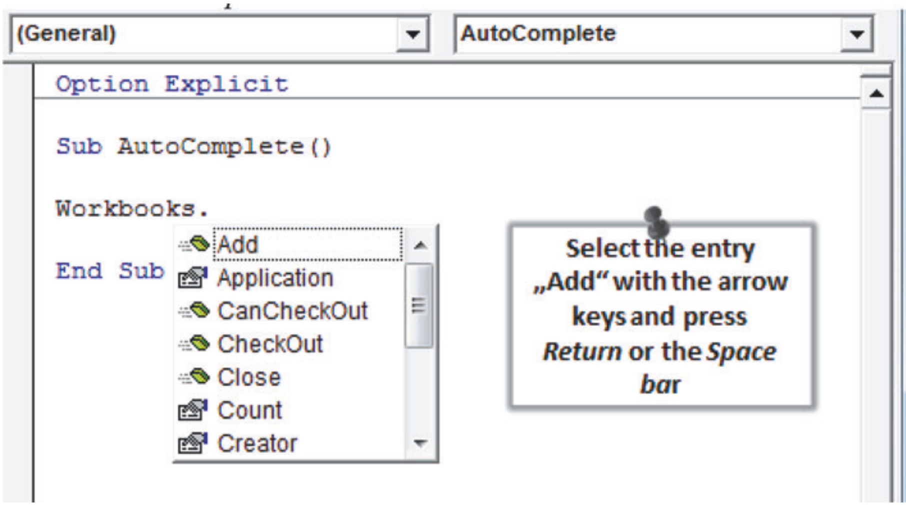

Fig. 7.24 The VBA Editor can save various typing tasks

period is entered. Excel lists the properties and methods available for the object and the user can select the needed element for his program:

1. Enter a command in the VBA Editor (such as `workbooks`).
2. As soon as you put a period after the command, a list with all the appropriate commands will be displayed.
3. For example, to select the entry *Add*, double-click left with the mouse. Alternatively – if you prefer to work without the mouse – go to the command with the arrow keys and press *Return* or the *Space bar* Fig. 7.24.

With the two functions that were presented and a bit of practice, you can significantly increase your speed and gain the understanding necessary to select suitable programming elements.

QuickInfo: Automatic and Direct Help

Given the large number of commands in VBA, it is almost impossible for the user to remember them all. QuickInfo provides the programmer with the information necessary to structure a function or procedure. This saves a lot of time, as it reduces the need to consult the online help and to search for errors Fig. 7.25.

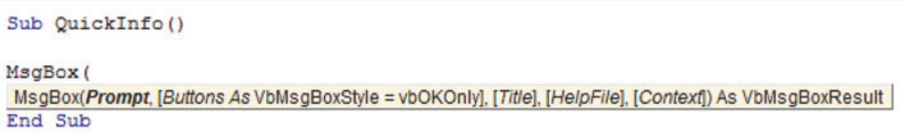

Fig. 7.25 QuickInfo

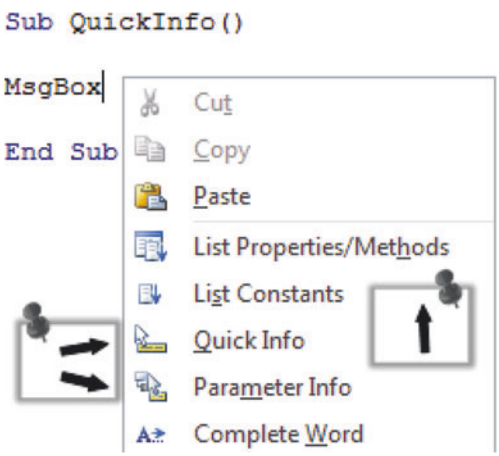

Fig. 7.26 Parameter Info, Quick Info or Display Properties/Methods

This automatic help function is available when entering commands for which information is available. For example, enter the command *MsgBox*, followed by a blank space. You will be provided with the complete syntax of the command.

If you require additional information about a command, an object or a constant in a completed source text, put the cursor on the relevant position and choose the entry *Parameter Info, Quick Info* or *Display Properties/Methods* in the context menu Fig. 7.26.

Practical Tip

Obtaining suggestions from other programs with the help of *QuickInfo*

In order to enhance your programming skills you should utilize the programs from other users and from this book. By retracing what is happening during the different programming steps, you can enhance your knowledge. *QuickInfo* and the online help support you in these activities.

Displaying constants

With the automatic display of constants you can access a list of all available constants.

> Constants never change their value and remain unchanged during the entire process. A distinction is made between global and local constants.
> Global constants are defined outside a specific macro and can thus be used with all macros in the module.
>
> Local constants meanwhile are only valid for the macro in which they were defined.

Constants save time, since they are defined at the beginning of the program and only need to be adjusted once in case of required modifications.

The syntax for a constant may look as follows:

```
Const StartDate = #1/1/2009#
Const VAT = 1.19
Const pi As Double
   =3.14159265358979323846264338327950288841972
```

The key combination *Ctrl* + *Tab* + *J* will display a dropdown menu with all available constants, methods and properties. This list contains both specifically defined constants as well as preset ones.

Color Coding – Signaling with Colors

Assembling a program code is supported by so-called color coding, which displays for the programmer key terms, comments and possible errors in different colors. This makes it easier to track interlinkages and mistakes:

- Mistakes (red): A line will have a red background and an error message appears as soon as a syntax error is caused and the *Return* key is used to move to the next line.
- Commentary (green): Text and entire lines of commentary are written in green following the single quotation mark (‘).
- Key terms (blue): Key terms are frequently used terms and for that reason are already known to Excel. They are shown in blue and in bold letters Fig. 7.27.

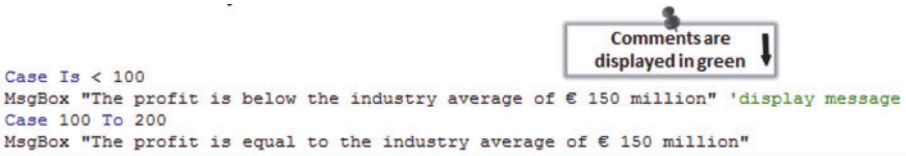

Fig. 7.27 Color Coding

4.3.5 Support from the Online Help

A further possibility to make quick progress in the programming with VBA is to utilize the help function. Several possibilities exist.

The VBA Editor helps you in the following ways:

1. Refer to a listing.
2. Put the cursor on any command and press the *F1* key in order to activate the online help function.
3. If this topic is available in the help function, you will be directed there.

Practical Tip

Using examples from the online help for your own purposes
The online help frequently also contains examples in addition to the explanations, which can be utilized for your own purpose as follows:

1. Use the left mouse key to highlight the example program.
2. Open the context menu with the right mouse key and select the command *Copy*.
3. Move to the VBA Editor and insert the example at the correct position by choosing the command *Insert* from the context menu.

Another possibility to stay informed about a help topic is found on the very right of the menu bar in the development environment. Enter a search term in the field provided and hit the *Return* key Fig. 7.28.

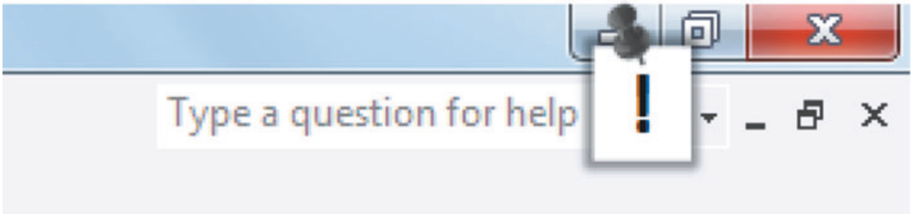

Fig. 7.28 How online help can help

4.3.6 The Object Catalogue: Improved Knowledge about Objects

VBA is an object oriented programming language. Objects, properties and methods are the main components of these programming languages. To facilitate the use of objects, the development environment provides the object catalogue. It is a database and thus a good source of information concerning objects, properties and methods.

> Objects are the elements which are used in VBA. This includes all elements that are familiar from Excel. It includes for example workbooks, spreadsheets, cells, symbols and diagrams.
>
> Methods are actions in VBA which are conducted on objects. Just as the properties which are described later, they are tied to the objects via the syntax.

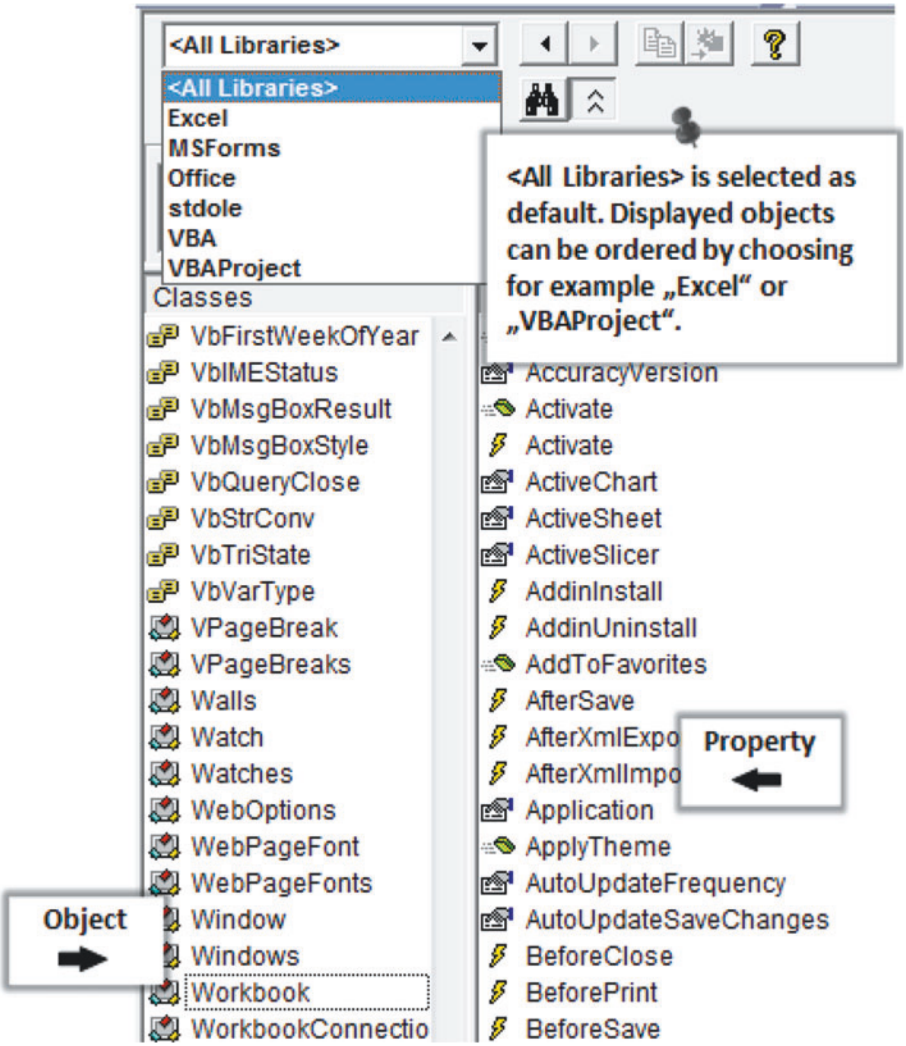

Fig. 7.29 The object catalogue: The symbols clarify whether it is an object, a property, a meth-od or an event.

There are several possibilities to get to the object catalogue in the development environment:

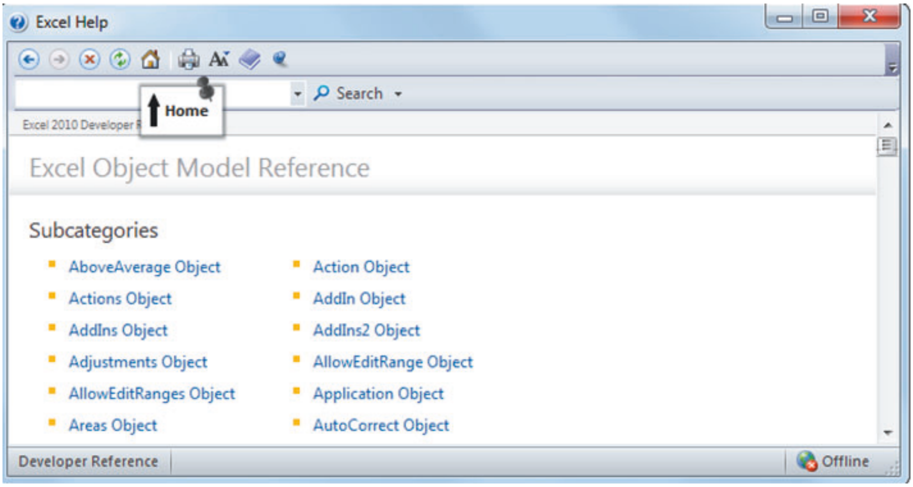

Fig. 7.30 All Excel objects at a glance

- From the menu *View,* choose the command *Object Catalogue*.
- Press the *F2* key.
- From the VBA Editor you can directly get to the object catalogue via the context menu (right-clicking the mouse) Fig. 7.29.

Another solid overview of the objects available in Excel is provided by the *Object Model Reference*. It can be accessed as follows Fig. 7.30:

1. In the online help function, go the symbol *Start*.
2. Click the *Hyperlink Excel 2007-Developer Reference*.
3. Select the *Hyperlink Object Model Reference for Excel*.

4.3.7 Fast Programing with the Key Combinations

All commands can be accessed via the different menus. More convenient and faster is the work with the key combinations. Here is an overview of the most important commands Fig. 7.31.

Key/Key combination	Command
(F7)	Code Window
(F2)	Object Browser
(Ctrl) + (F)	Find
(Ctrl) + (H)	Replace
(F3)	Continue Search
(Shift) + (F3)	Find Previous
(Ctrl) + Arrow Down	Next Procedure
(Ctrl) + Arrow Up	Previous Procedure
(Shift) + (F2)	Procedure Definition
(Ctrl) + (Page Down)	Jump to Next Procedure
(Ctrl) + (Page Up)	Jump to Pervious Procedure
(Ctrl) + (Shift) + (F2)	Jump to Previous Position
(Ctrl) + (Home)	Top of Module
(Ctrl) + (End)	Bottom of Module
(Ctrl) + (Arrow Right)	One Word to the Right
(Ctrl) + (Arrow Left)	One Word to the Left
(End)	End of Line
(Home)	Beginning of Line
(Ctrl) + (Z)	Undo
(Ctrl) + (C)	Copy
(Ctrl) + (X)	Cut
(Ctrl) + (V)	Paste
(Ctrl) + (Y)	Cut Entire Line
(Ctrl) + (Del)	Delete to End of Word
(Tab)	Indent
(Shift) + (Tab)	Outdent
(Ctrl) + (Shift) + (F9)	Clear All Breakpoints
(Shift) + (F10)	Show Context Menu
(Ctrl) + (P)	Print
(Ctrl) + (E)	Export Module
(Ctrl) + (S)	Save

Fig. 7.31 Key combinations

4.3.8 Identifying and Avoiding Errors, Suggestions for Correcting Errors

Especially when starting with a programming language, programmers naturally make frequent mistakes. Therefore it is important to know how to find and eliminate mistakes and tools available for that purpose.

Finding and correcting errors is called debugging. There are three types of mistakes which can happen in programming with VBA: syntax errors, run time errors and logical errors.

Syntax errors

Syntax errors are rather frequent. They can be detected and corrected with relative ease. They occur if a command is written incorrectly (such as switching letters) or a keys word is left out. The editor helps in identifying syntax errors by coloring the relevant line in red via the so-called color coding.

Practical Tip

Enter all commands in lower case letters
Make it a habit to enter all commands in lower case letters. Each time you hit *Enter* at the end of a line, you can see whether the commands were actually recognized by the *Editor*: The first letters in the correctly recognized commands will become upper case letters.

The input
`activecell.colorindex = 3`
will become the command
`ActiveCell.ColorIndex = 3`
in upper case letters.

Runtime Errors

Runtime errors are harder to detect than simple syntax errors. They can occur, for example, if an array is overflowing, because there is insufficient storage space. A runtime error can also occur in case an *If* branch is not ended with the command *End If*. Such errors will result in the termination of the program and the incorrect line in the program will be marked in yellow.

Missing objects

An error that occurs regularly is the *runtime error 1004*. It is an error that can have multiple causes. It can occur, for example, if an attempt is made to access an object which does not exist. A typical error is the attempt to open a workbook which is not available.

If these types of errors appear during programming, they are not easily understood by the user and do not usually provide guidance for remedial action. For improved and user-friendly programming such error messages should be avoided if possible and a routine for dealing with errors should be included in the programming code Fig. 7.32.

A routine for treating errors could look as follows:

Listing 8

```
Sub OpenWorkbook()

Workbooks.Open Filename:="D:\Workbook2.xls"

End Sub
```

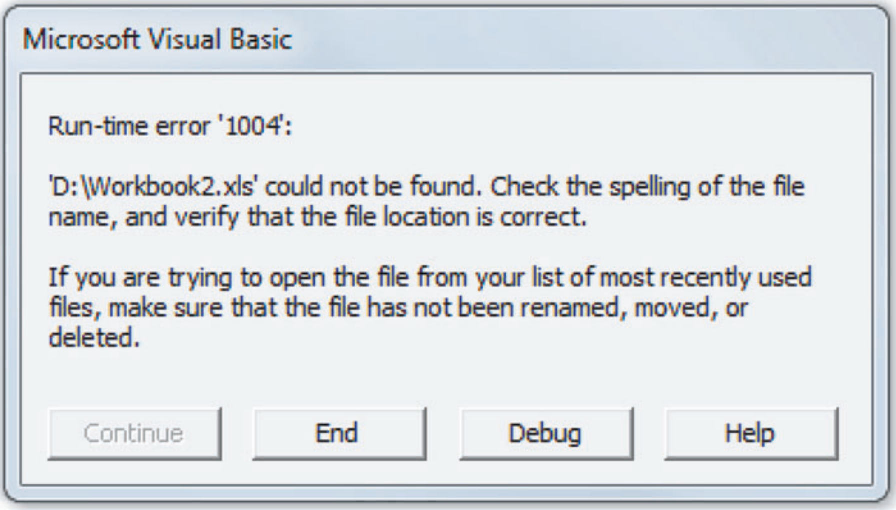

Fig. 7.32 Runtime error 1004: Object not found

Routine for treating errors

```
Sub FileOpenBetter()
    On Error GoTo Faulty     'Going to the
    'error treatment routine
     Workbooks.Open Filename:="D:\ Modelling.xls"
    '... Additional commands...
Exit Sub

    Faulty: 'Beginning of the routine to prevent error
    MsgBox"The file you are trying to open cannot
    be found", _ vbCritical + vbOKnly, ,,"Error"
```

The command in *On Error GoTo Faulty* allows an elegant approach to suppress the standard error message and replace it with a user-defined message Fig. 7.33.

In case Excel finds an error, it directly goes to the routine for preventing errors and the specified actions are taken. The command *Exit Sub* is placed before the routine for preventing errors. This is necessary in case there is no error in the program: the routine for preventing errors is not executed and the macro continuous as planned.

The presented routine for preventing errors is suitable in situations where the programmer can anticipate potential disruptions. If this is not possible, listing 9 supports the user. In contrast to the standard error messages of VBA, a specifically programmed routine can provide an additional description of the error. To do so, a query is

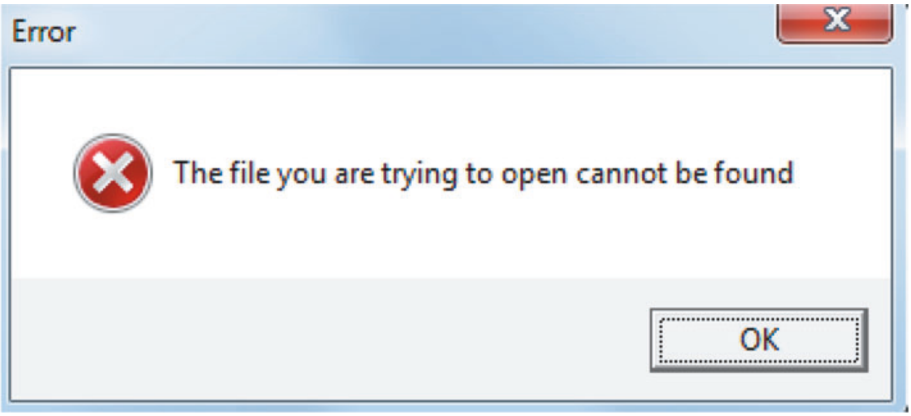

Fig. 7.33 On Error GoTo Faulty

needed to pinpoint the specific cause of the error plus the error number (*Err.number*) and a meaningful description using the command *Err.Description*.

Modify the routine for avoiding errors from listing 8:

Listing 9

Routine for treating errors with error number and description

```
    Faulty: 'Beginning of the routine to prevent error
    MsgBox "The file you are trying to open cannot be
    found" & Chr(10) & Chr(10) & _
    "Error number: " & Err.Number & Chr(10) & _
    "Error description: " & Err.Description
        & Chr(10) & _
    "Source of error: " & Err.Source
End Sub
```

The resulting message looks as follows Fig. 7.34:

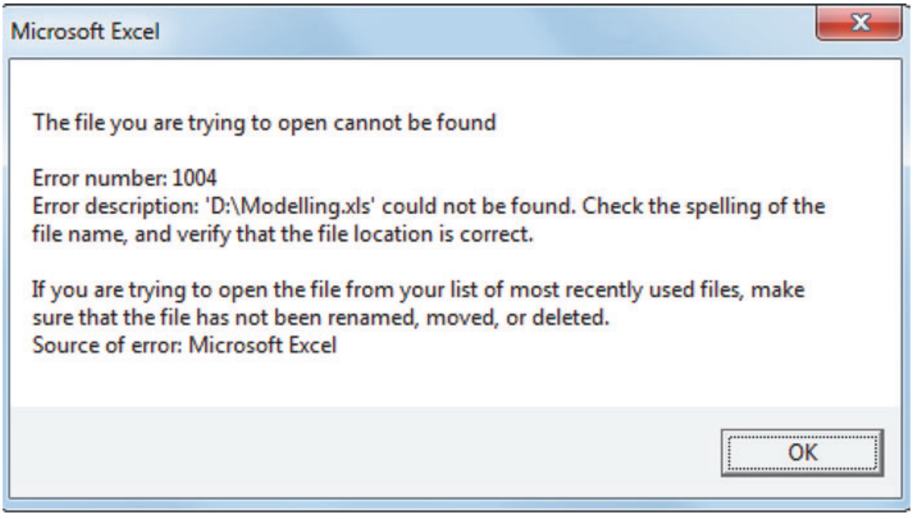

Fig. 7.34 Treating errors with error number and description

Unavailable properties and methods

If an attempt is made to apply to an object an unavailable property or method, the error message "run time error 438: Object does not support this property or method."

The original command which triggered the error message:

```
Sub Frame()
ActiveCell.LineStyle = xlContinuous
End Sub
```

In order to display the frame for a cell, the command must also include the object *Borders*. The correct command is:

```
Sub FRame()
ActiveCell.Borders.LineStyle = xlContinuous
End Sub
```

Two possibilities exist to make the needed correction:

1. It can be looked up in the object catalogue.
2. If the input of the object (here *interior*) is followed by a period, the correct command can be selected from the context menu (see Section *IntelliSense*).

Overflow – Run time error 6

If an incorrect data type is used in declaring a variable, the error message *Runtime error 6 is* displayed. For example, a variable declared as *Byte* can only take on a value in the range from 0 to 255. If a value outside of this defined range is assigned, the buffer overflows. A possible solution is the use of the data type *Integer*. Additional information is found in Section 3: Variables and the Most Important Data Types.

Logical Errors

Logical errors are the third type of errors. It is the most severe error type, because in many cases the error goes unnoticed and the flawed results of the program are trusted and used.

Listing 10

Example of a logical error

```
Sub LogicError()
    Dim dblAverage As Double
    Dim dblA As Double
    Dim dblB As Double

    dblA = 5
    dblB = 10
    dblAverage = dblA + dblB /2
End Sub
```

The listing contains a typical example of a logical error. The programmer intends to calculate the average of two numbers. The program provides the output 10 as the average instead of the correct result of 7.5. Reason: there is a missing bracket in the calculation and the program divides only the second number by two instead of the sum of the two numbers.

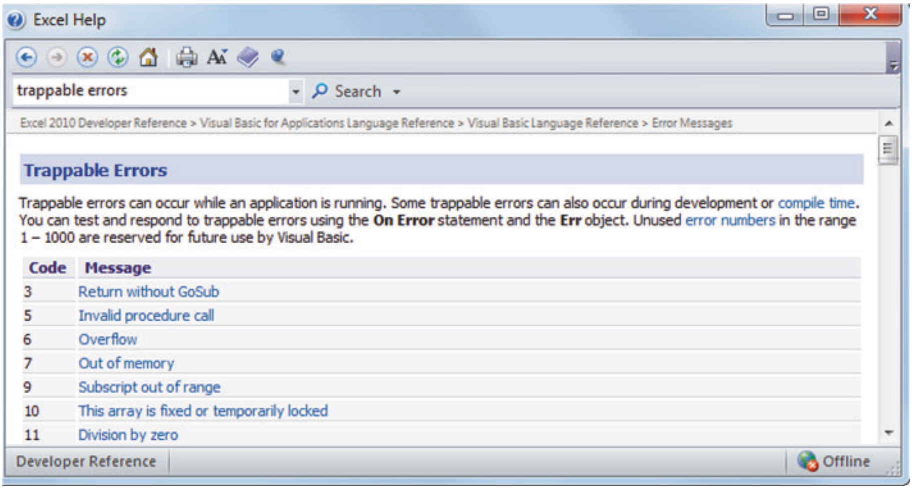

Fig. 7.35 The online help feature

Using Available Information for Detecting Errors

The online help function provides a listing of error messages in VBA under the search term *trappable errors* Fig. 7.35.

In addition to the online help function, the internet can also be used.

Practical Tip

Searching for errors and solutions online

Not only inexperienced beginners make errors. You can be assured that other programmers have already made the same mistake. Search the internet for potential sources of error. In most cases you will find suitable suggestions to fix them.

Follow these steps:

1. Open a search engine such as Google or Yahoo.
2. Enter a description of your problem in the search field such as "Excel VBA & Runtime error 6."
3. Groups are also a good source of information. They can be found, for example, at http://groups.google.de/groups.

Step-by-Step Analysis of Programs and Error Correction in the Debug Mode

The debug mode offers the possibility to go through a program line by line or up to a stopping point to search for errors and to observe the contents of key variables during the course of the program.

Let us once again turn to Listing 10, which incorrectly calculated the average of variables *dblA* and *dblB*, since the wrong number was divided by two. To search for the error, you can use the debug mode, which allows an analysis of the source text line by line:

1. Access the local window in the development environment (*View* ➲ *Local Window*). The window is initially empty and will be filled successively as it conducts a line by line analysis. In this way you are provided with important information:

2. The column *Variable* provides the variable name, the column *Value* provides the contents or the value of the variable and the column *Type* displays the associated data type (for example double, integer).
3. Via the buttons *Debug➲ Single Step* (alternatively *F8 key*) it is possible to switch between the various lines of the program. The currently active line is colored in yellow. In Fig. 7.36, the debug mode is in the line of the program which calculates the average.

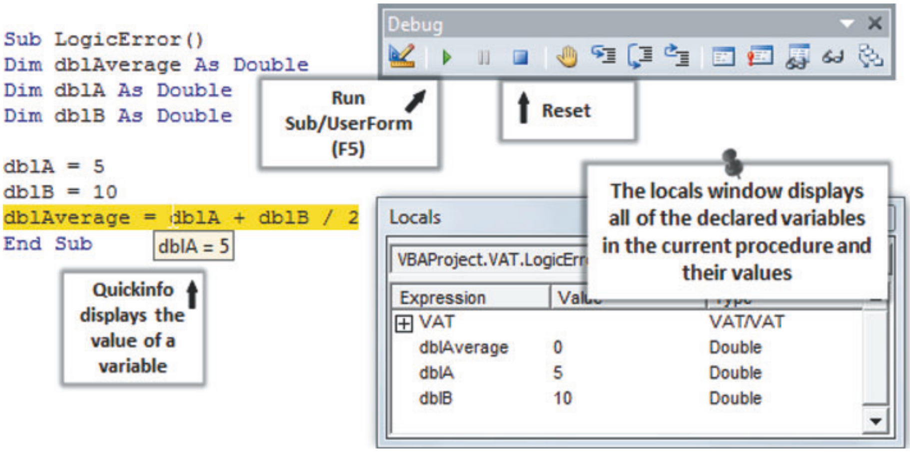

Fig. 7.36 Finding errors in the debug mode

4. Pressing the *F8 key* one more time (alternatively via the symbol on the debug menu bar) moves you to the next line.

   (In case the debug menu bar is not shown at the moment, move the cursor into the blue field in the development environment and open the context menu by right-clicking. Choose *Debugging* from that menu.)
5. Holding the cursor on a variable returns its current value in a small window (so-called *Quick info*). For example, the variable *dblAa* has a value of 5. The variable *dblAverage* still has a value of 0, since the calculation will be executed only after the line has been passed.

6. The value of the variable *dblAverage* is calculated after pressing the *F8* key and is equal to 10. It is easily recognized that the average of *dblA=5* and *dblB=10* cannot be 10. The error and its cause have been identified Fig. 7.36.

5 Variables and the Most Important Data Types

As in most other programming languages, data is stored temporarily in variables. Two different types of variables exist:

- **Local variables**: Local variables can only be used as part of the procedure for which they were declared. At the end of one processing run of a macro, the local variables are again deleted from the memory. They are declared at the beginning of a macro **after** the command *Sub* with the command *Dim*.
- **Global variables**: Global variables are of a general character – they can be used across modules. They are not deleted once the program is completed and retain their current value. The variable is declared **before** the Sub command. Instead of the term *Dim,* the term *Public* is used. Global variables should only be used in exceptional cases since they unnecessarily require storage space and lengthen the time it takes to run a program.

5.1 Declaring a Variable

In order to work with variables, they must be introduced to the program via so-called declarations. For local variables this is done with the command *Dim* and for global variables with *Public*.

> The command Dim is an abbreviation which stands for Dimensions. It reserves storage space in the main memory, which is again deleted after completion of the program.

The volume of data used and the corresponding computational effort differs by type of data. The datatype can be thought of as a formatting for variables similar to the formatting of cells (a figure without decimals, a number with thousands separator, date formats and so forth).

There are many different data types depending on the required operation. The most frequently used data types fulfill tasks such as storing numbers, strings or logical values.

When declaring a variable, the syntax needs to be as follows: It begins with the command *Dim*, followed by a prefix and the variable name, which can be chosen freely. Next follows *As* and the data type of the variable.

Listing 11

Declaring variables

```
Sub DeclaringAVariable
    Dim intSum As Integer
    intSum = 5* 17
    Debug.Print intSum
End Sub
```

In the listing a simple calculation of a sum is performed and shown in the *direct window*. With *Dim,* the variable for the sum is declared as *intSum* and the datatype *int* (integer) (In case the *direct window* is not shown, press the key combination *Ctrl* + *G*).

The most frequently used datatypes and their meaning: Fig. 7.37–Fig. 7.38

Less frequently used datatypes are:

Practical Tip

Variable type	Meaning	Typical example	Prefix	Storage needed
Integer	A variable that only uses whole numbers with sign, in other words no decimals. The value range spans -32,768 to + 32,767.	Dim intCalenderWeek as Integer	int	2 Bytes
Long	A data type to store numbers that fall outside the range of Integer.	Dim lngLiter as Long	lng	4 Bytes
Double	A very frequently used type of data for numbers which provides the greatest flexibility concerning possible values. It can handle numbers between -1.79769313486231 x10308 and 1.79769313486231 x10308 and deal with up to 15 decimal places.	Dim dblDistance as Double	dbl	8 Bytes
String	A data type to handle alphanumerical characters or strings. Strings can	Dim strMessage as String	str	10 Bytes plus length of sequence of characters
	contain up to 2 billion characters.			
Boolean	This type stores logical values, in other words values that are either "True" or "False."	Dim blnCondition as Boolean	bln	2 Bytes

Fig. 7.37 Frequently used data types

The requirement to declare a variable can help to avoid errors. The development environment can be adjusted in a way that helps to avoid errors. In the command *Option Explicit* it can be specified that every variable must be declared before it can be used.

This has one big advantage: The program will run only if the variable has been declared – otherwise the editor will provide an error message. Without the command *Option Explicit* the VBA Editor would

Variable type	Meaning	Typical example	Prefix	Storage needed
Byte	Integers between 0 and 255.	Dim bytAlter as Byte	byt	1 Byte
Currency	Decimal numbers with 15 digits before the point and 4 digits after the point.	Dim curUSD as Currency	cur	8 Bytes
Date	Type that stores time and date.	Dim datEffectiveDate as Date	dat	8 Bytes
Object	Data type which contains a reference to an object, such as a range.	Dim objWorkspace as Object	obj	4 Bytes
Single	Floating point number with up to 8 digits after the point.	Dim sngVAT as Single	sng	4 Bytes
Variant	Standard type – if no other data type was defined, it is selected automatically.	Use of this data type appears simple and convenient at first glance, since it can handle any type of data. Disadvantages are the lack of specificity and the required large storage space. Recommendation: Use only in exceptional cases.	var	16 Bytes

Fig. 7.38 Less frequently used datatypes

ignore the error or display an empty message box. Trying to identify such a mistake can be very time consuming, especially if the source code is comprehensive.

Follow these steps in order to automatically enter the command *Option Explicit* in the first line of each new module:

1. Go to the D*evelopment Environment* with the key combination *Alt + F11*.
2. In the menu *Extras* go to the command *Options*.
3. In the dialogue field *Options* go to the tab *Editor*.
4. Activate the control box *Declaration of Variable Required* Fig. 7.39.

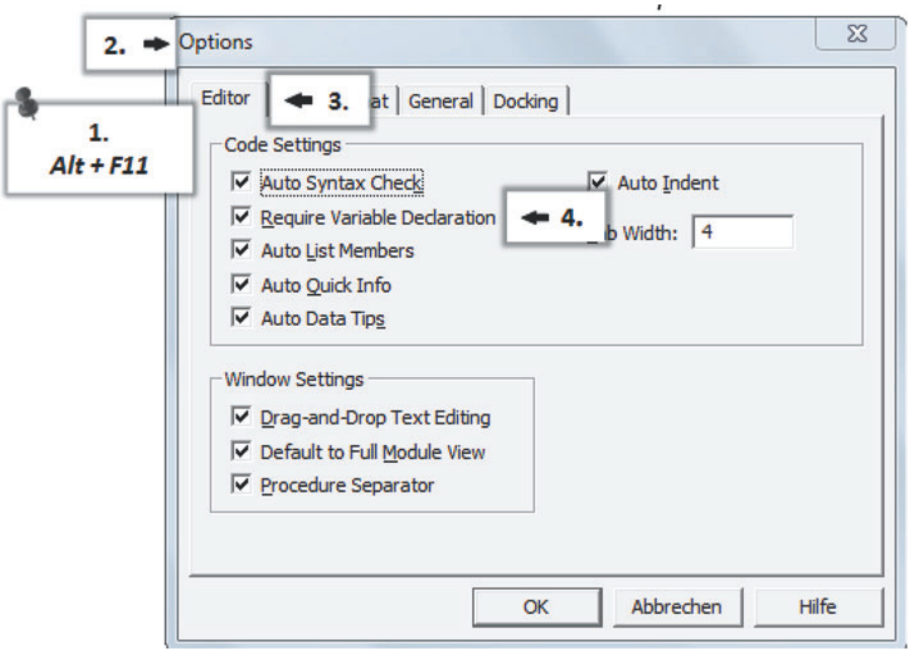

Fig. 7.39 Option Explicit

5.2 Conventions for Variable Names

> Widely accepted conventions exist for the naming of variables. The variable names should be self-explanatory, so that the programming code can be easily understood even as its complexity increases.

During the course of history of software development, three methods for assigning names have been most successful:

- **Pascal**-style: It is derived from the programming language Pascal and uses names such as *ValueAddedRate*, where all first letters in the variable name are capitalized.

- **Camel**-style: Similar to the method used in Pascal, the first letters of all words included are capitalized with the exception of the first word. This method is derived from the programming language Apache Camel. Example: *valueAddedRate*
- **Hungarian convention**: This is an even more precise method for the description of the contents of a variable and was developed by a Hungarian programmer. It states that every variable ought to begin with a prefix consisting of three characters, which represent the type of data. As an example, the tax rate would be named *dbl Value-AddedRate*. *dbl* stands for the data type Double. Integer would be *int*, Boolean would be *bln*, String would be *str* and so forth (see column prefix in Figs. 7.37 and 7.38).

The advantage for the programmer is his ability to immediately derive the type of data from the variable name. He is not required to go to the beginning of the source text and search for the data type declaration of the variable (Keyword: *Dim* command).

Practical Tip

Rules for assigning names

- Variables should begin with a letter.
- All following characters can be letters, numbers and some special characters.
- Spaces and special characters such as #, %, &, ! or ? are not permitted.
- Less suitable are variables such as the capital letter *I*, the lower-case *l*, and the number *1*. They are too similar and are frequently confused in actual applications. Do not use these characters in isolation.
- If you want to separate individual words, use the underscore (for example `Dim Cash_Flow_Calculation_May As Currency`).
- Instead of single letters such as *x* or *y*,meaningful names such as Sales or Cost should be utilized.

6 Process Flow Models and Charts

6.1 Process Flow Models

Process flow models help in planning and implementing an algorithm in a program. They allow the early detection of possible problems and to capture logical errors in the process. They furthermore facilitate tracking of the sequencing of operations which solve certain tasks.

The IPO-model, which stands for Input, Process, Output is frequently applied in programming. It provides a structure which the programmer can follow when working on a procedure. According to this structure, the data needs to be read first, then it needs to be processed and finally output is generated.

Charts provide additional help during the implementation process. They are used to clarify interrelationships among large volumes of data. Two frequently used charts are the flow chart and the hierarchy chart.

6.2 Flowchart

A flowchart shows the flow of data and consists of specific geometric symbols which are connected by lines.

It offers the advantage of visualizing the needed programming steps. It also helps to explain the logic of the program to third parties and clarifies the sequence of steps needed. The flow of the program is independent of the programming language and only serves as a rough overview.

If complex processes are involved, they can be described in a separate flowchart. Each symbol represents a specific function in the flow chart and is standardized by the American National Standards Institute (ANSI).

Symbol	Name	Meaning
	Flow line	Used to connect symbols.
	Terminal	Identifies the starting point or the ending point.
	Input/Output	Identifies an input or output.
	Processing	Operation/process.
	Decision	Is used for logical operations or for comparisons. In contrast to the input/output and processing symbols, the decision symbol has one entry line and 2 exits. The choice of exit depends on the condition being "true" or "false."

Fig. 7.40 Symbols in a flowchart

The shape of the symbol indicates its type. As an example, parallelogram represents an input or output. The lines which connect the symbols are called flow lines and display the structure of the program. Flowcharts run from top to bottom Fig. 7.40.

6.3 Hierarchy Chart

A hierarchy chart is used to display the entire program structure.

It is particularly valuable during the initial planning stages and can be used to highlight general tasks that must be completed. The hierarchy chart is also called top-down chart or VTOC Chart (**V**isual **T**able of **C**ontents). Hierarchy charts do not contain the operational logic, but only the program structure. They clarify the type of task that must be completed by each individual module of the program and how these modules are connected. It also runs from top to bottom Fig. 7.41.

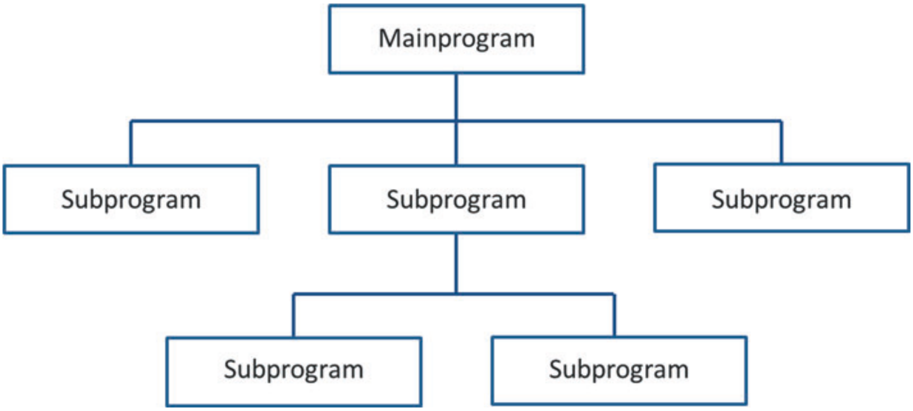

Fig. 7.41 Hierarchy Chart

7 The Most Important Language Elements of VBA

In this Section, programming commands and their operators are discussed. They enable the user to program decisions.

7.1 Programming with Branches

> Branches in VBA – as in real life – are points where a decision is made about avenues to be pursued in the future.

Depending on the result of the assessment, a predefined action is triggered. In this section, the different types of branches are presented (different types of *If* operators, the underlying logic and relational operators). Branches can be used to improve the structure and efficiency of programs.

7.1.1 *IF Branches*

IF Branches enable a program to implement various operations under conditions that need to be determined. Two kinds of *IF Branches* are available: Single-line *IF Branches* and extended *IF Branches*.

In the case of single-line *IF Branches*, operations are implemented when the conditions defined in the first line of the command are fulfilled. For programs where, depending on the result of the assessment (*True* or *False*), different operations are implemented, extended *IF Branches* are used.

The syntax of an extended *If* Branch is as follows:

```
If Condition Then
... Operations ...
Else
... else-Operations
End If
```

The extended *If* Statement, in contrast to the single-line statement, ends with the command *End If*.

Listing 12
Profit_IF_Statement

Example for an extended If Branch

```
Public Function Profit(Income, Expenses)
     Profit = Income – Expenses
     If Profit ≥ 0 Then
     MsgBox "The profit is greater or equal 0"
     Else
     MsgBox "The profit is below 0"
     End If
End Function
```

The listing as a flow diagram Fig. 7.42:

In this example, the profit of a company is determined and a message is displayed concerning the quality of the earnings. The flow diagram describes the structure of the small model: following the calculation of the profit, an IF branch compares the profit with the number 0. Depending on the result of this query – the number is either greater or less than zero – a *MsgBox* with this information is displayed.

The programming code utilizes a user-defined function in VBA. Thus the code begins with the command *Public Function*. In the following,

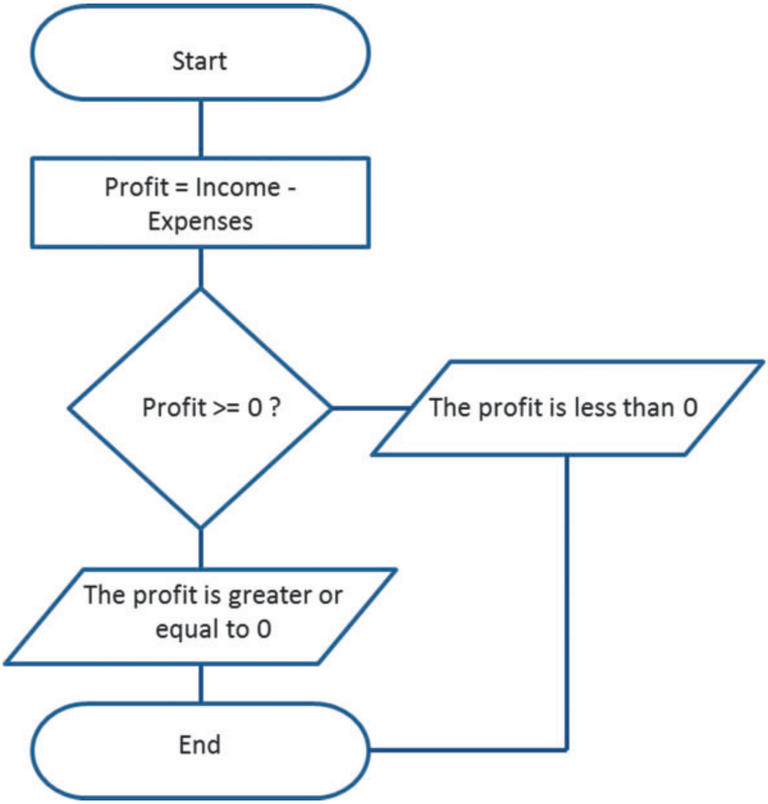

Fig. 7.42 If Branches

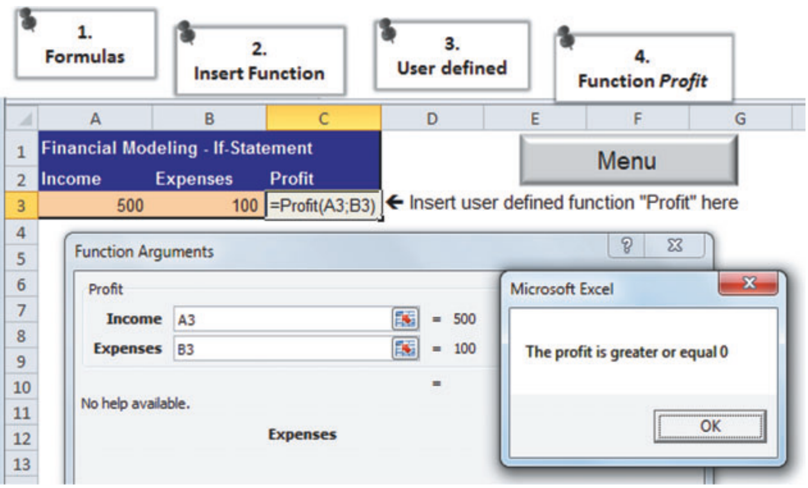

Fig. 7.43 Example of an If Branch (Excel File Workshop VBA, Spreadsheet Profit_If_Statement)

the profit is calculated (Profit = Income – Expenses) and an *If* Branch assesses whether the condition Profit > 0 is met. In case of a match, a popup –window (*MsgBox*) displays the following message: "The profit is greater or equal 0." In case the first condition is not fulfilled, the program continues (*Else)* and the message "The profit is below 0" is displayed Fig. 7.43.

Try the applied example for the *IF Branch* (Excel File Workshop VBA, Spreadsheet Profit_If_Statement), by inserting in Cell `C3` the user-defined function *Profit*: *Formulas* ➲ *Inserting Formulas* ➲ *User Defined* ➲ *Profit*

7.1.2 Nested Decisions

We can expand the above example and assume that we are not only interested in a single firm, but a group of companies. Top management wants to obtain information about the profitability of the entire group as well as of individual subsidiaries.

The demands on the program are now somewhat more complex, since an additional *If* Branch inside the initial one is needed. A structure which requires the consideration of several conditions is called a nested decision. Each *If* Branch must be a complete *If* command. This can be either single-line or an extended *If* branch.

The flow diagram and the VBA code are expanded accordingly Fig. 7.44:

Listing 13 Module GroupProfit_IF_Statement

Example of a nested decision

```
Public    Function    GroupProfit1(Income_Subsidiary1,
Expenses_Subsidiary1,                    Income_Subsidiary2,
Expenses_Subsidiary2)

   Dim ProfitSubsidiary1 As Double
   Dim ProfitSubsidiary2 As Double
   ProfitSubsidiary1 = Income_Subsidiary1
      -Expenses_Subsidiary1
   ProfitSubsidiary2 = Income_Subsidiary2
      -Expenses_Subsidiary2
   GroupProfit1 = ProfitSubsidiary1
```

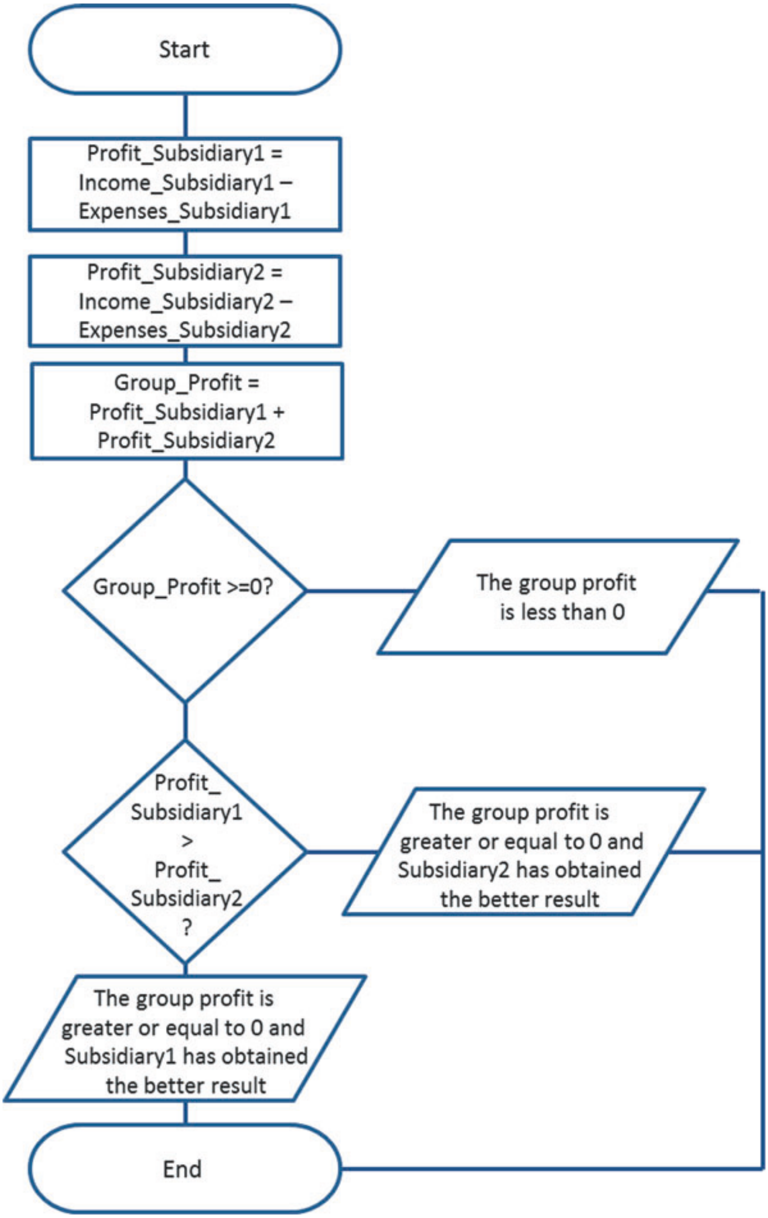

Fig. 7.44 Nested Decisions

```
  + ProfitSubsidiary2
If GroupProfit1 ≥ 0 Then
If ProfitSubsidiary1 > ProfitSubsidiary2 Then
MsgBox "The group profit is greater or equal to
```

```
0 and Subsidiary1 has obtained the better result."
Else
     MsgBox "The group profit is greater or equal
     to 0 and Sub sidiary2 has obtained the better
     result."
End If
Else
MsgBox "The group profit is less than 0"
End If
End Function
```

As can be seen from this example, the second *If* Branch (comparison of the two subsidiaries) begins immediately following the condition of the first *If* Branch, where the group profit is assessed. In case statements are nested as in the above example, each subsequent *If* Branch is indented to improve visibility Fig. 7.45.

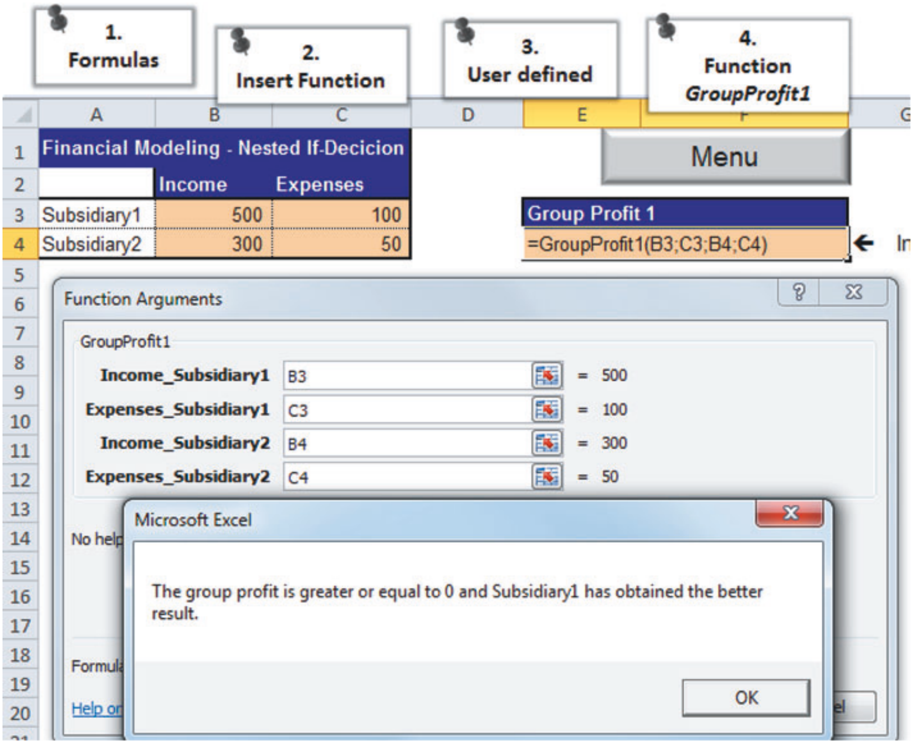

Fig. 7.45 Example of a nested decision with a user-defined function (Excel File Workshop VBA, Spreadsheet GroupProfit_IF_Statement)

Try the applied example for the decision (Excel File Workshop VBA, GroupProfit_IF_Statement), by inserting the user-defined function *GroupProfit* in cell `E5`: *Formulas* ➲ *Insert formulas* ➲ *User defined* ➲ *GroupProfit*

7.1.3 Relational Operators

Relational operators serve to carry out a comparison and thus to check various conditions. In addition to "less than" and "greater than," which were already used in the above examples, other relational operators exist as well Fig. 7.46.

Operator	Meaning
<	Less than
>	Greater than
<=	Less than or equal
>=	Greater than or equal
=	Equal
<>	Unequal

Fig. 7.46 Relational operators

7.1.4 Logical Operators

Following a change of strategy at the group level, the IT department is given the task of modifying the program which deals with profitability. In the future, the management wants to put a greater focus on the level of the subsidiaries. So it initially wants to be informed about the performance of the subsidiaries. For the implementation in the program, so-called logical operators are needed.

Logical operators are used for the comparison of Boolean values (true and false) and return a third Boolean value. In programming, they are regularly used together with relational operators. This allows conducting complex comparisons, which are related to more than one variable.

For the programming version of our example, the two operators *AND* and *OR* are utilized. The difference between the two is:

- For an *OR* operation **one** of the conditions must be fulfilled in order to execute the relevant code.
- For an *AND* operation, meanwhile, **both** conditions need to be fulfilled.

In the following, the modified VBA code and the modified flow diagram are presented:

Listing 14
Module GroupProfit_LogicOp

The modified comparison of profitability

```
Public Function GroupProfit2(Income_Subsidiary1,
Expenses_Subsidiary1, Income_Subsidiary2,
Expenses_Subsidiary2)

  Dim ProfitSubsidiary1 As Double
  Dim ProfitSubsidiary2 As Double
  ProfitSubsidiary1 = Income_Subsidiary1
                    - Expenses_Subsidiary1
  ProfitSubsidiary2 = Income_Subsidiary2
                    - Expenses_Subsidiary2
  ++
  GroupProfit = ProfitSubsidiary1
              + ProfitSubsidiary2
  If ProfitSubsidiary1 Or ProfitSubsidiary2 > 0 Then
  If ProfitSubsidiary1 And ProfitSubsidiary2 Then
  MsgBox "Both subsidiaries achieved profit greater 0"
  Else
  MsgBox "Only one of the subsidiaries achieved
  profit greater 0"
  End If
```

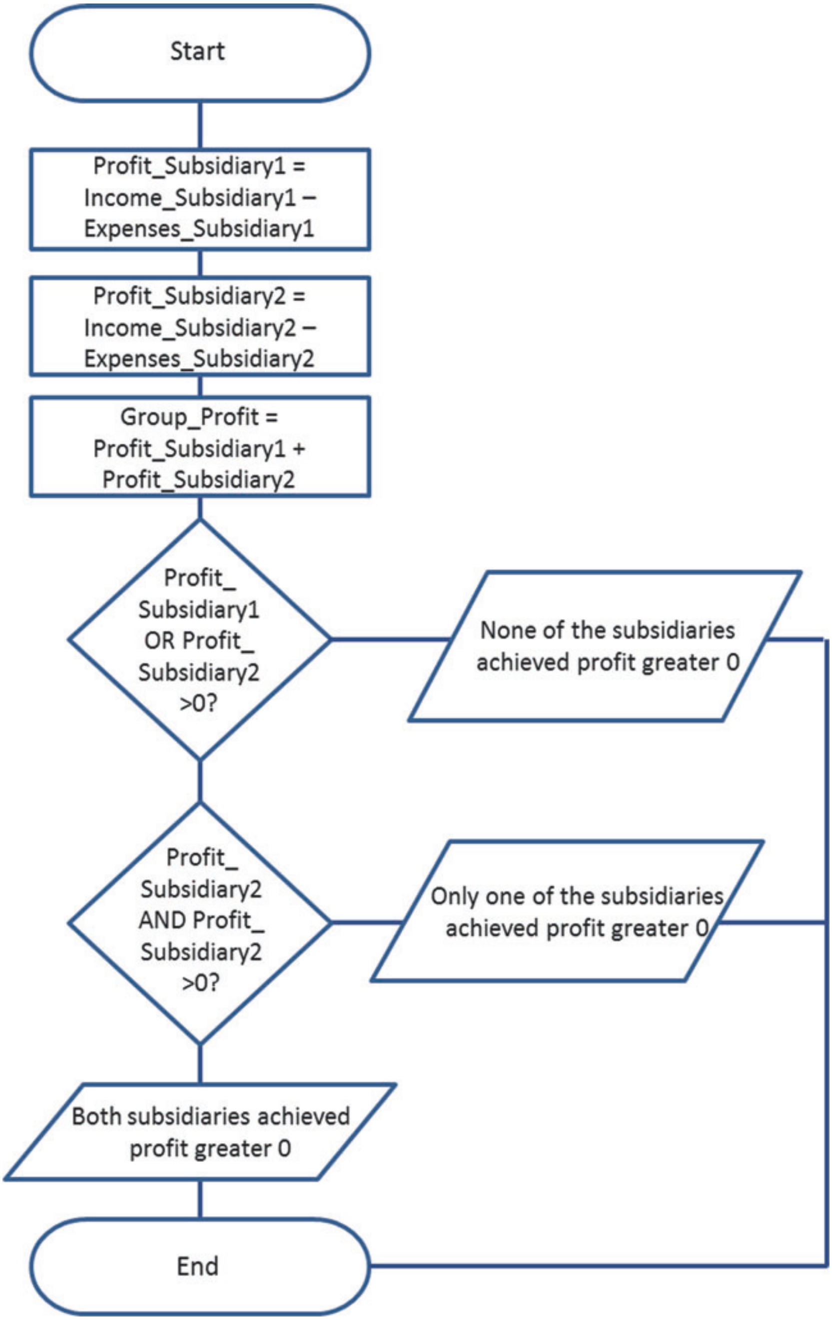

Fig. 7.47 Logical operators

```
Else
MsgBox "None of the subsidiaries achieved
profit greater 0"
End If
End Function
```

The modified example of the comparison of profit with logical operators in the flow diagram Fig. 7.47:

In Listing 14 it is initially checked with the help of an *OR* operation whether one of the two firms has managed to achieve a profit. If this is the case, an *AND* operation is used to check at the next *If* Branch whether both firms have made a profit. For every possible case, a message is displayed (*MsgBox*).

7.1.5 *Select Case*: Better Structure than *If*

The example of the comparison of profits shows clearly that several nested *IF Branches* lack clarity and can become very difficult to handle. In such cases, VBA offers the command *Select Case* as a simpler alternative. *Select Case* means that one of several commands will be executed and every command can have its own conditions.

The syntax of *Select Case* is as follows:

```
Select Case
Case ... cases that need to be considered
... command for each case
Case Else
... else Command
End Select
```

The example of the comparison of profits will now be enhanced to allow for an external perspective. Management now wants to compare the group profit with the industry average.

Listing 15
Modul GroupProfit_SelectCase

Example for the use of *Select Case*

```
Public    Function    GroupProfit3(Income_Subsidiary1,
Expenses_Subsidiary1,                 Income_Subsidiary2,
Expenses_Subsidiary2)

     Dim ProfitSubsidiary1 As Double
     Dim ProfitSubsidiary2 As Double

     ProfitSubsidiary1 = Income_Subsidiary1
                         – Expenses_Subsidiary1
     ProfitSubsidiary2 = Income_Subsidiary2
                         – Expenses_Subsidiary2

     GroupProfit3 = ProfitSubsidiary1
                    + ProfitSubsidiary2

     Select Case GroupProfit

     Case Is < 100
          MsgBox "The profit is below the industry
          average of € 150 million"
     Case 100 To 200
          MsgBox "The profit is equal to the industry
          average of € 150 million"
     Case Is > 200
          MsgBox "The profit is above the industry
          average of € 150 million"
     End Select

     End Function
```

In this example it is assumed that the average profit in the industry is € 150 million. The *Select-Case* command checks whether the company profit is below, at or above this average. If one of the three cases is matched, a corresponding message is displayed. An arbitrary number of additional cases could be added if desired. Similar to the *If* command, the *Select Case* command ends with *End Select* *Fig. 7.48*.

Try the applied example for a *Select Case* command (Excel File Workshop VBA, Spreadsheet GroupProfit_SelectCase) by inserting in cell `E5` the user-defined function *GroupProfit3*: *Formulas* ➲ *Insert Formula* ➲ *User Defined* ➲ *GroupProfit3*

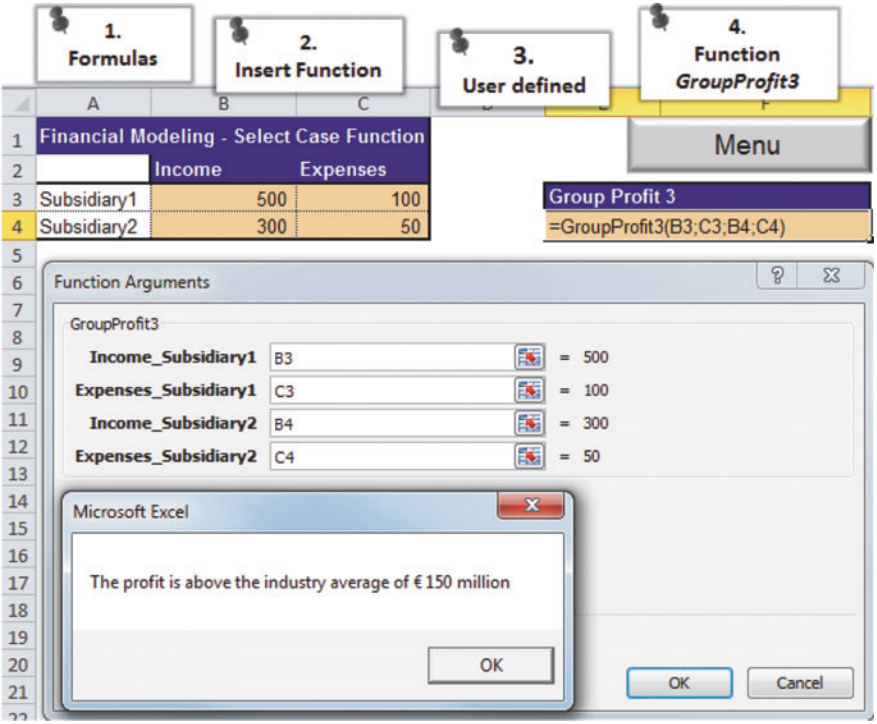

Fig. 7.48 Example of a Select Case command with a user-defined function

7.2 Loops

> Loops are used for tasks that are repeated frequently. They are passed until one or several conditions are fulfilled. This causes the loop to end.

Depending on the type of loop, the termination test will take place either at the beginning or at the end of the loop:

- If the termination test takes place **at the beginning of the loop**, it is possible that the loop will not even be executed once. This is the case if the condition is already fulfilled initially. In this case, the commands in the loop are not executed. It is possible, for example, to implement a counter in this manner, which will completely abort if a password has been entered incorrectly three times.
- If instead the termination test is placed **at the end of the loop**, it will be executed at least once Fig. 7.49.

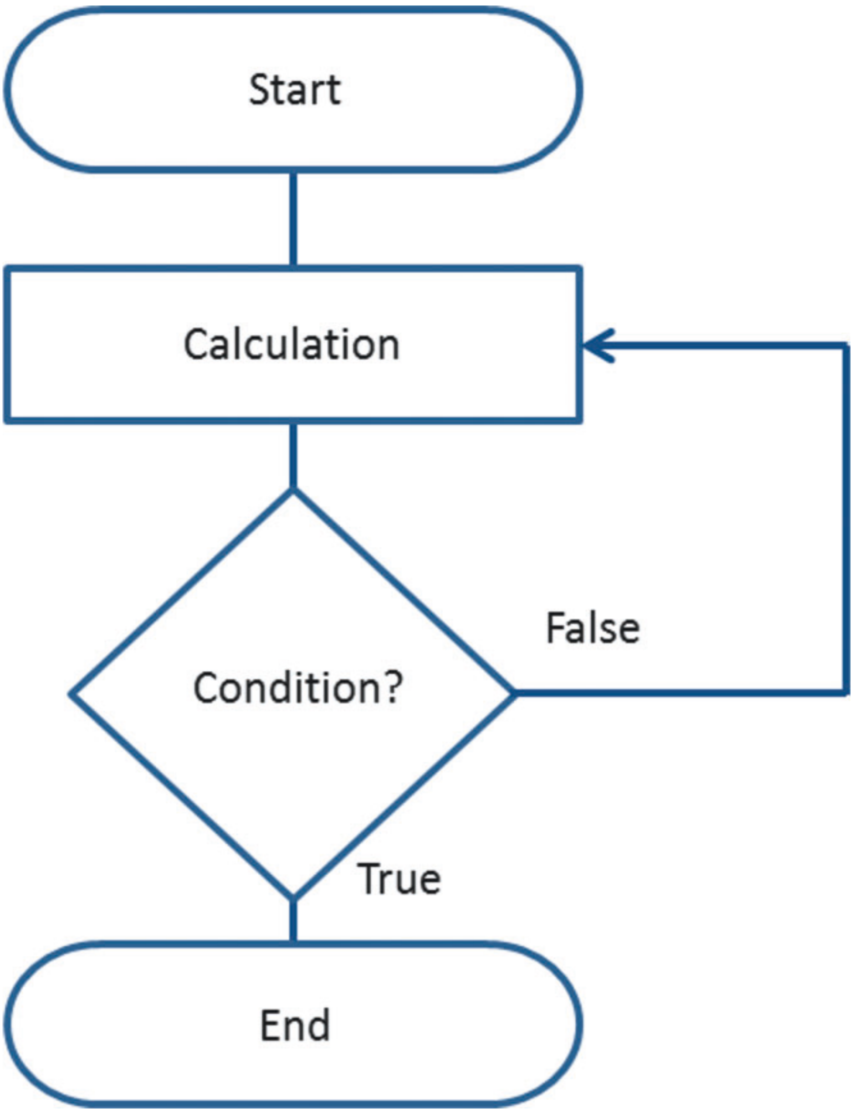

Fig. 7.49 Loops for frequently repeated tasks

7.2.1 The Loop *For… Next*

A loop control variable called counter is integrated in a *For Next* loop. It is appropriate for a block of commands that needs to be repeated a number of times. This counter starts with a beginning value, which is defined initially. Unlike other loops, this one does not require increasing or decreasing the counter, as this is done automatically. Each time VBA encounters the command *Next*, the counter is increased by 1. Then VBA returns to the *For* command. The counter is again compared to the ending value, and depending on the result of this comparison, the block is either executed again or the loop is terminated. This is repeated until the counter has passed the end value or an *Exit For* command is executed.

The syntax of a *For Next loop*:

```
For i = Beginning To End Step Step
 ... Commands...
 Exit For
Next i
```

Listing 16 Module For_Next

Example of a *For Next loop*

```
Public Sub ForNext()
     Dim i As Integer
     For i = 1 To 5
       MsgBox "The current value i is:" & i
     Next
End Sub
```

The beginning value of the counter *i* in this case is 1 and the ending value is 5. On the first iteration, the counter has a value of 1. The program determines that 1 is less than 5 and thus the following code is executed. A *MsgBox* displays the current value of the counter variable *i*. The command *Next* assures that *i* is increased to 2. Now the program goes back to the first line of the loop and checks whether or not the conditions are met. This is repeated until *i* is equal to the value of 6, in other word exceeds the value of 5.

Try the applied example for a *For Next* loop (Excel File Workshop VBA, Spreadsheet For_Next_Loop) by activating the macro with the button *Start example*. Each time you hit *OK*, the current value of *i* is increased Fig. 7.50.

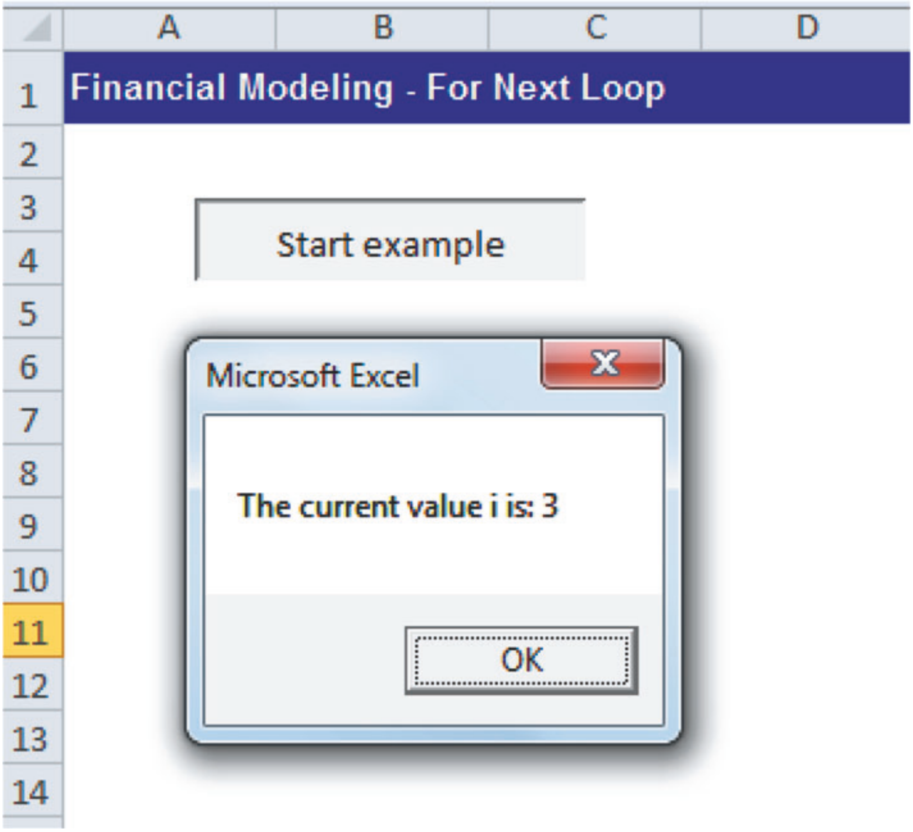

Fig. 7.50 Example of a For Next loop (Excel File Workshop VBA, Spreadsheet For_Next_Loop)

7.2.2 The *Do While… Loop*

In a *Do While* loop, the termination test is placed at the beginning of the loop. It repeats the code until the condition takes on the value "True." Possible conditions for termination are for example that the counter reaches a specific value or that a cell displays a specific text (see Held, 2007b, p.103).

The syntax of a *Do While* loop:

```
Do While Condition
... Command...
Exit Do
... Commands...
Loop
```

Listing 17
Module Do_While

Example of a *Do While loop*

```
Sub Search()
  Dim intLine As Integer
  intLine = 1
  Do While Cells(intLine, 1) <> "4"
       intZeile = intLine + 1
  Loop
  MsgBox "Found in cell" & Cells(intLine, 1).Address
End Sub
```

In this *Do While* loop, the cells `A3` and below are checked for the existence of a search term. In the program code, the search term is defined as 4. If this number is found, the loop is terminated and a message is displayed Fig. 7.51.

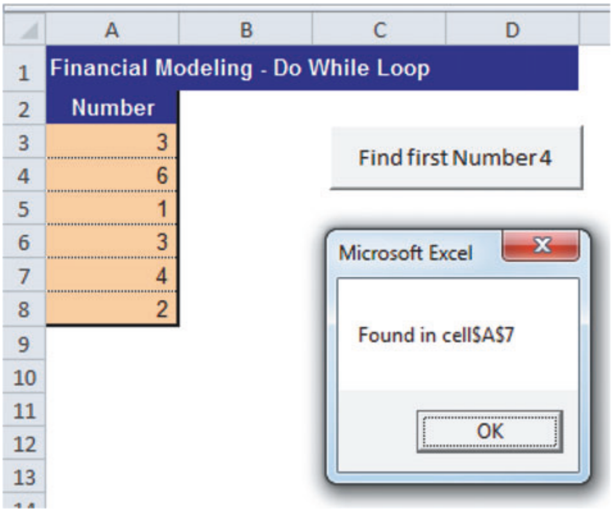

Fig. 7.51 Example of a Do While loop (Excel File Workshop VBA, Spreadsheet Do_While_Loop)

7.2.3 The *Do Until…Loop*

The *Do Until* loop has the termination test at the end of the loop. It also repeats a block of commands until the condition takes on the value "True." But this is ascertained only at the end of the loop. As discussed earlier, in contrast to a loop with a termination test at the beginning, this loop will be passed at least once.

The syntax of a *Do Until…Loop*:

```
Do Until Condition
... Commands...
Exit Do
... Commands...
Loop
```

Listing 18
Module DoUntil

Example of a *Do Until…Loop*

```
Sub Test_Values()
    Dim intCounter As Integer
    intCounter = 1
    Do Until Month(DateSerial(Year(Date),
      intCounter, 1)) = Month(Date)
      intCounter = intCounter + 1
    Loop
    MsgBox ''Current month is:'' & vbLf & _
    Format(DateSerial(Year(Date), intCounter, 1),
    ''mmmm'')
End Sub
```

In this *Do Until…Loop* a counter is increased until the current month is reached. This month is displayed in a message box Fig. 7.52.

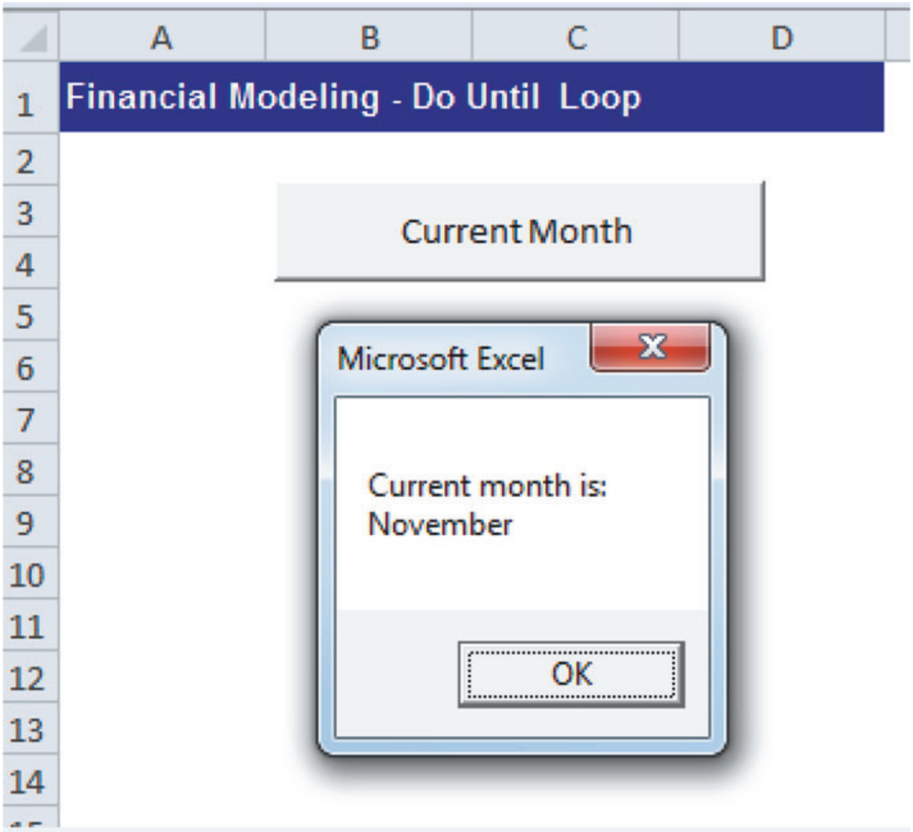

Fig. 7.52 Example of a Do Until…Loop (Excel File Workshop VBA, Spreadsheet Do_While_Loop)

7.3 Programming Cells and Ranges

In Excel, cells and entire ranges can be formatted. As an example, you can format the font size and color and insert and copy cells. All this is certainly familiar from your daily work with Excel. In the next Section, you will learn how to also program these tasks in VBA in order to automate your processes.

7.3.1 Considering the Hierarchy of Objects

In order to use cells and ranges in VBA in a meaningful way, it is important to understand the strict hierarchy which exists. To be able to work with a specific data range, it is necessary to list both the spreadsheet and the workbook in which it is contained.

As you can see in the next figure, the structure of the object hierarchy is logical and starts with the Excel application – the program Excel itself. In second place follow the workbooks. They contain worksheets, which are placed below the workbook in the hierarchy. Contained in the spreadsheets are rows, columns, ranges and cells. Cells in turn can contain elements such as characters, comments and so forth Fig. 7.53.

Here is an example:

```
Workbooks("Key_Figures").Worksheets("PandL").
Range("A1:D4")_.Clear
```

The workbook Key_Figures (*Workbooks* is the object name for Workbook) comtains the spreadsheet PandL (*Worksheet* for Spreadsheet). In this spreadsheet, the cells in the range `A1` to `D4` are deleted (*Clear*). In line with the object hierarchy, the command is structured from top (workbook) via spreadsheet to the bottom, namely cell. Names of workbooks or spreadsheets are given in quotation marks.

Practical Tip

Do not leave out any objects

The command for addressing the workbook and the spreadsheet can be omitted. At first glance, this allows the elimination of seemingly superfluous source text. However, in this case VBA will automatically select the current workbook and the active spreadsheet. For that reason, the abbreviated way of writing the syntax cannot be recommended. If several workbooks and spreadsheets are active when the programming code is executed, it is possible that the program selects the wrong objects.

Methods: How to Use Objects

Addressing or changing objects such as cells and ranges (for example mark, copy, delete, print and so forth) involves the use of so-called

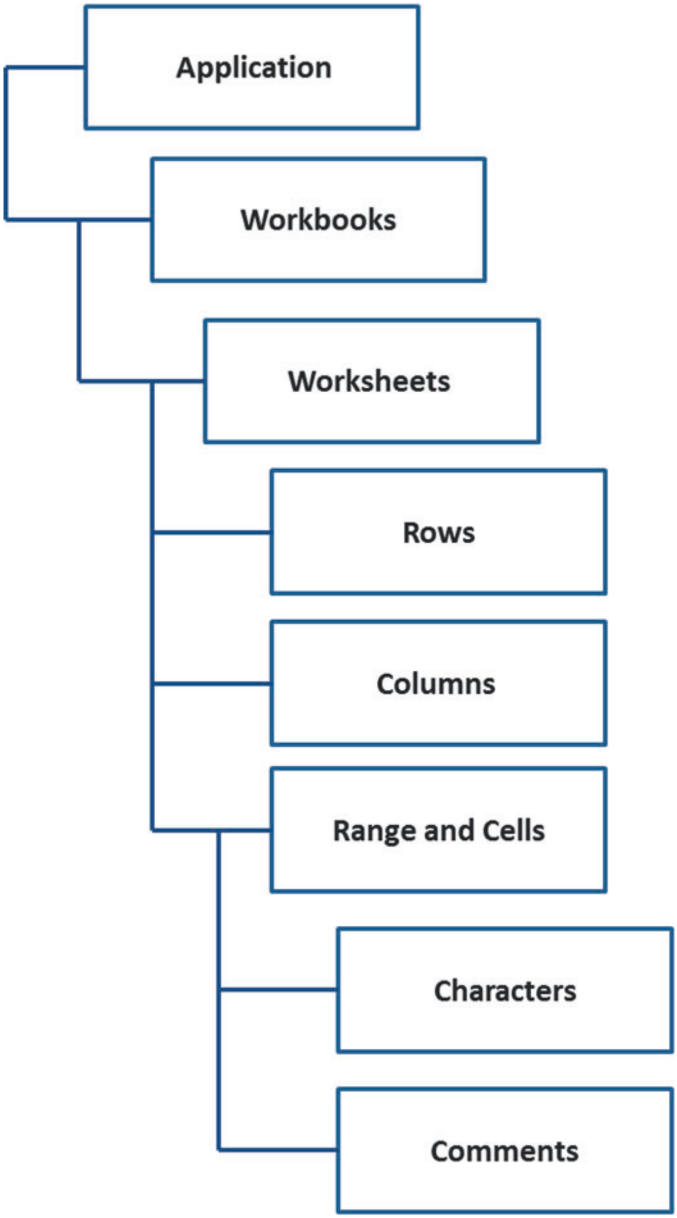

Fig. 7.53 Understanding the hierarchy of objects

methods. As was already covered in the Section on the object catalogue, methods are affiliated with objects.

Affiliation simply means that the method is written behind the command. In the above example the method *Clear* and in the following

Method	Explanation	Example
Clear	Format, contents and commentary of a data range is cleared. In contrast to *Delete,* the neighboring cells are not moved.	`Range("C2").Clear`
ClearContents	The values in the data range are deleted, while the formatting is maintained.	`Range("D5").ClearContents`
Copy	Copies a data range. Following the command *Destination,* the target range where the cells are moved to is given.	`Range("F5").Copy Destination:=Range("F7")`
PasteSpecial	Only values, formats, comments and so forth are inserted from the cache. This is analogous to the command in the ribbon command bar *Start* ➲ *Clipboard* ➲*Insert* ➲ *Insert Contents*.	`Range("A1:B4").Copy` `Range("A5:B8").PasteSpecial Paste:=xlPasteValues` The first instruction copies the range A1:B4. With the second instruction, only numerical values are entered in the range A5:B8.
Select	*Select* has the same function as marking cells in the table view. Avoid as much as possible the methods *Select* and *Activate*. Address data ranges directly (see Practical Tip).	`Range("B1:C7").Select`
Activate	With *Activate* you can activate the table or cell that needs to be edited. Since only one object can be worked on in Excel, only one cell, for example, can be active at any moment.	`Sheets("Table1").Activate`

Fig. 7.54 Frequently used methods in alphabetical order

example the method *Copy* to copy the range B5:D7 were positioned behind the objects Fig. 7.54.

Practical Tip

Superfluous commands in the source text such as *Select* and *Activate* can be avoided

The two methods *Select* and *Activate* are used by programmers only in exceptional cases, since they unnecessarily increase the size of the source text. They should be avoided as much as possible and can be replaced by directly addressing the cell range. The result is a more structured and professional program.

As an example, the complicated command, which stretches over two lines and results in a range that is colored in blue

```
Range(‘‘B2:D3’’).Select
Selection.Interior.ColorIndex = 5
```

can be optimized by the following single-line command, which achieves the same outcome by directly addressing the cells:

```
Range(‘‘B2:D3’’).Interior.ColorIndex = 5
```

Editing date ranges with *Range*

As already mentioned, the object *Range* allows working with specific data ranges. The following overview clarifies the various commands and the associated assignment of ranges. As a representative example the method *Copy* was selected – it can be replaced with any other method Fig. 7.55.

Action	Command
Individual cells	`Range("G7").Copy`
Individual data range	`Range("A1:C10").Copy`
Cells that are not connected	`Range("A1,A3,A5,A7").Copy`
Several ranges	`Range("A1:A10,C1:C10").Copy`
All cells in the spreadsheet	`Cells.Copy`
Area surrounding one cell	`Range("D5").CurrentRegion.Copy`
Table range that is used. All cells which contain a value will be affected.	`Range("L8").UsedRange.Copy`

Fig. 7.55 Editing cells and data ranges

Editing entire rows and columns with *Rows* and *Columns*

The commands *Rows* and *Columns* are an efficient way to edit rows and columns.

- Marking rows with *Rows*:

`Rows("4:5").Select` (Marking rows 4 and 5)
`Rows(ActiveCell.Row).Select` (Marking the active row)

- Marking columns with *Columns*:
  `Columns("C:D").Select` (The columns C and D are marked)
  `Columns(ActiveCell.Column).Select` (The active columns are marked.)

The relevance of the presented functions (*Range*, *Rows* and *Columns*) becomes apparent, especially in case it is intended to insert or delete rows or columns. This is illustrated by the following program.

The program automatically searches for existing empty cells in a table and inserts "empty cell" into the corresponding cell.

Listing 19 Module Empty_Cell

Example searching for empty cells in a table

```
Sub SeekFreeRow ()
     Dim area As Range
     Dim rngCell As Range
     Set area = Worksheets("VBA_10").
      Range("D13:D25")
     For Each rngCell In area
      If rngCell.Value = "" Then cell.Value =
      "Blank cell"
     Next rngCell
End Sub
```

With the command `Range("D13:D25")`, the data range is restricted to the cells D13 to D25. Within this range, a *For Each* loop goes through each individual cell until an empty one is discovered. In VBA two quotation marks without a space "" symbolize an empty cell. If an empty cell is found, the program marks this cell, for example with the words "Empty cell Fig. 7.56."

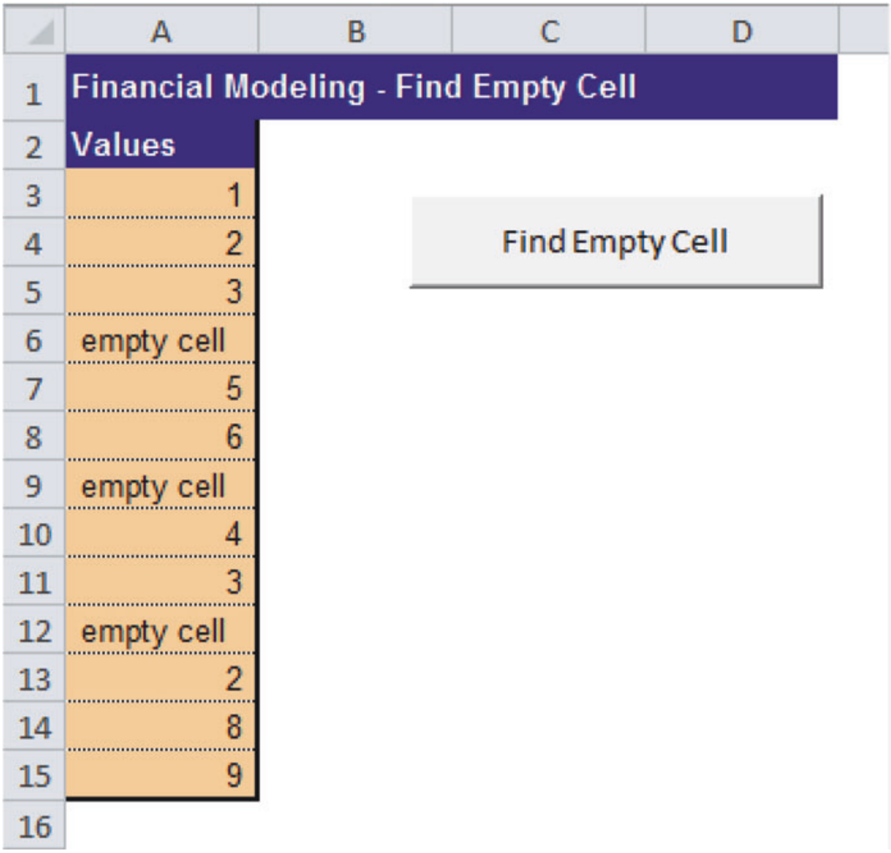

Fig. 7.56 Searching for empty cells (Excel File Workshop VBA, Spreadsheet VBA_10)

Properties: How to Change Objects

You already studied the properties of VBA. Properties can be used to change objects (for example formatting the color of a cell or assigning a value).

Here are two examples:

- `Worksheets("BusinessFigures").Cells(2,2).Value = 40`
- This command line assigns in the spreadsheet BusinessFigures a value of 40 to the cell in Row 2/Column 2.
- `Worksheets("Table2").Name = "A new spreadsheet name"`

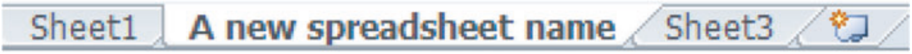

Fig. 7.57 Assigning a new name to a worksheet

Property	Comment	Example
Address	It returns the address of the data range in a string format.	Worksheets("Table1")._ Cells(1, 1).Address() returns the value $A$1
Cells	References a specific cell.	`Range("A1:A6").Cells(3)` makes a reference to the third cell inside the data range, hence the cell A3
Column	Returns the number of the column. Column A has the number 1, Column B has the number 2, and so forth.	object.Column(column, row) with column and row as integers
Font	This property allows setting the font such as "Times New Roman" and its properties (such as bold, cursive).	`Range("A1:B4").Font.Bold = True` `Range("A1:B4").Font.Name = "Times New Roman"` Formats the characters inside the range as bold.
HorizontalAlignment	With this property it is possible to view or to set the alignment of the data range. The three possible values are xlRight for right-aligned, xlLeft for left-aligned and xlCenter for centered.	`myChart.ChartTitle.HorizontalAlignment = xlCenter`
Interior	*Interior* is a reference to the cell contents within a range. This property is frequently used to determine the background color of a cell.	`Range("A1").Interrior.Color = vbRed` The cell A1 is colored red.
Name	This command allows the definition of a range.	`Range("A1:C1").Name = "Cashflows"` The data range contains a name.
NumberFormat	With this property, a specific number format is assigned to a specific data range.	`Range("A1:F1").NumberFormat ="hh:mm:ss"` Converts numbers in the cells A1 to F1 into the format for Hours:Minutes:Seconds.
Offset	Offset is frequently used for single cells and is very useful to target neighboring cells.	`Range("A1").Offset(1, 4)` Targets a cell which is one row below and four columns to the right of the *Range* A1.
Row, EntireRow	This returns the number of the row.	`ActiveCell.EntireRow.Cells(1, 1).Value = 1` Writes the number 1 in the first column of the marked cell.

Fig. 7.58 Most important properties

With the command *Worksheet. Name="New Name"* a worksheet is renamed Fig. 7.57.

Most of the objects have a large number of properties, but only a few are used regularly. Following is a list of the most important properties in alphabetical order Fig. 7.58.

8 Comfortable Input and Output Using Dialogue Fields

VBA offers the comfortable option of providing data input and output with the functions InputBox and MsgBox.

The function *MsgBox* – a field to provide dialogue output – was already used repeatedly in previous listings. In the following sections, you will find out how these functions can significantly facilitate your work.

8.1 Reading Data with the InputBox

You are already familiar with the function Range, which allows you to read data from cells. A solid alternative is the *InputBox*.

The InputBox can be utilized to read data and the user can additionally determine the text which appears in the input dialogue and define standard parameters for the input field.

The *InputBox* opens a window which asks the user to provide certain values. The necessary programming steps are shown in the following example which calculates the net present value.

Listing 20
InputBox

Example of an *InputBox*

```
Sub PVCalculation()
     Dim CF As Double
     Dim i As Double
     Dim T As Double
     Dim PV As Double
     CF = Application.Inputbox("Enter the cash flow",
     & _ "PV Calculation", "100")
     i = Application.Inputbox("Enter a decimal number
       for" & _ "the interest rate", "PV Calcula-
tion", "0.05")
     t = Application.Inputbox("Enter the number of
         years", & _ "PV Calculation", "4")
     PV = CF /((1 + i)  ^ T)
     i = i * 100
     MsgBox "The present value of the following cash
       flows" & _ & CF & "with an interest rate of"
       & i & "% and a" & _ "maturity of"
       & T & "years is:" & PV & "."
End Sub
```

Following the declaration of the variables using the command *Dim,* this short program asks the user for three input values (*CF*=Cash flow, *i*=Interest rate und *T*=Number of years) using the *InputBox*.

The example of the InputBox for the cash flow (CF) can be used to trace the structure of the syntax:

```
     CF = InputBox("Enter the cash flow", "PV Calcula-
tion", "100")
```

The values read by the *InputBox* are stored in the variable CF. Inside the first set of quotation marks is the text for the prompt, the second set of quotation marks determines the title bar and the third set the default for the input field. This can either be accepted or replaced by the user Fig. 7.59.

In the next programming step, the calculation is based on the formula for the net present value and then the result is provided via the message box (*MsgBox*). The individual elements of the message (text and variables) are inserted using a *&*:

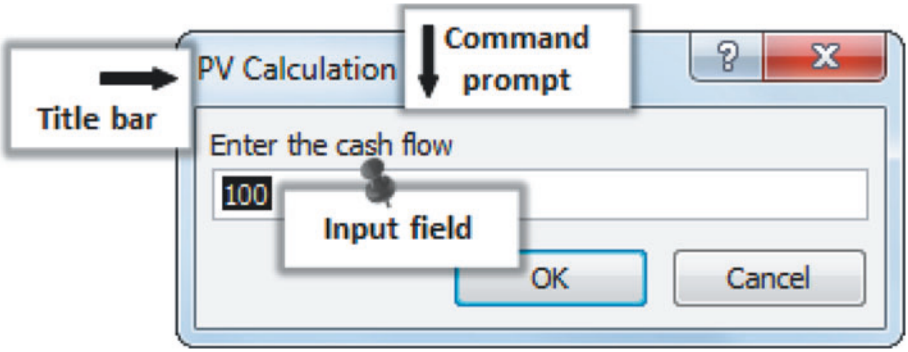

Fig. 7.59 Input box for the PV calculations (Excel File Workshop VBA, Spreadsheet InputBox)

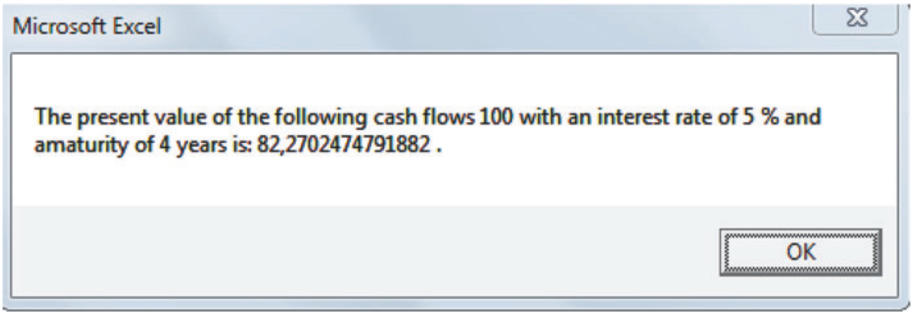

Fig. 7.60 The message box

```
MsgBox "The present value of the following cash
flows" & cf _ "with an interest rate of" & i & "%
and a maturity of " & t_ & "years is:" & pv & "."
```

The result is displayed in the message box (*MsgBox*) Fig. 7.60:

8.2 Data Output with the *MsgBox*

In most cases it is fully sufficient to provide output in a message box (*MsgBox*) as shown above. But the output function can even be enhanced: a button and a symbol can be defined, which are shown in the dialogue box. In addition, a return value of the *MsgBox* can be used to determine which button was chosen by the user when he closed the application.

As a standard setting, VBA displays the button *OK* in a message field. Additional buttons can be shown if desired. As an example, a query involving a yes/no decision (*vbYesNo*) can be used to demand a decision by the user. The result is then saved in a variable and can be processed further.

The syntax for this is as follows:

```
Result = MsgBox(''Would you like to continue'',
         vbYesNo)
```

The command *vbYesNo* assures that two buttons are added to the dialogue field (buttons on the right in Figure 7.61). The values which can be stored as results are *vbYes* or *vbNo* and are predetermined constants in VBA. An applied use of a yes/no query would be to follow up with an *If* branch, so that – depending on the result – differing operations can be performed. In Listing 21, an answer is displayed, which depends on the button chosen Fig. 7.61.

Listing 21 Module Message_Field

Example of a message field with a yes/no combination

```
Sub OutputDialogueYesNo()
     Dim strErgebnis As String
     strResult = MsgBox("Do you want to continue?",
                 vbYesNo)
     If strResult = vbYes Then
       MsgBox "The answer is yes"
     Else
```

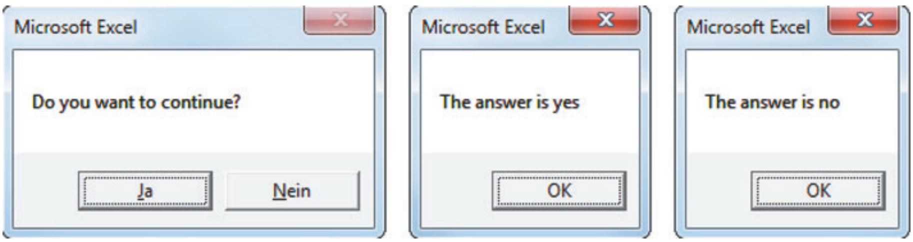

Fig. 7.61 Message field with button (Excel File Workshop VBA, Spreadsheet Message_Field)

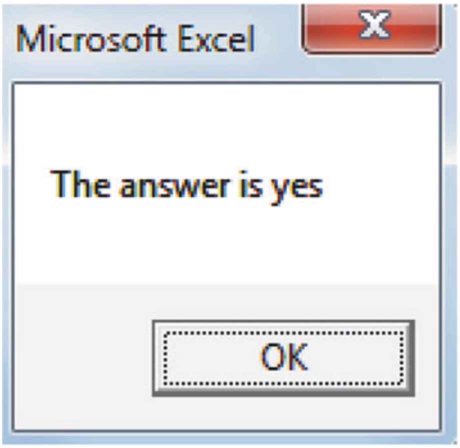

Fig. 7.62 vbInformation

```
        MsgBox "The answer is no"
     End If
End Sub
```

Further modifications

Other properties of the message field can be amended as well. For example, you want to display a symbol and change the title of the dialogue field, which is "Microsoft Excel" in the default setting? You need to provide the command *vbInformation* separated by a comma and followed by the desired title. Here is an example Fig. 7.62:

```
  MsgBox "The answer is yes", vbInformation,
"Calculation completed"
```

9 Programming Your Own Dialogues

> If you want to use VBA for comprehensive tasks and dialogues, for which the previously presented functions InputBox and MsgBox are insufficient, you should familiarize yourself with the user-defined dialogues (also called UserForms).

Here you will learn how to create your own dialogues and how to automate them with the help of programs. A user-defined dialogue facilitates the input of data and saves them in a table. In order to create a dialogue, a so-called *UserForm* (a type of user interface) must be established.

9.1 Steps Needed to Create Your Own Dialogue

With the help of the example of a telephone list, you will learn how to create a *UserForm* *Fig. 7.63*:

1. Access the *Development Environment* with the key combination *Alt + F11*.
2. Go to *Insert*.
3. Choose *UserForm*.

In order to create a dialogue, the needed control elements are inserted via Drag and Drop in the grey area of the *UserForm*. In the Workshop Excel you already familiarized yourself with handling and use of control elements.

In the example of the telephone list, three variables are defined (first name, last name and telephone number). A *text field* is placed next to them, which is used for entering the data. Below, two *command buttons* (Save and Abort) are inserted.

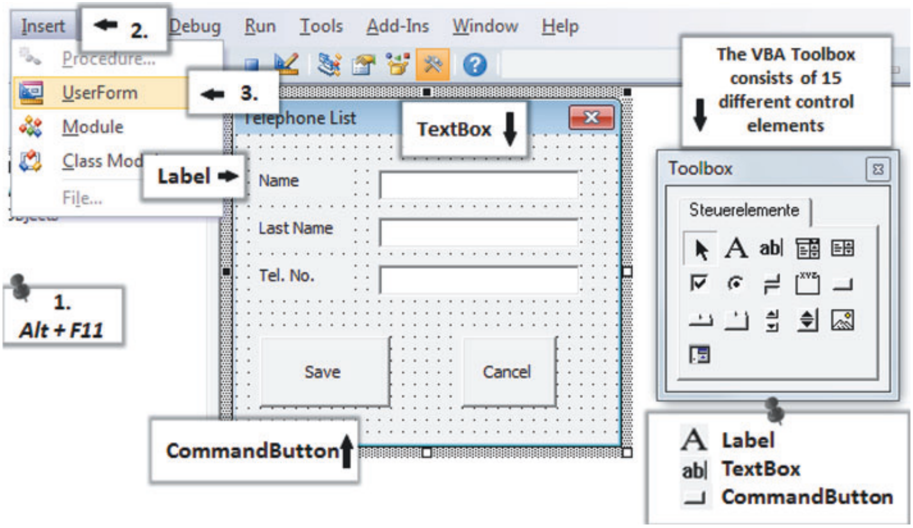

Fig. 7.63 Creating a UserForm

9.2 Control Elements

9.2.1 Setting Properties of the Control Elements

In the next step, the *Property Window* is used to define the performance and optical appearance of the control elements. For the majority of the property fields, a list box can be opened, from which several options can be selected.

Properties which determine the appearance of the buttons are for example *BackColor* (background color), *ForeColor* (color of the font) and *Font* (type of font). Other properties define the performance. These include for example *AutoSize*, which automatically adjusts the breadth and the width of the button to the size of the message displayed, and *WordWrap*, which automatically carries out a line break for the message.

The properties are assigned as follows:

1. Mark the button.
2. The *Property Window* shows a list for the relevant element.
3. There you can make all changes Fig. 7.64.

It is important to assign a name which is used later in the program to address the individual control elements. It needs to be kept in mind that two different properties exist: the property *Name* as well as the property *Caption*:

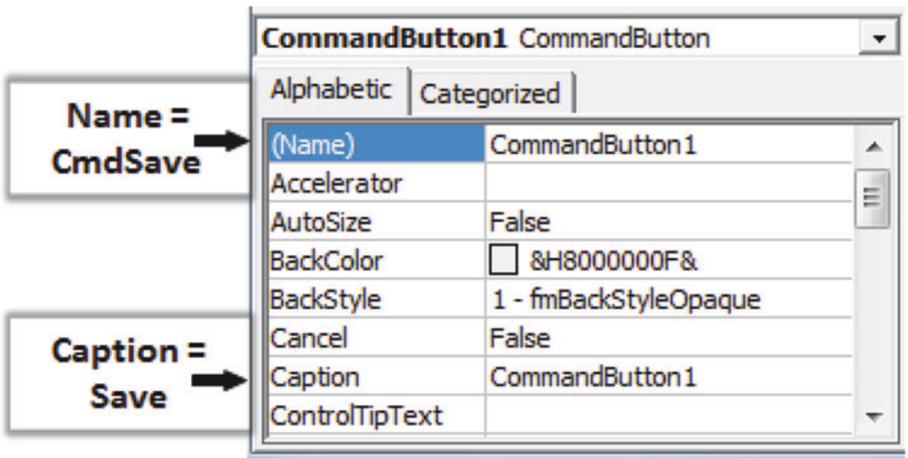

Fig. 7.64 The Property Window

Control element	Prefix		Term used
	Chk		CheckBox
	Txt		TextBox
	Cmd		CommandButton
	Opt		OptionButton
	Lst		ListBox
	Cbo		ComboBox
	Tgl		ToggleButton
	spn		SpinButton
	vsb/hsb		ScrollBar
	lbl		Label

Fig. 7.65 Frequently used prefixes for buttons

- The property *Caption* determines the name shown on the button (such as Save) and
- *Name* the label which is used in VBA to address the element (such as *cmdSave*).

The default setting of VBA is to assign names with numbers in ascending order (*CommandButton1, CommandButton2* and so forth). It is preferable to replace the default *Name* of the button with self-explanatory descriptions. In order to maintain clarity concerning control elements in comprehensive source texts, it is recommended that they are given a *Prefix* as well as a descriptive name.

If, in the example of the telephone list, you want to save entries from text fields in a table by clicking an element, it is advisable to use the *Name cmdSave*. The prefix *cmd* in the source text will later signal that this is a *CommandButton*. The name *Save* signals that it is intended to save data Fig. 7.65.

9.2.2 Programming Control Elements

Events define the activity of control elements. For example the event *Click* will result in the execution of the code. Other possible events for a button are *DblClick* (Double click), *Error*, if an error message is shown and *Keypress*, if a specific key is pressed. These types of events are defined in the VBA Editor in a list field in the upper right margin.

Take the following steps to assign an event to a control element:

1. Mark the button *Save* on the *UserForm* telephone list.
2. Access the context menu with the right mouse button and select *Show Code*.
3. Enter Listing 22 Fig. 7.66.

Listing 22 Form frmPhoneList

Program code of the form for the telephone list

```
Private Sub cmdSave_Click()
     Dim Name As String
     Dim LastName As String
     Dim Telno As String
     Name = txtName.Text
     LastName = txtLastName.Text
     Telno = txtTelno.Text
     Set frm = frmPhoneList
     Sheets("VBA_13").Activate
     Range("A500").End(xlUp).Offset(1, 0).Select
     With frm
         ActiveCell.Value = Name
         ActiveCell.Offset(0, 1).Value = LastName
         ActiveCell.Offset(0, 2).Value = Telno
     End With
End Sub
```

Following the declaration, the data from the text fields of the form PhoneList is read. It is stored in variables of the type *string* and afterwards stored in the next free space of the table *PhoneList*. The command O*ffset*(0,1) respectively (0,2) prevents that values are overwritten in the same cell and defines that the entries are placed one, respectively two columns to the right of the active cell.

Combining *UserForm* with a macro:
To run the *UserForm* telephone list comfortably with the help of a VBA program, follow these additional steps:

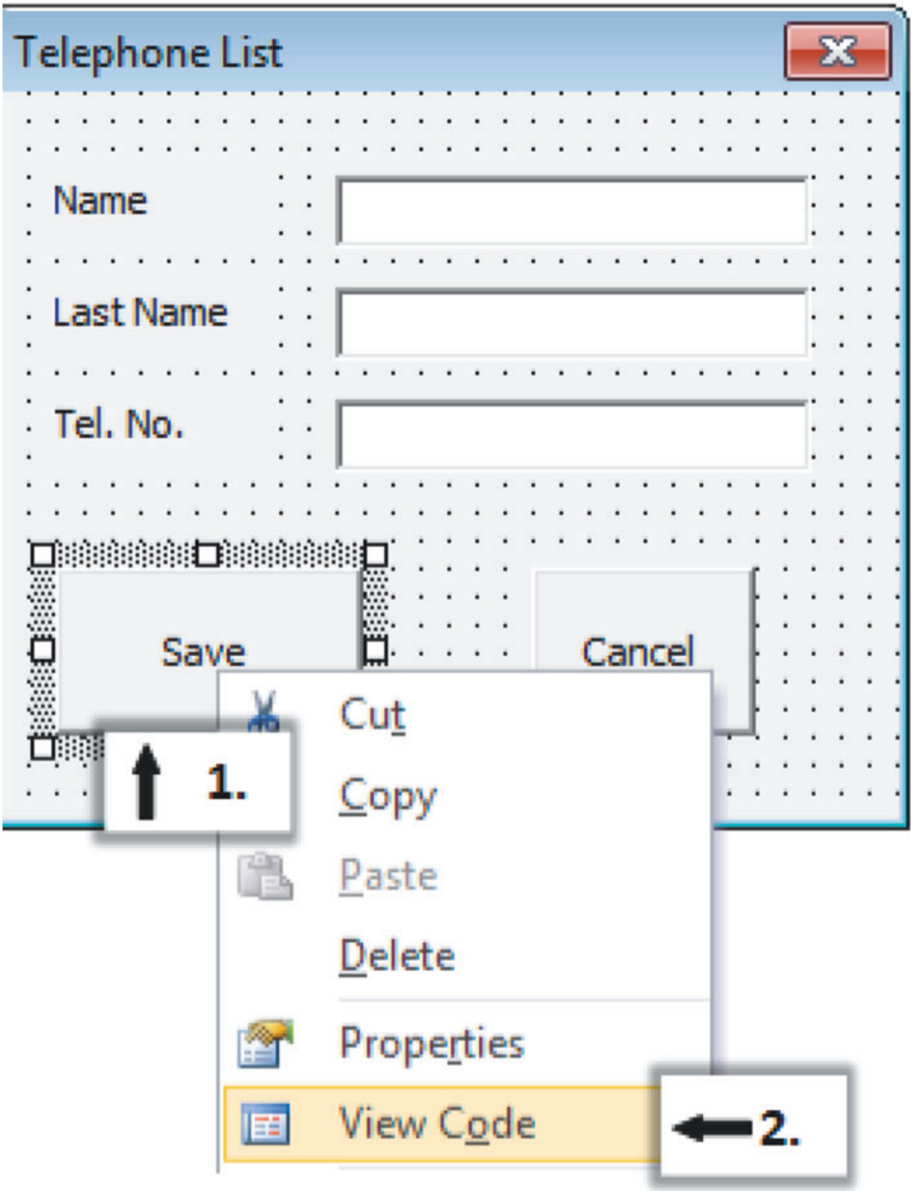

Fig. 7.66 Programming a control element

Listing 23
Form frmPhoneList

Displaying a UserForm

```
Private Sub UserForm_Click()
End Sub
```

4. Switch to the spreadsheet Phone_List.
5. Insert a command button via *Developer Tools* ➲ *Control Elements* ➲ *Insert* ➲ *Button* (Fig. 7.67).
6. Should the menu *Developer Tools* be unavailable, you can activate it Fig. 7.67
7. Click the button with the mouse. The menu *Assign Macro* will appear.
8. Select the macro *ShowUserForm Fig. 7.68*.

The complete dialogue telephone list Fig. 7.69.

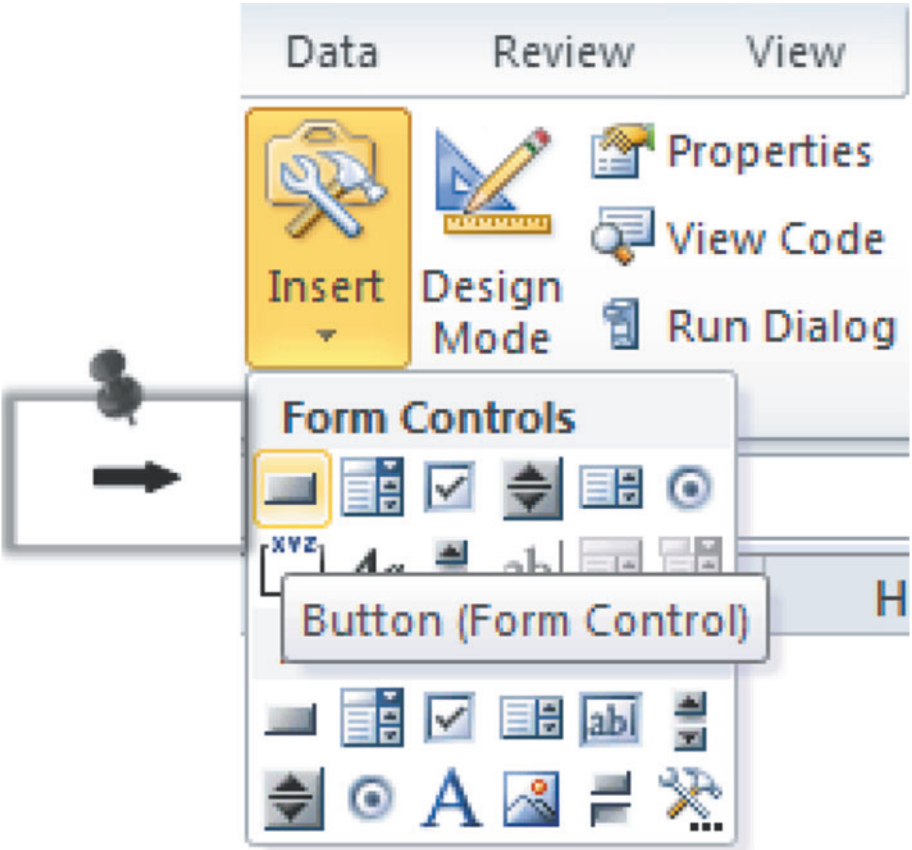

Fig. 7.67 Command button for inserting UserForm

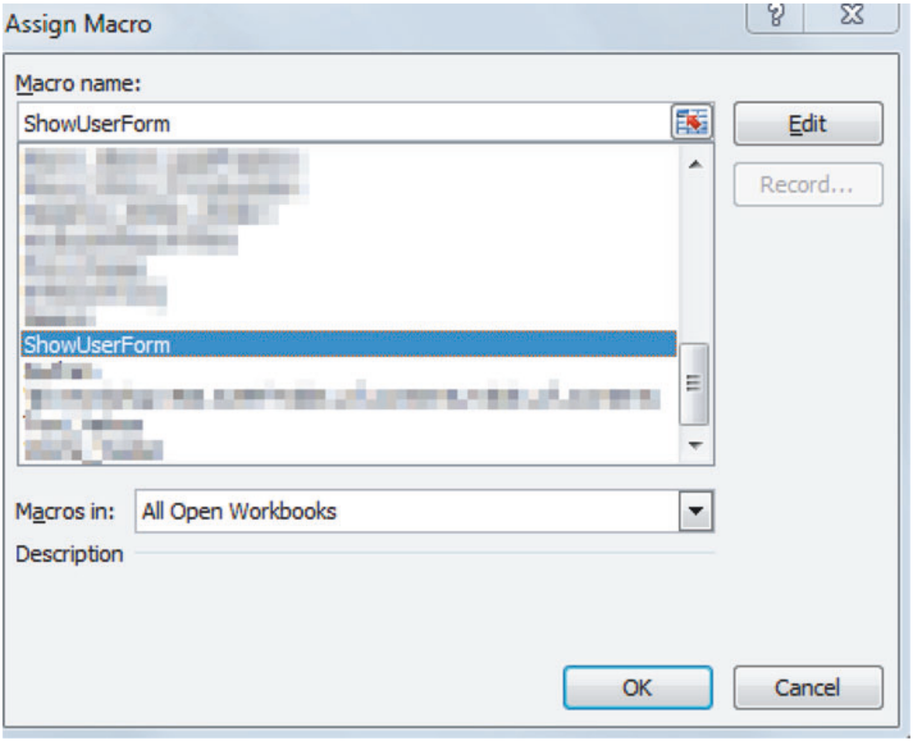

Fig. 7.68 The macro ShowUserForm

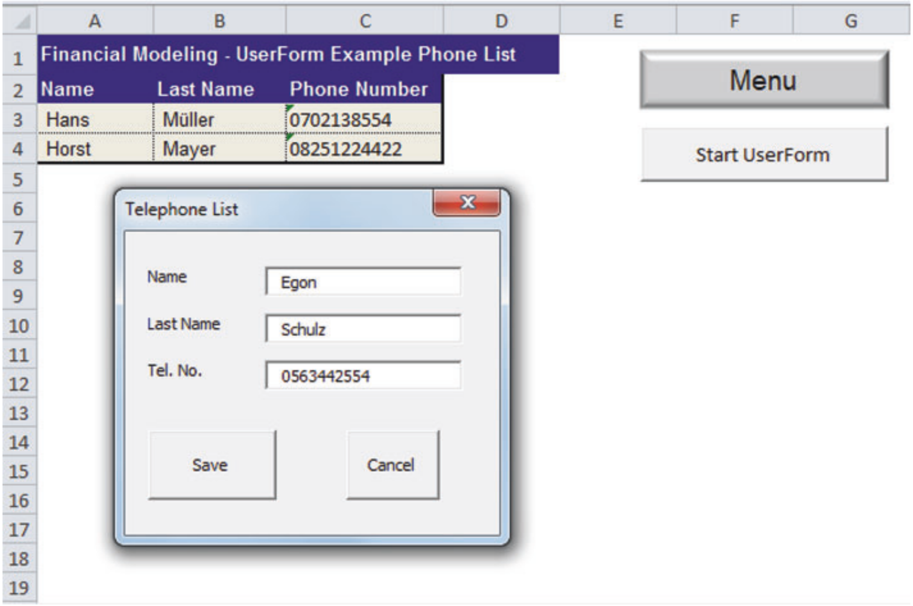

Fig. 7.69 Creating the telephone list (Excel File Workshop VBA, Worksheet Phone_List)

10 Creating Charts with VBA

10.1 Information needed and Types of Diagrams

Diagrams help to visualize data and thus make it easier for the user to comprehend interlinkages. Working with diagrams was already presented in the Workshop Excel. However, it can occasionally be very time-consuming to generate charts manually. The chart assistant can be very helpful in this regard, but standardized tasks are even more efficiently solved in VBA. In this Section, you will therefore become familiar with basics of creating diagrams:

- Setting a data range,
- Presenting chart titles,
- Choosing display and type of chart.

The information in Fig. 7.70 contains a portfolio consisting of different allocations from five industries. The task is to present these with the help of a pie chart. Listing 24 presents a possible solution for this task Fig. 7.70.

Listing 24
Module Create_Diagram

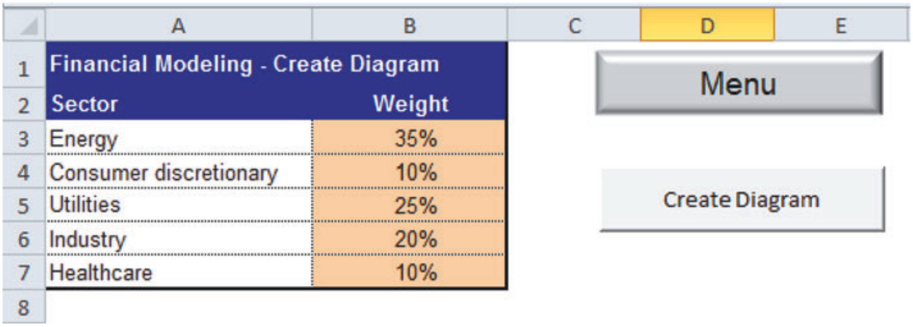

Fig. 7.70 Information needed for a diagram (Excel File Workshop VBA, Spreadsheet Create_Diagram)

Program code for diagram

```
Sub CreateDiagram ()
   Dim rngData As Range
   Dim shtName As String
   Set rngData = Range(''A1:B7'')
   shtName = ActiveSheet.Name
   Charts.Add
   With ActiveChart 'Display settings
      .ChartType = xlPie
      .SetSourceData Source:= rngData
      .ApplyDataLabels xlDataLabelsShowPercent
      .HasTitle = True
      .ChartTitle.Text = shtName
      .Legend.Format.TextFrame2.TextRange.Font.Size = 14
      .SeriesCollection(1).DataLabels.Format.TextFrame2&_
      .TextRange.Font.Size = 16
      .ChartStyle = 1
   End With
End Sub
```

Following the declaration of the required variables, the data range for the diagram is set. It is stored in the variable *rngData*. The command `Set rngData = Range("A1:B7")` determines the target cells for the diagram. In this example, the title of the diagram is the table name.

Below follows the source code, which is relevant for the display of the diagram. The method *Add* creates the diagram. With the method *ChartType,* the constant *xlPie* selects the diagram type pie chart. In Fig. 7.71 you find additional examples of diagram types and the corresponding constants.

The data sources for the diagram are established with the methods *SetSourceData* and *ApplyDataLabels*. *HasTitle* is a property used to display the diagram title. The value *True* enables the display. The variable *shtName* sets the text of the heading via the property *ChartTitle.Text Fig. 7.71*.

As is apparent in Fig. 7.70, the button *Create Diagram* was inserted. It is generated via the commands *Developer Tools* ➲ *Insert* ➲ *Form Control Elements* ➲ *Button*.

The macro will create this diagram, which is displayed in a new spreadsheet Fig. 7.72.

Description	Constant
Grouped Columns	xlColumnClusterd
3D-Columns	xl3DColumn
3D-Columns grouped	Xl3DColumnClusterd
Stacked columns	xlColumnStacked
Grouped Bars	xlBarClustered
3D-Bars grouped	xl3DBarClustered
Bars stacked	xlBarStacked
3D-Bars stacked	xl3DBarStacked

Fig. 7.71 Different types of diagrams

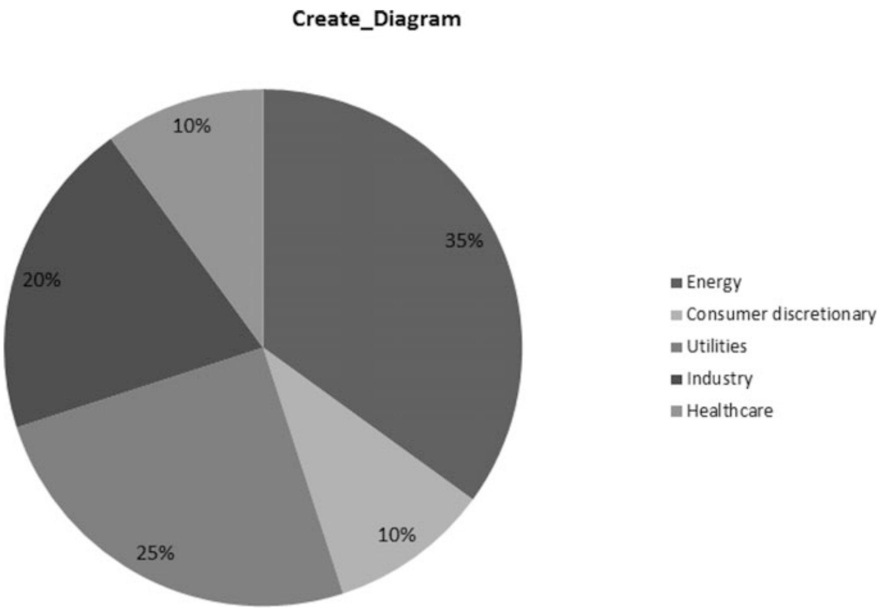

Fig. 7.72 Pie chart created in VBA

10.2 Useful Programs for Diagrams

In its current version, Excel offers mature functions which allow the effective creation of diagrams, even without the use of VBA. Nonetheless, numerous daily activities continue to be rather cumbersome given the available standard solutions. The following listings aim at facilitating your work with diagrams.

10.2.1 Saving Embedded Diagrams as Graphics

In Excel there is no direct option to export embedded diagrams. (Note: embedded diagrams are placed on the data spreadsheet and not on a separate sheet for the diagram.) Such a tool is advantageous if diagrams need to be forwarded via email or used in a text program such as Word without resorting to links. A possible solution is a program which converts diagrams in a graphics format such as gif or jpg and stores them in a separate file.

The program in Listing 24 converts all embedded diagrams of a workbook into a graphics format (gif) and exports them to the directory "D:\Diagrams."

At the core of the macros are two *For Next* loops. The first one searches for diagrams in all spreadsheets and the second one exports all diagrams that were found in a graphics format. The command

Sheets (Counter variable for the tables present). *ChartObjects* (Counter variable for the tables present). *Select* is used to address the diagrams. With the *Set* command, information is provided about the location of the integrated diagram. Next follows the method of export *.Export* with the filename used to store the chart. The format of the graphics is determined with *FilterName*. Finally the user is informed about the storage location via a *MsgBox*. However, this directory needs to be created first, otherwise it cannot be found and an error message is displayed Fig. 7.73.

Listing 25
Module Export_Diagram

Saving diagrams as graphs

```
Sub DiagramPicture ()
    Dim dia As Chart
    Dim intSht As Integer
    Dim intDia As Integer
    Dim intln As Integer
    intln = 0
    For intSht = 1 To Worksheets.Count
    For intDia = 1 To Sheets(intSht).ChartObjects.Count
    Sheets(intSht).ChartObjects(intDia).Select
```

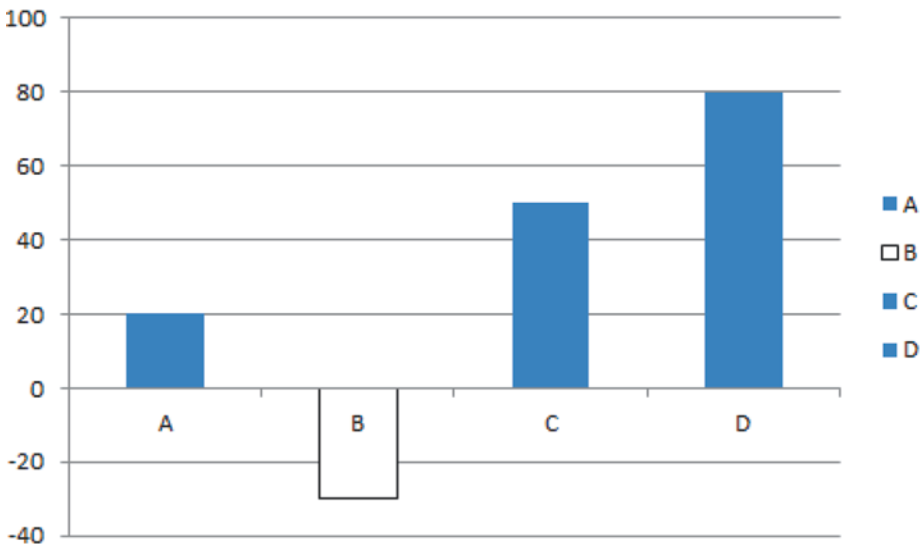

Fig. 7.73 Exporting diagrams (Excel File Workshop VBA, Spreadsheet Export_Diagram)

```
    Set dia = Sheets(intSht).ChartObjects(intDia) & _
              .Chart
    intln = intln + 1
    dia.Export ThisWorkbook.path & "" & No." & intln
      & _ & ".gif", "GIF"
    Next intDia
    Next intSht
    MsgBox"The charts are saved in the parent folder
    of" & _ "this file"
End Sub
```

10.2.2 Printing Embedded Diagrams

Working with embedded graphs is not only challenging in the case of exports: printing several embedded diagrams on a single sheet of paper can only be solved with the help of a program.

Listing 26 Module Printing Diagram

Printing embedded diagrams

```
Sub Print_Embedded_Diagram ()
     Dim chtDia As ChartObject
     For Each chtDia In ActiveSheet.ChartObjects
       chtDia.Chart.PrintOut
     Next chtDia
End Sub
```

The loop *For Each* determines that a printout should be made of each diagram. This is done until there are no more active diagrams in the active table.

10.2.3 Use of Color to Highlight Negative Numbers in a Diagram

In business life it occasionally happens that companies produce negative results, even if this is not intended. If it is desired to highlight negative numbers in diagrams in a different color, Excel requires a lengthy and complicated chain of commands:

1. Mark the negative data series with the right mouse button.
2. In the context menu, choose the command *Formatting Data Series*.
3. In the dialogue field *Filling* activate the control field *Invert if Negative*.

Additional information on this topic can be found in the Workshop Excel (Section Time Series Comparison: How does a Value Driver Change over Time?)

A more elegant solution is provided by the program in Listing 27. With the help of the macro, all negative columns are colored in white. If additional negative numbers are recorded at a later point in time, the program automatically colors these as well. No program restart is needed.

Listing 27
Module Changing_Column_Color

Showing negative values in white (see Weber/Schwimmer, 2008, p. 554)

```
Sub Change_Negative_Numbers()
    Dim i As Integer
    Dim chDiagram as Chart
    Set chDiagram = Work-sheets("Change_Bulk_Color").
                    ChartObjects(1).Chart
    For i = 3 To 6
    j = i -- 2
    If Cells(i, 2) < 0 Then
       chDiagram.SeriesCollection(1).Points(j).Fill.
       ForeColor.Scheme_ Color = 3
    Else
       chDiagram.SeriesCollection(1).Points(j).Fill.
       ForeColor._ SchemeColor = 4
    End If
    Next
    End Sub
```

Following the declaration, the program determines the number of data sets with the help of the *Chart.SeriesCollection* method. A *For-Next* loop goes through all the data sets and assumes the setting *InvertIfNegative = True*. In other words, it uses the property to invert any negative number that exists.

10.2.4 Creating Dynamic Diagrams

A frequent problem in applied work is the inability to assess in advance how many data periods are required in a diagram. If new data is added, the diagram needs to be created again or time consuming adjustments must be made. The following listing provides relief by creating dynamic diagrams, which can be easily extended.

Listing 28 Module Dynamic_Diagrams

Creating dynamic diagrams (see Weber/Schwimmer (2008), pp. 570 following)

```
Sub DynDiagram ()
     Dim dblColumnn As Double
     Dim dblRow As Double
     Dim works As Worksheet
     Set works = Worksheets("Dynamic_Diagram ")
     dblRow = Cells(1048000, 1).End(xlUp).Row
     dblColumnn = Cells(1, 16000).End(xlToLeft).Column
     'Creating the diagram
     With Charts.Add
       .ChartType = xlColumnClustered
       .SetSourceData Source:=works.Range(works.Range
       (``B3"), works.Cells(dblRow, dblColumnn))
       .Location where:=xlLocationAsObject,
     Name:=``dynamic_diagrams"
     End With
End Sub
```

Two border variables are assigned in this program with the cell positions (1048000,1) and (1, 16000). The program code then checks all cells inside the allowed range. As soon as data is contained, it is linked with the diagram and displayed.

11 Tool Kit: Practical Excel Tools for Modeling

11.1 Programming Headers and Footers

The creation of headers and footers can be realized efficiently with a macro. Specific values such as table name, page numbering, cell references as well as date can be accessed by adding several buttons in the Excel environment.

The following program will display this information in the header and footer of a table:

- header left: the theme of the table (from the contents of cell A2)
- Header middle: the author of the table (from the document properties)
- Header right: the date (month is spelled out and year has four digits)

- Footer left: the name of the file/table
- Footer right: the page numbering (page X of Y pages)

Listing 29 Module Header_and_Footer

Setting header and footer for a table

```
Sub HaF_Create_sht ()
     With ActiveSheet.PageSetup
     .LeftHeader = ActiveSheet.Range("C2").Value
     .CenterHeader = _
     ThisWorkbook.BuiltinDocumentProperties("Author")
     .RightHeader = Format(Date, "DD. MMMM YYYY")
     .LeftFooter = "&F/&A"
     .RightFooter = "Page &P of &N"
     End With
End Sub
```

In order to access individual components such as left headers, the object *PageSetup* must be used in the beginning. The respective position of the *Header* or *Footer* is determined by *Left*, *Center* or *Right* and can be filled by assigning any value. The content of the left header is determined by the value in cell *C2*.

The name of the author of the table can be displayed with the command `ThisWorkbook.BuiltinDocumentProperties("Author")` and put in the desired position. In case the macro needs to be utilized for the complete workbook, the previous program can be modified as follows:

Listing 30 Module Header_and_Footer_Workbook

Setting headers and footers for a workbook

```
Sub HaF_Create_Workbook()
   Dim Table As Worksheet
   For Each Table In ThisWorkbook.Worksheets
      With Tabelle.PageSetup
      .LeftHeader = Table.Range("A1").Value
      .CenterHeader = _
      ThisWorkbook.BuiltinDocumentProperties("Author")
      .RightHeader = Format(Date, "DD. MMMM YYYY")
      .LeftFooter = "&F/&A"
      .CenterFooter = ThisWor-
      book.BuiltinDocumentProperties("Author")
      .RightFooter = "Page &P of &N"
      End With
  Next Table
End Sub
```

Here a *For-Each* loop goes through all the spreadsheets in the workbook and individually places the needed settings.

11.2 Transferring Comments to a List

The following program code can be used to transfer tables with many comments and the corresponding cell addresses to a list in order to maintain a protocol.

Listing 31
Module Commentary_List

Listing commentaries

```
Sub ListComments ()

     Dim Note As Comment
     Dim Table As Worksheet
     Dim DokuSheet As Worksheet
     Dim intZ As Integer
     Set DokuSheet = Worksheets.Add
     intZ = 1
```

```
    For Each Table In ThisWorkbook.Worksheets
         For Each Note In Tabelle.Comments
            DokuSheet.Cells(intZ, 1).Value = Note.Text
            DokuSheet.Cells(intZ, 2).Value = & _ Note.
            Parent.Address & _
            "in" & Table.Name
            intZ = intZ + 1
         Next Note
    Next Table
    With DokuSheet.Columns("A")
    .ColumnWidth = 40
    .HorizontalAlignment = xlLeft
    .VerticalAlignment = xlCenter
    End With
    With DokuSheet.Columns("B")
    .ColumnWidth = 10
    .HorizontalAlignment = xlLeft
    .VerticalAlignment = xlCenter
    End With
End Sub
```

First an object variable of the type *Comment* must be declared to address the comments in the workbook. Two object variables of the type *Worksheet* as well as two counter variables of the type *Integer* are also created. In the following, the method *Add* is used to create a new table, which is then used to store all comments including their address dates.

The counter variable *intZ* is set at its starting value and the following loop goes through the individual spreadsheets in the workbook. Inside this loop, an additional loop checks all comments and transfers cell contents with the property *Text* into the newly created table. In the next command line the address information of the cell with the property *Parent* is read and also transferred to the newly created spreadsheet.

Once all the loops have been processed, several formatting commands are executed such as the properties *ColumnWidth* for the width of the column and *HorizontalAlignment* respectively *VerticalAlignment* for the alignment of the text for column `A` and `B`.

11.3 Creating a Table of Contents

The following programming code can be used to create a table of contents in a separate spreadsheet. This is particularly relevant if a workbook contains a large number of spreadsheets. The program determines the name of the spreadsheet, adds it to a table, and provides a link. In this way, the user can access the desired cell with a simple click of the mouse.

Listing 32 Module Table_of_Contents

Creating a table of contents

```
Sub Table_of_Contents ()
    Dim dblTab As Integer
    Dim dblRow As Integer
    Dim Table As Worksheet
    For Each Table In ActiveWorkbook.Sheets
     If Table.Name = "Contents" Then
      MsgBox ("Existence of Spreadsheet Content &_
          determined. To update, please confirm ")
      Sheets("Contents").Delete
     End If
     Next
    Set Table = Worksheets.Add(Before:=Worksheets(1))
    With Table
      .Name = "Contents"
      .Range("A1").Value = "Table_of_Contents"
      .Range("A1").Font.Bold = True
      dblRow = 3
      For dblTab = 2 To ActiveWorkbook.Sheets.Count
      .Cells(dblRow, 1).Value = dblRow - 1
      .Cells(dblRow, 2).Value = Worksheets(dblTab).Name
      .Hyperlinks.Add Anchor:=.Cells(dblRow, 2), _
      Address:="", SubAddress:= _
      .Cells(dblRow, 2).Value & "!A1"
```

```
      dblRow = dblRow + 1
      Next dblTab
    End With
End Sub
```

Following the declaration, *Method.Add* is used to create a new table. The parameters `Before:=Worksheets(1)` determine the positioning of the table. In this case the new table is moved to the front. The command `Name ="Contents"` determines the name of the spreadsheet. In the table itself, the commands `.Range("A1") .Value = "Table_of_Contents"` and `.Range("A1").Font.Bold = True` mean that the word "Table of Contents" will be inserted in bold letters in cell `A1`. Subsequently, the variable `Row` is set equal to 3 in order to achieve space between the heading and the actual table of contents.

With the help of a *For* loop, all tables in the workbook are searched. The names of the various tables are collected in the table Contents and links are created via the chain of commands `.Hyperlinks.Add A chor:=.Cells (dblRow, 2), Address:="", Sub-Address:=.Cells(dblRow,2). Value & "!A1".` This is repeated until the names of all tables and the corresponding links have been inserted.

11.4 Protecting Cells with Formulas

It is possible to protect certain cells from changes. This can make sense if they contain important formulas, which should definitely not be altered. The advantage is that only parts of the spreadsheet are protected while others can still be edited.

The following program enables you to recognize cells that contain formulas and to protect them against changes.

Listing 33
Module Formula_Protect

Protecting formulas

```
Sub Formula_Protect ()
   Sheets("Protect_Cells").Activate
   Cells.Select
   Selection.Locked = False 'Cancel all existing locks
   Selection.SpecialCells(xlCellTypeFormulas).Select
   Selection.Locked = True 'Lock all formulas
   Sheets("Protect_Cells").Protect Password:=
     "Formula", _
   DrawingObjects:=True, Contents:=True,
     Scenarios:=True
End Sub
```

First the relevant table is selected via the *Activate* command. Next, all cells are selected and with the command *Selection.Locked = False* all cells are unlocked. In the next step, all cells that contain formulas are selected. With the command *Selection.Locked = True* all selected cells, namely all cells that contain formulas, are protected.

In the end, the password needed to unlock all cells is determined. The command is

```
Sheets("Protect_Cells").Protect Password:
="Formula", _
DrawingObjects:=True, Contents:=True,
Scenarios:=True.
```

Any accidental deletion of formulas in the table is prevented.

Concluding remarks:

As you have noticed, a wide range of VBA commands exists and there are many opportunities to use them in Excel. Obviously it is very difficult or even impossible to commit all of these commands to memory. Fortunately this is not necessary, since the VBA Editor provides sufficient guidance to become familiar with the needed commands and operations. The commands discussed in this chapter provide a solid foundation for the writing of additional user-defined programs. The programming elements presented here will enable you to implement a large portion of the total programming code of future programs.

Specific commands are mostly needed for the core function of the programs. However, these are surrounded by loops or IF Branches, which assure that the commands are applied to several ranges simultaneously or only under certain conditions.

Looking ahead:

In the following finance modules, you will become familiar with a number of applications that are programmed in VBA (for example sensitivity analysis in corporate finance and user-defined functions for the calculation of calls and puts), which draw on many of the functions discussed in this chapter.

12 Summary

In this chapter, the Financial Modeler learned how to:

- Activate the development environment and how to set the virus protection,
- Use the macro recorder,
- Execute existing macros,
- Read and understand programming code,
- Navigate the development environment with the areas project explorer, property window and VBA Editor,
- Differentiate between *Sub* and *Functions* procedures,
- Clearly structure programming code with the help of bookmarks and indentation,
- Use the supporting functions of the VBA Editor such as ColorCoding, IntelliSense and Quickinfo,
- Utilize the object catalogue and its functions,
- Use keyboard commands for quicker programming,
- Avoid errors such as runtime errors, typographical errors and logical errors when using the VBA Editor,
- Eliminate errors with the debugging functions,
- Work with different types of data, the corresponding notations, and possible applications,
- Assign variable names,

- Use flow diagrams as a helpful tool for planning and implementing of different programs,
- Use *IF Branches*, nested *IF Branches* and the corresponding relational and logical operators,
- Use commands to activate *Select-Case*,
- Work with the frequently used loops such as *For-Next*, *Do-While* and *Do-Until* to support the user in case a set of commands needs to be repeated,
- Change objects such as cells and ranges for example, by using methods and properties,
- Program data input and output via an input and output box,
- Utilize UserForms, control elements as well as the tool box to set up dialogues. The properties of the control elements can be set by calling the property window,
- Create diagrams with the help of VBA,
- Use practical preprogrammed Excel tools for financial modeling.

Further Reading

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8

Investment Appraisal

1 Executive Summary

Pharma Group wants to determine the most suitable investment appraisal methods. Both static and dynamic methods are taken into consideration.

Among the static methods are the cost comparison method, the profit comparison method, the average rate of return method as well as the static payback period method. The values underlying the investment decision are calculated for an average period such as one year. This simplifying assumption is lifted for the dynamic methods, where all relevant periods which generate cash inflows and cash outflows are considered. Pharma Group utilizes the following dynamic methods of investment appraisal: net present value method, annuity method and internal rate of return method.

While the static methods of investment appraisal are easy to apply, it is also clear that the short-term perspective, i.e. the time span of one (average) period and the fact that the timing of cash flows is ignored are serious flaws. It is also revealed that the static methods of investment appraisal can lead to different investment decisions.

The various dynamic investment appraisal methods allow greater precision in the assessment of investments than the static procedures, consider more than one time period and acknowledge the time value of money. At the same time, they are more complex and challenging concerning data requirements and methodology and – just as the static methods – can still lead to different investment decisions.

J. Häcker and D. Ernst, *Financial Modeling*,
Global Financial Markets, DOI 10.1057/978-1-137-42658-1_8

When comparing the three possible approaches net present value method, annuity method and internal rate of return method, it is revealed that the net present value method and the annuity method always lead to the same investment decision. An investment project is favorable for Pharma Group whenever the present value and thus the annuity of an investment project are greater than zero. In this case the internal rate of return also exceeds the discounting factor (imputed interest). The investor relations department of Pharma Group will only present to the shareholders a single method of assessing the investment outcome. They select the net present value method and choose to ignore possible debates about differences in methodology.

2 Learning Outcomes, Definitions, Model Structure and Case Study

Structure

This chapter deals with the topics of investment and provides answers for the following questions:

- What is meant by investment and which methods of investment appraisal are available?
- How can an investment decision be reached based on static investment appraisal methods?
- What are the advantages and disadvantages of static investment appraisal methods?
- How can an investment decision be reached on the basis of dynamic investment appraisal methods?
- What are the advantages and disadvantages of dynamic investment appraisal methods?

Learning outcomes

The financial modelers are able to:

- Provide an overview of the most important methods of investment management.

- Compare the most important methods of investment, critically discuss advantages and disadvantages and draw conclusions for their use in applied work.
- Relate investment to other chapters, especially financing and corporate finance.
- Use their knowledge of investment to develop professional models which can be utilized to assess the viability of investment opportunities on the basis of the financial modeling standards.
- Independently structure complex tasks in investment and to develop independent modules for their solution.
- Critically assess the outcomes of investment measures and explain differences.
- Interpret the outcomes of investment measures and independently draw conclusions for investment decisions.
- Review the structure and results of investment models using Model Review/Audit.
- Manage a project in the field of investment and jointly develop solutions with a group of finance specialists.
- Develop a transparent and complete documentation of assumptions and methods for a given investment project.
- Recognize the linkages among different investment methods and apply the most suitable approach for a given case.
- Structure the process of investment decisions and apply the standards of professional financial modeling.
- Apply the knowledge to specific investment projects and modify it to meet the demands of the actual valuation situation.
- Solve new and unfamiliar tasks in the field of investment with the help of financial modeling instruments.
- Critically challenge the assumptions, algorithms and results of every investment decision.
- Present and defend the results of the valuation in front of clients.

Case Study

The financial models for the case studies are found in the download offering in the Excel files “Investments”. Use the contents of the download offering as you work through the text:

- The individual learning steps are separated into small units on different worksheets.
- All calculations are done directly in Excel, in order to assure their traceability.
- All input data that are assumptions and needed for the calculations in the financial model are found in the worksheet “Assumptions”.
- All input data are marked in the color light orange. These values are assumed by the valuation expert and entered individually.
- All calculations and output data are marked in the color gray. These are values that result from calculations.
- Mixed formulas that contain both numerical values and cell references are highlighted by the font color green.
- Assumptions and calculations are found on different sheets to improve clarity of presentation.
- The static investment methods are discussed first, followed by the dynamic approaches.

3 The Term Investment and Methods of Investment Appraisal

> Investments are defined as the use of non-financial assets and financial assets in order to create wealth.

An investment is defined as the use of financial means to create tangible and intangible assets (real investments) as well as financial assets (financial investments). Initial investment outlay is compared to future inflows and outflows, which result from the use of the newly created assets. This comparison determines the viability of the investment.

If a company is viewed as a portfolio of investment objects, the investment decisions (together with the financing decisions) of the management are of particular importance. These decisions are based on methods of investment appraisal, which try to answer the fundamental economic questions of whether an investment should be made and which investment should be chosen among a selection of different alternatives.

From a theoretical perspective, dynamic investment methods are preferred over static approaches.

In contrast to static methods, dynamic investment approaches precisely capture all inflows and outflows. In addition, the timing of these cash flows, which are not constant over time, is taken into consideration. This is done by discounting all future cash flows (which can also be negative) related to an investment project that are due at different points in time to the valuation date (time the investment takes place) based on the principle of compound interest. In a simplified version of investment appraisal, the period-specific interest rates are replaced with an interest rate that is constant over time and reflect the average level of interest rates in the market.

In applied work, the assumption of a perfect capital market is not defendable. Investments are financed using equity and/or debt and different costs of capital exist. If an investment is financed exclusively with equity, the discount rate can be derived from an alternative return available in the capital markets (cost of equity) or the average return of a similar investment object. Investments that are exclusively debt financed can be assessed using the cost of debt to discount the net cash flows. If an investment relies on both equity and debt financing, the discount rate can be calculated as the weighted average of cost of equity and cost of debt. In this respect, the discount rate can be interpreted as the minimum rate of return that the investor demands for his activities.

Investment appraisal forms the basis for making decisions about investments.

The task of investment appraisal is to forecast the financial effects of a planned investment and to present the data in such a way that a reasoned investment decision can be reached.

In theoretical work and in the literature, a distinction is made between the following two major groups of investment appraisal methods:

- Static methods
- Dynamic methods

4 Static Investment Appraisal Methods

The static methods of investment appraisal are used frequently in applied work.

Static methods of investment appraisal are frequently used in applied business practice due to their simplicity and clarity.

Static methods are considered static due to the fact that they fully or partially ignore the timing of inflows and outflows and assess the profitability of an investment for a time span of one (average) period.

Essentially only three basic data are needed

1. Cost of the investment: These are not the costs of acquisition or production, but rather the costs that accrue during the term of the investment, such as depreciation, personnel expenses, maintenance and so forth. However, these costs are linked to the magnitude of the acquisition or manufacturing costs.
2. Capital needed for the investment: Acquisition or production costs plus all auxiliary costs needed to obtain a functioning investment.
3. Sales that result from the investment: Ideally (frequently not possible) all sales that are directly attributable to the investment are considered.

This data set is sufficient to work with the main static methods (see Fig. 8.1). Among the static methods of investment appraisal are the

- Cost comparison method,
- Profit comparison method,

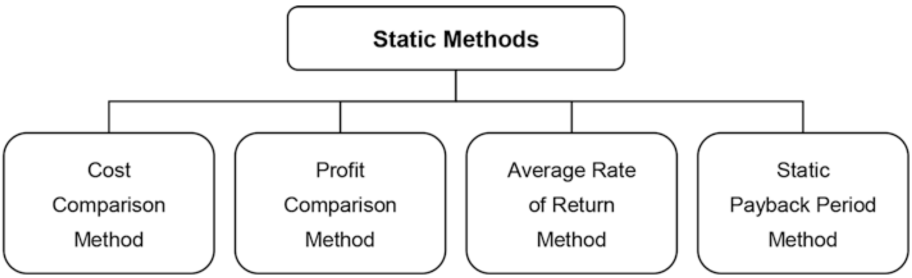

Fig. 8.1 Static methods of investment appraisal methods

- Average rate of return method and
- Static payback period.

Costs and revenues are used as the project data. Costs can be cash relevant such as material, energy, and wages or imputed costs such as imputed interest, imputed depreciation, and imputed entrepreneurial profit. They are stated as annual averages.

It is the aim of the investor to:

- Minimize the cost or the static payback period
- Maximize the profit or the average rate of return

Example:

The static methods of investment appraisal are presented with reference to a comprehensive example and are compared. Investment opportunities in two machines need to be assessed (Machine 1 and Machine 2). Figure 8.2 shows the starting data for the example.

Assumptions Investment Object

Basic data	Machine 1	Machine 2
Investment in depreciable capital equipment (in €)	100,000	70,000
Useful life (in years)	5	5
Residual value of equipment (in €)	10,000	5,000
Investment in non-depreciable capital equipment (in €)	12,500	9,000
Planned utilization (units per annum)	20,000	20,000
Sales revenue per unit (in €)	4.20	4.30
Fixed cost excluding cost of capital (in €)	7,500	5,000
Imputed interest rate (% p.a.)	10%	10%
Wages and incidental wage costs (€/unit)	0.8	1.2
Raw, auxiliary and operating materials (€/unit)	0.2	0.2
Other variable cost (€/unit)	0.1	0.3

Fig. 8.2 Assumptions concerning the methods of static investment appraisal (Excel File Investment, Worksheet Assumptions_Stat._Invest.Calc)

4.1 Cost Comparison Method

The cost comparison method only considers costs.

The cost comparison method is the simplest method of investment appraisal.

The cost comparison method looks at the costs of two or more alternative investments during a period of planning or usage.

The cost comparison method can be applied to new projects (expansion investment) or a comparison between old and new projects (replacement investment).

It is possible to either compare the overall cost of the investment over a planning period or to analyze the cost per unit of output. If the capacity of the investments differs (quantitative performance), the comparison of overall costs and costs per unit does not necessarily yield the same result. Costs per unit should be used in this case.

Decision rule:
The alternative investment which yields the lowest total cost per planning period or the lowest cost per unit is selected.

The cost comparison method is utilized especially in the case of replacement investments or regulatory requirements. It is also used for all investments where a direct link to sales or profits does not exist. Frequently, the profit is not the result of a single investment, but rather reflective of the performance of the entire corporation. In such a case it can be difficult or even impossible to allocate the profit to the different machines or investments. For that reason, the cost comparison method is very frequently used in applied work.

Example:
The results of the cost comparison method are presented below.

First fixed costs and capital costs are calculated. The following formulas (shown for Machine 1) are particularly relevant (see Fig. 8.3):

Position	Formula	Excel implementation
Depreciation (=Cost_Comparison_Method!E22)	=(Investment in depreciating capital equipment (in €) – Residual value of the asset) (in €) / Operating life of the asset in years	=(E7-E9)/E8
Implied interest payment (=Cost_Comparison_Method!E23)	Average amount of capital tied up * Relevant interest rate (% p.a.)	=E11*E14

Fig. 8.3 Calculating fixed costs and capital costs

	A	B	C	D	E	F
18						
19		Fixed costs and cost of capital			Machine 1	Machine 2
20						
21		Fixed costs excluding cost of capital			7,500	5,000
22		Depreciation			18,000	13,000
23		Implied interest payment			6,750	4,650
24						
25		Sum of fixed costs			32,250	22,650
26						

Fig. 8.4 Calculating fixed costs and capital costs (Excel File Investment, Worksheet Cost_Comparison_Method)

Position	Formula	Excel implementation
Wages and incidental wage costs (=Cost_Comparison_Method!E29)	=Planned utilization (units per annum) * Wages and incidental wage costs (€/unit)	=E12*E15
Raw, auxiliary and operating materials (=Cost_Comparison_Method!E30)	=Planned utilization (units per annum) * Raw materials, auxiliaries and operating materials (€/unit)	=E12*E16
Other variable costs (=Cost_Comparison_Method!E31)	Planned utilization (units per annum) * Other variable costs (€/unit)	=E12*E17

Fig. 8.5 Calculating variable costs

The calculation of fixed costs and capital costs is shown in Fig. 8.4:

Variable costs are calculated next. The following formulas (shown for Machine 1) must be considered in particular (see Fig. 8.5): The calculation of variable costs is shown in Fig. 8.6:

Adding fixed costs/cost of capital and variable costs leads to the following total cost and the corresponding cost per unit (see Fig. 8.7).

Since the decision criterion for the cost comparison method is the lowest total cost or per unit cost, the following result follows for the cost comparison method. The selection is done based on the following formulas (see Fig. 8.8).

The decision based on the cost comparison method is shown in Fig. 8.9:

Variable costs	Machine 1	Machine 2
Wages and incidental wage costs	16,000	24,000
Raw, auxiliary and operating materials	4,000	4,000
Other variable costs	2,000	6,000
Sum of variable costs	22,000	34,000

Fig. 8.6 Calculating variable costs (Excel File Investment, Worksheet Cost_Comparison_Method)

Total cost	Machine 1	Machine 2
Total cost	54,250	56,650
Per unit cost	2.71	2.83

Fig. 8.7 Calculating total cost (Excel File Investment, Worksheet Cost_Comparison_ Method)

Position	Formula	Excel implementation
Decision criterion: Alternative with lower total cost (=Cost_Comparison_Method!E43)	=IF(Total cost machine 1 < Total cost machine 2; Total cost machine 1; blank cell)	=IF(E37<F37;E37;"")
Decision criterion: Alternative with lower per unit cost (=Cost_Comparison_Method!E44)	=IF(Per unit cost machine 1 < Unit cost machine 2; Per unit cost machine 1; blank cell)	=IF(E38<F38;E38;"")
Decision (=Cost_Comparison_Method!E45)	=IF(Total cost machine 1 < Total cost machine 2; favorable; unfavorable)	=IF(E37<F37;"favorable";"not favorable")

Fig. 8.8 Decision based on the cost comparison method

Results for the cost comparison method	Machine 1	Machine 2
Decision criterion: Alternative with lower		
Total cost	54,250	
Per unit cost	2.71	
Decision	favorable	not favorable

Fig. 8.9 Decision based on the cost comparison method (Excel File Investment, Worksheet Cost_Comparison_Method)

When assessing the viability of investments, it is frequently not sufficient to determine that an investment is preferred over another one for a specific capacity. Instead it is of interest which level of capacity utilization yields identical results for the investment alternatives (situation of indifference). The quantity or degree of capacity utilization for which the cost per unit of time or output for two different investments is equal is called "critical quantity" or "critical level of capacity utilization".

If

$$C_1 = c_{v,1} \cdot x_1 + C_{fix,1}$$

defines the cost function for investment 1 and

$$C_2 = c_{v,2} \cdot x_2 + C_{fix,2},$$

the cost function of investment 2, with $c_{v,1}$ and $c_{v,2}$ as variable unit costs of investment 1 and investment 2, x_1 and x_2 the output of investment 1 and investment 2 and $C_{fix,1}$ and $C_{fix,2}$ the total fixed costs of investment 1 and 2, the critical quantity is obtained by setting the two cost functions equal. From

$$c_{v,1} \cdot x_1 + C_{fix,1} = c_{v,2} \cdot x_2 + C_{fix,2}$$

it finally follows for $x_1 = x_2 = x_{critical}$ that the critical quantity is

$$x_{critical} = \frac{C_{fix,2} - C_{fix,1}}{c_{v,1} - c_{v,2}}.$$

For this output level (units), the total cost is equal for the two investment alternatives.

Figure 8.10 shows the determination of the critical output level in a comparison of total cost.

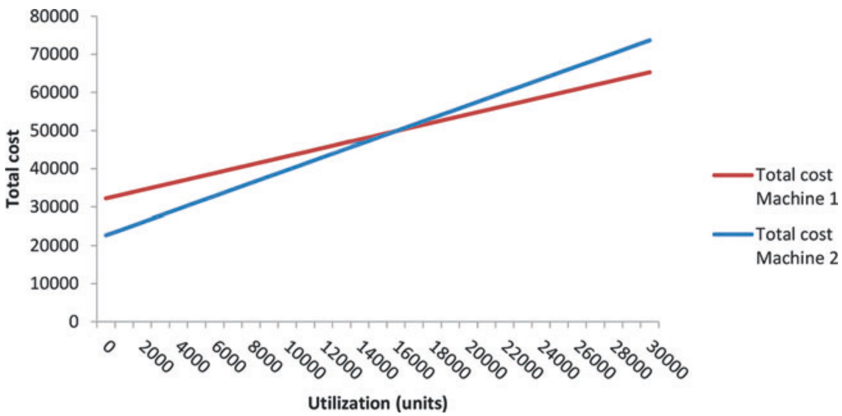

Fig. 8.10 Comparing total cost to determine the critical output level

4.2 Profit Comparison Method

> The profit comparison method is an extension of the cost comparison method, which also includes revenues.

If the performance of the investment objects that need to be compared is not identical, the results from the cost comparison method cannot be used. In this case, the inclusion of revenues calls for the profit comparison method.

According to the profit comparison method, the profit for a representative period is determined for the investment alternatives. The definition of profit P is as follows:

$$P = R - C,$$

where R stands for the revenues from the project and C for the corresponding costs.

Decision rule:
According to the profit comparison method, each investment which yields a profit greater zero is favorable. When comparing alternatives, the investment opportunity which leads to the largest expected average annual profit is selected.

The profit comparison method is used if it is possible to directly assign the profit to an investment.

It is also possible to use the profitability threshold as the decision criterion in the profit comparison method. The profitability threshold indicates the quantity for which all costs are covered. It is calculated with the following formula:

$$\text{Break even} = \frac{\text{Fixed Cost}}{(\text{Price per unit} - \text{Variable cost per unit})}$$

Example:
Continuing with the previous example, it is possible to utilize the profit comparison method. In addition to the total cost which was already determined for the cost comparison method, revenues are now also taken into consideration:

The revenue (shown for Machine 1) is calculated with the following formula (see Fig. 8.11):

Position	Formula	Excel implementation
Sales revenue (=Profit_Comparison_Method!E38)	= Planned utilization (units per annum) * Sales revenue per unit (in €)	=E12*E13

Fig. 8.11 Calculating sales revenue

	A	B	C	D	E	F
35						
36		Sales revenue			Machine 1	Machine 2
37						
38		Sales revenue			84,000	86,000

Fig. 8.12 Calculating sales revenues (Excel File Investment, Worksheet Prof-it_Comparison_Method)

	A	B	C	D	E	F
39						
40		Profit			Machine 1	Machine 2
41						
42		Total profit = Revenue - Total cost			29,750	29,350
43		Profit per unit = Total profit/Planned utilization			1.49	1.47

Fig. 8.13 Calculating total profit and profit per unit (Excel File Investment, Worksheet Prof-it_Comparison_Method)

Position	Formula	Excel implementation
Decision criterion: Alternative with the higher profit (=Profit_Comparison_Method!E48)	=IF(Total profit machine 1 > Total profit machine 2; Total profit Machine 1; Empty cell)	=IF(E42>F42;E42;"")
Decision criterion: Alternative with the higher profit per unit (=Profit_Comparison_Method!E49)	=IF(Profit per unit machine 1 > Profit per unit machine 2; Profit per unit machine 1; Empty cell)	=IF(E43>F43;E43;"")
Decision (=Profit_Comparison_Method!E50)	=IF(Total profit machine 1 < Total profit machine 2; favorable; unfavorable)	=IF(E42>F42;"favorable";"not favorable")

Fig. 8.14 Decision based on the profit comparison method

The calculation of the sales revenue is shown in Fig. 8.12:

In the next step the total profit can be calculated by subtracting fixed costs inclusive capital costs and variable costs from the revenues. The profit per unit is determined by dividing total profit by planned utilization (see Fig. 8.13).

Since the decision criterion for the profit comparison method is to select the alternative with the highest total profit or profit per unit, the following result is obtained with the profit comparison method. The selection is based on these formulas (see Fig. 8.14):

	A	B	C	D	E	F
44						
45		**Total return**			**Machine 1**	**Machine 2**
46						
47		Decision criterion: Alternative with				
48		higher total profit			29,750	
49		higher profit per unit			1.49	
50		Decision			favorable	not favorable

Fig. 8.15 Decision based on the profit comparison method (Excel File Investment, Worksheet Profit_Comparison_Method)

The decision based on the profit comparison method is shown in Fig. 8.15:

In line with the approach taken for the determination of the critical output level for a given cost function, it is also possible to obtain the critical output level for the total profit comparison by equating the profit functions of both investments.

From

$$p_1 \cdot x_1 - c_{v,1} \cdot x_1 - C_{fix,1} = p_2 \cdot x_2 - c_{v,2} \cdot x_2 - C_{fix,2}$$

and

$$\left(p_1 \cdot c_{v,1}\right) \cdot x_1 - C_{fix,1} = \left(p_2 \cdot c_{v,2}\right) \cdot x_2 - C_{fix,2}$$

It follows that if $x_1 = x_2 = x_{critical}$:

$$x_{critical} = \frac{C_{fix,2} - C_{fix,1}}{\left(p_2 - c_{v,2}\right) - \left(p_1 - c_{v,1}\right)}.$$

where

p_1 and p_2 are the revenues per unit of investment alternative 1 and investment alternative 2. For this output level, the profit of both investment alternatives is equal.

Figure 8.16 shows the determination of the critical output level by comparing the profitability of the two alternatives.

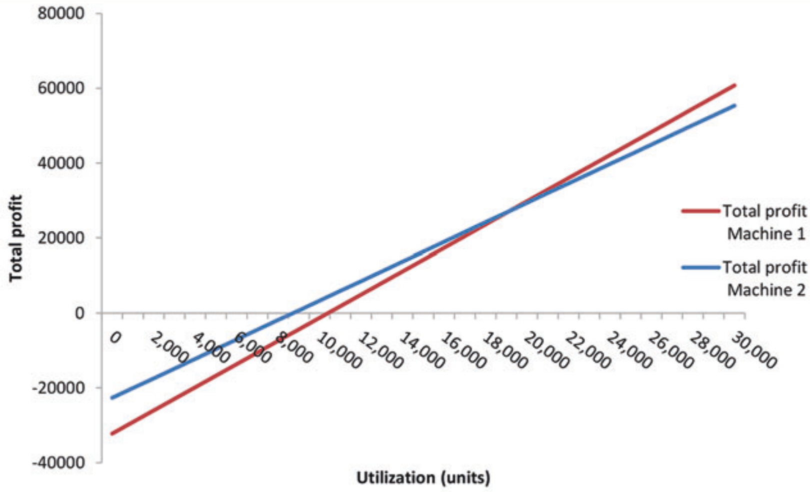

Fig. 8.16 Determination of the critical output level by comparing profitability

4.3 Average Rate of Return

> The average rate of return enriches the profit comparison method by also considering the investment capital.

Profit stated as an absolute number is not always a meaningful figure. It is also important to know the amount of capital that was utilized to obtain it.

The average rate of return calculation relates the expected profit of an investment to the capital invested.

This method of investment appraisal, which is widespread in Anglo-American business practice is also called Return on Investment (RoI) or Return on Capital Employed (RoCE).

The return is stated per period and the following formula is used:

$$\text{Return} = \frac{\text{Average profit} + \text{Average interest}}{\text{Average capital used}}$$

For depreciating tangible assets (which are assumed in our case), the average amount of capital utilization must be used. Only in the case of assets that are not subject to depreciation (plot of land, current assets and so forth) can the initial capital outlay be used.

Decision Rule:
When calculating profitability, the project-specific average rate of return is compared to the return desired by the investor. If the project-specific average rate of return exceeds the return demanded by the investor, the investment is implemented. When comparing several alternatives, the investment with the highest average rate of return is selected.

Example:
The following formula is used for calculating the total return (see Fig. 8.17):

The calculation of the average rate of return is shown in Fig. 8.18:

If the project-specific average rate of return exceeds the return demanded by the investor, the investment is profitable. If two investment alternatives are compared, the one with the higher average rate of return is preferred. The selection is based on the following formula (see Fig. 8.19).

The decision based on the average rate of return calculation is shown in Fig. 8.20:

Position	Formula	Excel implementation
Total return on capital (=Average_Rate_of_Return_Method!E47)	=Earnings before interest / Average amount of capital tied up	=E43/E11

Fig. 8.17 Calculating the average rate of return

	A	B	C	D	E	F
44						
45		Total return			Machine 1	Machine 2
46						
47		Total return on capital = Earnings before interest/ Average volume of capital tied up			54.1%	73.1%
48						

Fig. 8.18 Calculating the average rate of return (Excel File Investment, Worksheet Aver-age_Rate_of_Return)

Position	Formula	Excel implementation
Result: Total return on capital (=Average_Rate_of_Return_Method!E51)	=IF(Total return on capital machine 1 > Total return on capital machine 2; Total return on capital machine 1; Empty cell)	`=IF(E47>F47;E47;"")`
Decision (=Average_Rate_of_Return_Method!E52)	=IF(Total return on capital machine 1 > Total return on capital machine 2; favorable; not favorable)	`=IF(E47>F47;"favorable";"not favorable")`

Fig. 8.19 Decision based on average rate of return calculation

	A	B	C	D	E	F
48						
49		Result			Machine 1	Machine 2
50						
51		Total return on capital = Earnings before interest/ Average volume of capital tied up				73.1%
52		Decision			not favorable	favorable

Fig. 8.20 Decision based on average rate of return calculation (Excel File Investment, Worksheet Average_Rate_of_Return)

4.4 Static Payback Period Method

The static payback period method is the time it takes to recover the capital invested in the project.

The payback period method – also called payoff-method – is the only static approach which works with a time frame that is longer than one representative period. It can be determined on average figures or total figures.

The static payback period determines the time period needed to regain the capital invested from the average cash flow surpluses generated by the project. It is assumed that profit and depreciation are fully used to amortize the capital investment.

Die static payback period method facilitates an approximate risk assessment of different investment projects.

Decision rule:
An individual investment project can be considered profitable if its payback period is shorter than a target length of time defined by the investor. When comparing several investment projects, the alternative with the shortest payback period is selected.

Position	Formula	Excel implementation
Payback period (=Static_Payback_Period_Method!E47)	=(Investment in depreciable capital equipment + Investment in non-depreciable capital equipment – Residual value of equipment (in €)) / (Average cash flow surpluses)	=(E7+E10-E9)/E43

Fig. 8.21 Calculating the static payback period

	A	B	C	D	E	F
44						
45		Payback period			Machine 1	Machine 2
46						
47		Payback period = Capital tied-up/Average cash flow surpluses			2.15	1.75

Fig. 8.22 Calculating the static payback period (Excel File Investment, Worksheet Stat.__Payback_Period_Method)

Position	Formula	Excel implementation
Result: Payback period (=Static_Payback_Period_Method!E51)	=IF(Payback period machine 1 < Payback period machine 2; Payback period machine 1; Empty cell)	=IF(E47<F47;E47;"")
Decision (=Static_Payback_Period_Method!E52)	=IF(Payback period machine 1 < Payback period machine 2; favorable; not favorable)	=IF(E47<F47;"favorable";"not favorable")

Fig. 8.23 Decision based on the static payback period method

The static payback period is calculated with the following formula:

$$\text{Amortization period} = \frac{\text{Capital employed}}{\text{Average inflows}} = \frac{(\text{Initial investment} - \text{Residual value})}{(\text{Profit} + \text{Depreciation})}$$

Example:

The static payback period method requires determining the initial capital outlay and the net balance of cash inflows and outflows which can be approximated by using the net profit plus "earned" depreciation (see Fig. 8.21):

The calculation of the static payback period is shown in Fig. 8.22:

A single investment project is selected if its payback period is shorter than the maximum payback period required by the investor. When comparing two investment projects, the one with the shorter payback period is preferred. The selection is based on the following formula (see Fig. 8.23).

The decision based on the static payback method is shown in Fig. 8.24:

Result	Machine 1	Machine 2
Payback period = Capital tied-up/Average cash flow surpluses		1.75
Decision	not favorable	favorable

Fig. 8.24 Decision based on the static payback period method (Excel File Investment, Worksheet Stat._Payback_Period_Method)

4.5 Comparison and Assessment of the Static Investment Appraisal Methods

A comparison of the static investment appraisal methods shows that the investment decision can differ depending on the choice of method. Figure 8.25 shows the comparison.

The static investment appraisal methods are easily applied ("practitioner methods"). The effort needed to obtain data and implement the calculations is limited.

The biggest disadvantages of the static investment appraisal are the following:

Short-term perspective:
The short-term perspective assumes a constant environment over a longer time period (prices of raw materials, wages, output, revenue and so forth). This is usually not the case, since prices and volumes are frequently subject to major fluctuations.

No consideration of the timing of cash inflows and outflows:
Static methods of investment appraisal do not take into consideration the fact that cash inflows and outflows occur at different points in time and therefore need to be treated differently. For example, an inflow of 100,000 EUR from an investment could be reinvested as a

Method	Machine 1	Machine 2	Decision
Cost comparison method	54,250	56,650	Machine 1
Profit comparison method	29,750	29,350	Machine 1
Average rate of return method	54.1%	73.1%	Machine 2
Static payback period method	2.15	1.75	Machine 2

Fig. 8.25 Comparison of the decisions based on the static investment appraisal methods (Ex-cel File Investment, Worksheet Comparison_(1)

bank deposit. Interest would be paid every year. These alternative cash flows also need to be considered when assessing the viability of an investment. This means that an inflow that occurs early has a higher value than an inflow that occurs at a later point in time.

The general validity of static methods is reduced as the assumption of constant prices and volumes becomes less likely and the larger the timing differences of various investment alternatives become. Both effects are taken into consideration in dynamic investment appraisal methods.

5 Dynamic Investment Appraisal Methods

> Dynamic investment appraisal methods consider the timing of cash inflows and outflows.

Dynamic methods of investment valuation achieve a much greater precision in assessing the viability of investments than static approaches. At the same time, they are more complex and demanding concerning data requirements. Therefore they are less frequently used in daily business than the static methods.

The aim of dynamic investment appraisal methods is the recognition of the time value of money by discounting or compounding cash flows from different periods to compare them at specific points in time.

Among the most important dynamic methods of investment appraisal (see Fig. 8.26) are

- Net present value method,
- Internal rate of return method and
- Annuity method.

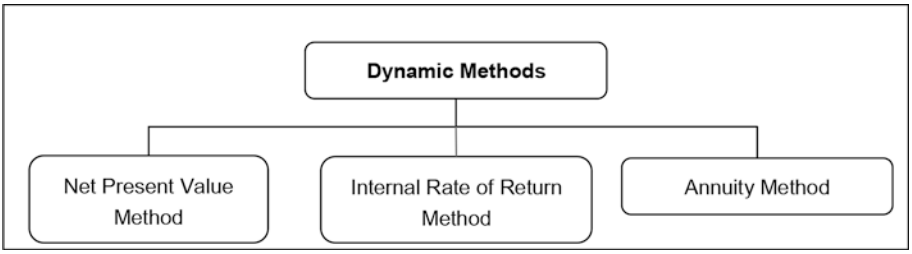

Fig. 8.26 Dynamic methods of investment appraisal

5.1 Net Present Value Method

> The net present value method achieves comparability of all cash flows by discounting to the beginning of the investment period.

The net present value method is the most frequently used approach among the dynamic methods and achieves comparability of cash flows that happen at different points of time by determining their present values. This means that all cash flows are discounted to t = 0 (time of the first payment related to the investment). These numbers are also called present values.

The present value is the difference between the discounted cash inflows and the discounted outflows related to an investment in time t_0.

The following approach is recommended for the calculation of the present value:

1. Determination of the initial outflow for the investment.
2. Estimate of the expected net cash flows from the investment for each period of the planning horizon.
3. Determination of the discount uniform rate (it is assumed that the discount rate remains unchanged over the life of the investment), in other words the rate of return required by the investor.
4. Discounting of the expected net cash flows with the discount rate to the time period when the investment is made (determination of the present value).
5. Subtraction of the initial outflow for the investment from the present value. This yields the net present value (*NPV*).

The determination of the initial outlay for the investment is usually unproblematic, since the data is readily available. Possible inputs which were required prior to the investment period such as research and development expenses need to be compounded to obtain their value in $t = 0$ and are part of the initial investment I_0. If the payments for the investment are spread out over several periods, all payments that take place in $t > 0$ are discounted to $t = 0$ and considered with their present values in I_0.

Significantly harder is the planning of the cash inflows (CIF_t) and outflows (COF_t) that result from the investment project in each period t (t = 1, 2, . . . , n) of the planning horizon. To arrive at a forecast of the market development and the positioning of the company, estimates of sales, prices, fixed and variable costs, depreciation, taxes, and unrealized profits and losses from a possible resale of the investment object are needed. The detailed planning of these cash flows is discussed in the chapter on Corporate Finance.

The discount rate which needs to be determined in step three can be derived from an alternative use of the funds needed for the investment, which should be in line with the risk and length of the investment period. Thus discounting should involve an interest rate which is equal to the riskless rate plus a risk premium. The determination of an appropriate interest rate is explicitly explained in the chapter Corporate Finance.

The difference between the cash inflows and cash outflows ($CIF_t - COF_t$) gives the net cash flow (NCF_t) of the corresponding period. Discounting of the expected net cash flows to $t = 0$ achieves comparability with the initial investment outlay. Subtracting the initial investment outlay I_0 from the present value of the net cash flows gives the net present value (NPV).

If a possible final payment L_n for the liquidation of the investment in $t = n$ is also considered, the calculation of the net present value can formally be written as follows:

$$NPV = -I_0 + \sum_{t=1}^{n} \frac{(CIF_t - COF_t)}{(1+i)^t} + \frac{L_n}{(1+i)^n}$$

where

t = Time index

n = Last period when cash flows take place

I_0= Investment outlay in t = 0

n = Number of periods

CIF_t = Cash inflows in period t

COF_t = Cash outflows in period t

($CIF_t - COF_t$) = Net cash flows in period t

L_n = Liquidation proceeds in $t = n$

A distinction between one-time (I_0 und L_n) and repeated ($CIF_t - COF_t$) cash inflows and outflows is not necessarily needed, since the *NPV* can also be written as the discounted sum of all cash inflows and outflows:

$$NPV = \sum_{t=0}^{n} \frac{(CIF_t - COF_t)}{(1+i)^t}$$

This specification allows the possible incorporation of payments from earlier periods and time periods $t < 0$ can also be considered. The discount factor $1/(1 + i)^{t}$ is automatically converted into a compounding factor and the final value of all cash flows which occur before time 0 is correctly assessed in in $t = 0$.

For so-called *normal investments*, which are characterized by an cash outflow in time t_0 followed only by net cash flows $NCF_t > 0$ it holds that:

$$NPV = -I_0 + \sum_{t=1}^{n} \frac{NCF_t}{(1+i)^t} + \frac{L_n}{(1+i)^n}$$

If the net cash inflows are uniform and equidistant and occur at the end of each period, the series of net cash flows can be interpreted as an annuity. Using the formula for the present value of an ordinary annuity, it follows that:

$$NPV = -I_0 + NCF \cdot \left[\frac{(1+i)^n - 1}{i \cdot (1+i)^n}\right] + \frac{L_n}{(1+i)^n}$$

For the special case that *NCF* is considered as a perpetuity, which is given for an infinite investment period, the series of cash flows can be expressed as follows:

$$NPV = -I_0 + \frac{NCF}{i}$$

In the case where the net cash flows are growing indefinitely at the rate *g* (growth rate), the following formula is obtained:

$$NPV = -I_0 + \frac{NCF}{i - g}$$

Obviously this formula is only defined for a discount rate which exceeds the growth rate.

If the assumption of a flat term structure of interest rates is lifted, then different interest rates i_τ are valid for different periods τ. The present value can then be determined from the equation

$$NPV = \sum_{t=0}^{n} (CIF_t - COF) \left[\prod_{\tau=1}^{t} (1 + i_\tau) \right]^{-1}$$

Decision rule:

- If $NPV > 0$, the investment should be made. It promises an increase in wealth (profit) in the amount of the net present value.
- If $NPV = 0$, the investment just returns the cost of capital (opportunity cost). No increase in wealth results.
- If $NPV < 0$, the investment should be turned down. An implementation would destroy wealth in an amount equal to the negative *NPV*.

The net present value method can also be used to compare several mutually exclusive, but otherwise identical investment opportunities (same investment amount and horizon). Preference should be given to the alternative with the highest net present value.

An investment can also be assessed with the help of the *future value FV* instead of the present value of the cash flows. The future value is calculated by compounding all cash inflows and outflows in t (t = 1, 2, . . . , n) to the end of the planning period $t = n$ and summing them up.

$$FV = \sum_{t=0}^{n} (CIF_t - COF_t)(1 + i)^{n-t}$$

In this case an investment is profitable if $FV > 0$.

Example:

Assumed is an investment in a production facility which requires an initial payment of € 1.2 million. Supplies (raw materials, auxiliary and operating materials) cost € 300 thousand. Revenues of 5 €/unit are expected and the variable costs are estimated at 3 €/unit while fixed costs are € 500 thousand per annum. The sales volume is estimated at 500 thousand units in the first year and 600 thousand units in years two

Project assumptions	t_0	t_1	t_2	t_3	t_4	t_5
Year	0	1	2	3	4	5
Investment in capital equipment	1,200					
Residual value of the equipment at the end of year 5 (in € thousand)						200
Useful life of the equipment (years)	5					
Investment in raw, auxiliary and operating materials (in € thousand)	300					
Sales volume	500	600	600	600	600	600
Sales price per unit (€/unit)		5	5	5	5	5
Variable costs per unit (€/unit)		3	3	3	3	3
Fixed costs excluding depreciation (in € thousand)		500	500	500	500	500
Depreciation, linear over useful life (in € thousand)		200	200	200	200	200
Relevant discount rate (% p.a.)	10%	10%	10%	10%	10%	10%
Tax rate (%)		40%	40%	40%	40%	40%

Fig. 8.27 Input data of the model (Excel File Investment, Worksheet Assumptions_Dynamic_Investment_Valuation)

to five. The useful life of the facility is five years, linear depreciation is applied and the tax rate is 40%. At the end of the fifth year, the facility is sold at the book value of € 200 thousand.

No internal funding is available. The investment could be financed via a loan. Interest payment (i = 10%) and repayment need to be financed using the cash flows of the project. The net present value method should be applied to determine the profitability of this project.

Figure 8.27 provides an overview of the input data of the model:

The project requires an initial investment of € 1.5 million and is expected to generate a cash flow of € 380 thousand in the first year, of € 500 thousand in years 2 to 4 and of € 700 in the final year.

Figure 8.28 shows the calculation of the cash flows. The data are taken from the assumptions and simple calculations to determine the cash flows are implemented.

To answer the question whether the investment should be implemented, the net present value is calculated. There are several ways to calculate this value. The calculations in cell `E38` are based on the sum of the present values of the individual cash flows:

$$NPV = -I_0 + \sum_{t=1}^{n} \frac{(CIF_t - COF_t)}{(1+i)^t} + \frac{L_n}{(1+i)^n}$$

Relevant for the calculations are the formulas for the present value factors and the present values, which are presented for the year t_0 (see Fig. 8.29).

It is also possible to calculate the *NPV* with the help of the Excel formula *NPV* (see Fig. 8.30). The name of the formula may suggest that all project payments (`row 27`) including the investment sum (`E27`)

	A	B	E	F	G	H	I	J
4								
5		**Cash flow calculations**						
6			t_0	t_1	t_2	t_3	t_4	t_5
7		Investment in capital equipment	1,200					
8		Investment in current assets	300					
9		Investment amount	1,500					
10		Sales volume		500	600	600	600	600
11		Price per unit		5	5	5	5	5
12		Revenues		2,500	3,000	3,000	3,000	3,000
13		Variable costs per unit		-3	-3	-3	-3	-3
14		Variable costs per unit		-1,500	-1,800	-1,800	-1,800	-1,800
15		Fixed costs (excluding depreciation)		-500	-500	-500	-500	-500
16		Depreciation		-200	-200	-200	-200	-200
17								
18		**Eearnings before taxes**		**300**	**500**	**500**	**500**	**500**
19								
20		Taxes		-120	-200	-200	-200	-200
21								
22		**Net profit**		**180**	**300**	**300**	**300**	**300**
23								
24		Depreciation		200	200	200	200	200
25		Dispositions at book value						200
26								
27		**Cash flow**	**-1,500**	**380**	**500**	**500**	**500**	**700**

Fig. 8.28 Cashflow calculation (Excel File Investment, Worksheet Net_Present_Value-Method)

Position	Formula	Excel implementation
Discount Factors (=Net_Present_Value_Method!E35)	=1/(1+Discount rate)^Year	`=1/(1+E34)^E33`
Present values (=Net_Present_Value_Method!E36)	=Cash flow* Discount factor	`=E27*E35`
Net present value (calculation 1) (=Net_Present_Value_Method!E38)	=Sum of the present values	`=SUM(E36:J36)`

Fig. 8.29 Calculating the present value (calculation 1)

Position	Formula	Excel implementation
Net present value (calculation 2) (=Net_Present_Value_Method!E39)	=Present value of inflows + Investment sum	`=NPV(E34;F27:J27)+E27`

Fig. 8.30 Calculating the present value (calculation 2)

should be used. But this approach would yield a value that has been discounted too heavily. It would not determine the net present value at $t = 0$ but instead at $t = -1$. The correct application of the *NPV* function requires the calculation of the present values of the expected values of the cash flows starting in $t = 1$. The result is a present value of € 1.9

Project analysis	t_0	t_1	t_2	t_3	t_4	t_5
Year	0	1	2	3	4	5
Discount rate	10%	10%	10%	10%	10%	10%
Discount factors	1.0000	0.9091	0.8264	0.7513	0.6830	0.6209
Present values	-1,500	345	413	376	342	435
Net present value (calculation 1)	**410**					
Net present value (calculation 2)	**410**					

Fig. 8.31 Determining whether the investment is favorable

million, which yields the net present value of €410 once the initial investment amount of €1.5 million in `E39` has been subtracted.

In case the payments are not evenly spread out (for example on 01.01.2012, on 13.03.2013 and on 30.10.2014), the present value can be calculated with the function ➲ *XNPV*. The results of the present value calculations (calculations 1 and 2) are presented in Fig. 8.31.

The net present value of €410 thousand from our example can be interpreted as follows:

- A positive net present value of €410 thousand implies an increase in wealth (profit) of €410 thousand. This amount could be at the investor's disposal (e.g. consumption) already today (in t_0) by borrowing against the final value (€661).
- The return on the capital tied up in the investment exceeds the discount rate.

These statements can be clarified with the following considerations: it is possible to obtain a loan in the amount of 1,500 in time t_0 at an interest rate of 10%. The cash flows from the project are sufficient to repay the loan including interest. At the end of the investment period in t_5 a surplus (profit) remains, which after discounting is equal to the net present value of 410. The following formulas support this argument (see Fig. 8.32):

The implementation of the financing plan I is shown in Fig. 8.33:

Financing plan II shows the approach with the help of an repayment schedule. Repayment is based on the payment surpluses which depends on the availability of the cash flows (after interest, but before repayment) of the investment. As soon as payment surpluses are available, they are used to repay the loan in order to reduce the loan amount as quickly as possible. At the end of the fifth year, the surplus in the amount of 700 is used to pay interest in the amount of 4 and to repay the remaining balance of the loan in the amount of 35.

Position	Formula	Excel implementation
Interest payment (=Net_Present_Value_Method!F52)	=–(Loan at the beginning of the year* Relevant discount rate)	`=-(F51*'Assumptions Dyn. Inv. Calc.'!F14)`
Repayment (=Net_Present_Value_Method!F53)	IF(Loan at the beginning of the year – Interest payment > Investment;-(Investment + Interest payment); – Loan at the beginning of the year)	`=IF(F51-F52>F49;-(F49+F52);-F51)`
Loan at the end of the year (=Net_Present_Value_Method!F54)	=Loan + Loan at the beginning of the year + Repayment	`=F50+F51+F53`
Profit (=Net_Present_Value_Method!F55)	=Investment + Interest payment + Repayment	`=F49+F52+F53`
Present value (=Net_Present_Value_Method!E56)	=Present value of profits	`=NPV('Assumptions Dyn. Inv. Calc.'!E14;'Net Present Value Method'!F55:J55)`

Fig. 8.32 Repayment from payment surpluses and remaining profit at the end of the period (financing plan I)

Financing plan I	t_0	t_1	t_2	t_3	t_4	t_5
Investment	-1,500	380	500	500	500	700
Loan	1,500					
Loan at the beginning of the year		1,500	1,270	897	487	35
Interest payment		-150	-127	-90	-49	-4
Repayment		-230	-373	-410	-451	-35
Loan at the end of the year	1,500	1,270	897	487	35	0
Profit		0	0	0	0	661
Present value	410					

Fig. 8.33 Repayment from cash flows and remaining profit at the end of the period

This leaves a profit of 661. The present value of this profit is

$$PV = \frac{661}{(1.1)^5} = 410$$

This amount can be made available already today (in t_0) by taking out (an additional) loan in the amount of 410. Interest payments and repayment are covered by the final value of the investment in in $t = 5$ in the amount of

$$410 \cdot (1.1)^5 = 611.$$

Position	Formula	Excel implementation
Interest payment (=Net_Present_Value_Method!F65)	=–(Loan + Loan at the beginning of the year)* Relevant discount rate)	=-((F63+F64)*'Assumptions Dyn. Inv. Calc.'!F14)
Repayment (=Net_Present_Value_Method!F66)	IF(Loan at the beginning of the year – Interest payment > Investment;-(Investment + Interest payment); –Loan at the beginning of the year)	=IF(F64-F65>F62;-(F62+F65);-F64)
Loan value at the end of the year (=Net_Present_Value_Method!F67)	=Loan + Loan at the beginning of the year + Repayment	=F63+F64+F66
Profit (=Net_Present_Value_Method!F68)	=Investment + Interest payment + Repayment	=F62+F65+F66

Fig. 8.34 Calculating repayment based on payment surpluses with profits taken out at the beginning of the period (financing plan II)

Financing plan II	t_0	t_1	t_2	t_3	t_4	t_5
Investment	-1,910	380	500	500	500	700
Loan	1,910					
Loan at the beginning of the year		1,910	1,722	1,394	1,033	636
Interest payment		-191	-172	-139	-103	-64
Repayment		-189	-328	-361	-397	-636
Loan at the end of the year	1,910	1,722	1,394	1,033	636	0
Profit		0	0	0	0	0

Fig. 8.35 Repayment based on payment surpluses with profits taken out at the beginning of the period

A total loan in the amount of 1,910, which is used to finance the investment and to take out the future profit already in t_0 is covered by the payment surpluses from the investment. The following formulas are used for the calculations (see Fig. 8.34):
The implementation of the financing plan II is shown in Fig. 8.35:

5.2 Internal Rate of Return Method

> The internal rate of return is the interest rate that gives a NPV of zero when applied as a uniform discount rate.

The method of the internal rate of return calculates the return on the invested capital. In contrast to the return derived from the balance sheet, the internal rate of return is not a static measurement, but instead an economic return of a project during its total life with a focus on cash flows.

To calculate the internal rate of return *IRR*, the net present value is set equal to zero and the equation is solved for *r*. The following formula is used:

$$NPV = -I_0 + \sum_{t=1}^{n} \frac{(CIF_t - COF_t)}{(1 + IRR)^t} + \frac{L_n}{(1 + IRR)^n}$$

Without making a distinction between I_0 and L_0:

$$NPV = \sum_{t=0}^{n} \frac{(CIF_t - COF_t)}{(1 + IRR)^t} = 0$$

Solving this equation for the internal rate of return is possible in the case of one or two periods and for an infinite investment period. However, most cases will be characterized by a polynomial of order n, which means that for $t > 2$ the solution cannot be determined directly and must be found with the help of an iterative procedure.

Finding a solution is straightforward with Excel, since add-ins for iterative solutions are available. For specific constellations of the underlying cash flows (several sign reversals of the cash flows) it is possible that in the relevant range of the *NPV* function either no or several zero points exist, which causes problems in interpreting the function. These so-called *non-normal investments* will no longer be pursued in this context.

Decision rule:

To assess a *normal investment,* the internal rate of return r is compared to the discount rate (alternative return, i.e. the investors required rate of return) i. An investor will pursue a project if the internal rate of return r exceeds the discount rate i, thus $IRR > i$. If $IRR = i$, the investor is indifferent. For $IRR < i$ the investment is unfavorable and the expected return cannot be realized.

With the help of the internal rate of return it is also possible to compare several mutually exclusive, but otherwise identical investment alternatives, as long as these are normal investments. Preference should be given to the alternative with the highest internal rate of return.

Example:
The example from Fig. 8.33 is used for the calculation of the internal rate of return (repayment based on payment surpluses with profits taken out at the beginning of the period).

The iterative calculation of the internal rate of return in Excel uses the function *IRR* and an internal rate of return of 19.32% is obtained in the example. If the cash flows are discounted at this interest rate, the *NPV* is zero. In the case where the payments are not made at fixed periodic intervals, the internal rate of return can be calculated with the function *XIRR*.

The following formulas are used for the calculations (see Figs. 8.36 and 8.37):

Figure 8.38 shows the present values. The corresponding net present value is calculated for each interest rate and displayed graphically. This approach utilizes the multiple input operators which were already presented in the Excel Workshop. Multiple input operators show how the change in one parameter (here: interest rate) affects the result (here: present value).

Position	Formula	Excel implementation
Internal rate of return (=Internal_Rate_of_Return!E8)	=IRR(Values)	=IRR(E7:J7)

Fig. 8.36 Calculating the internal rate of return (financing plan I)

	A	B	C	D	E	F	G	H	I	J
4										
5		Financing plan I								
6					t_0	t_1	t_2	t_3	t_4	t_5
7		Cash flows from the investment			-1,500	380	500	500	500	700
8		Internal rate of return			19.32%					

Fig. 8.37 Calculating the internal rate of return

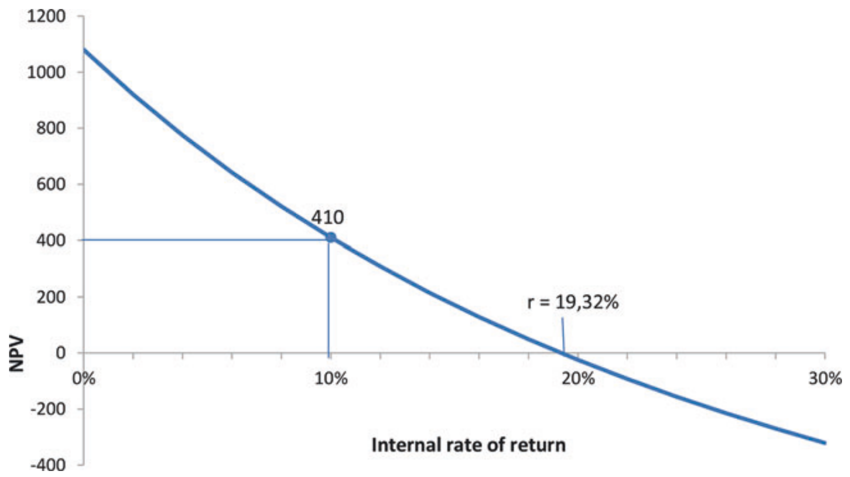

Fig. 8.38 Present value function in our example (Excel File Investment, Worksheet Internal_Rate_of_Return)

5.3 Annuity Method

An annuity method is not an alternative ranking method; it is a simple and convenient way to transform the NPV or unevenly structured cash flows of an investment into a uniform and equidistant series of payments.

In addition to the net present value and the internal rate of return, the annuity method is a third approach to determine whether an investment is profitable or not.

The annuity is a new series of payments which are uniform and equidistant derived from an initial payment stream that is unevenly structured. The net present values of the two series of payments are equal.

Determination of the annuity A requires knowledge of the net present value. It is calculated by multiplying the net present value with the annuity factor (also called capital recovery factor). This allows the precise calculation of cash inflows and outflows that are determined today, but that incur in the future. Starting from the equation

$$NPV = \sum_{t=0}^{n} \frac{(CIF_t - CF_t)}{(1+i)^t}$$

the annuity can be determined by comparing the following cash flows:

$$NPV = -I_0 + \sum_{t=1}^{n} \frac{(CIF_t - COF)}{(1+i)^t} + \frac{L_n}{(1+i)^n} = A \cdot \left[\frac{(1+i)^n - 1}{i \cdot (1+i)^n}\right]$$

The annuity for the investment A_I is then given by:

$$A = \left[-I_0 + \sum_{t=1}^{n} \frac{(CIF_t - COF_t)}{(1+i)^t} + \frac{L_n}{(1+i)^n}\right] \cdot \left[\frac{(1+i)^n \cdot i}{(1+i)^n - 1}\right]$$

The factor $\left[\frac{(1+i)^n \cdot i}{(1+i)^n - 1}\right]$ is called *annuity factor* or *capital recovery factor* and is the reciprocal of the present value factor of an ordinary annuity.

If uniform and equidistant net cash flows are assumed, the annuity can be calculated from the following equation:

$$NPV = -I_0 + NCF \cdot \left[\frac{(1+i)^n - 1}{i \cdot (1+i)^n}\right] + \frac{L_n}{(1+i)^n} = A \cdot \left[\frac{(1+i)^n - 1}{i \cdot (1+i)^n}\right]$$

with

$$A = \left[-I_0 + \frac{L_n}{(1+i)^n}\right] \cdot \left[\frac{(1+i)^n \cdot i}{(1+i)^n - 1}\right] + NCF$$

For unlimited project life and constant net cash flows, the present value is multiplied with the annuity factor, which takes on the value i as n goes towards infinity.

From

$$NPV = \frac{NCF}{i} - I_0 = A \cdot \left[\frac{(1+i)^n - 1}{i \cdot (1+i)^n}\right]$$

we obtain for $n \to \infty$:

$$NPV = \frac{NCF}{i} - I_0 = \frac{A}{i}$$

Thus the annuity becomes:

$$A = NCF - I_0 \cdot i$$

Project analysis	t_0	t_1	t_2	t_3	t_4	t_5
Year	0	1	2	3	4	5
Discount rate	10%	10%	10%	10%	10%	10%
Discount factors	1.0000	0.9091	0.8264	0.7513	0.6830	0.6209
Cash flows from the investment	-1,500	380	500	500	500	700
Present values	-1,500	345	413	376	342	435

Fig. 8.39 Calculating the present values of the cash flows resulting from the investment (Excel File Investment, Worksheet Annuity_Method)

Decision rule:
An investment is profitable if the annuity of the cash inflows exceeds the annuity of the cash outflows, which implies a positive annuity, in other words $A > 0$. Indifference is given for $A = 0$. The investment is unprofitable if the average cash inflows are below the average cash outflows, which implies a negative profit annuity, that is, $A < 0$.

The annuity method is also suitable for the comparison of several mutually exclusive investment alternatives. Selected is the alternative with the highest (non-negative) profit annuity.

Example:
The annuity method utilizes the present values of the cash flows resulting from the investment (see Fig. 8.39).

In the financing plan III the financing annuity A_F is calculated with the Excel function *PMT*. Next is the calculation of the investment annuity A_I, which again uses the Excel function *PMT*. Required inputs are the discount rate, the number of investment periods and the present values of the payments (*NPV*). Also needed is the final value of 0 and it must be determined whether the payments take place at the beginning or the end of a period. It must be kept in mind that the sign changes in the annuity method, therefore the present values have a minus sign. Finally, the annuity A can be calculated as the difference between the investment annuity and the financing annuity.

The calculation is based on the following formulas (using the example of period t_1) (see Fig. 8.40):

The financing annuity A_F is determined by multiplying the loan amount at origination with the annuity factor:

$$A_F = 1500 \cdot \left[\frac{(1+0.1)^5 \cdot 0,1}{(1+0.1)^5 - 1} \right] = 396$$

Position	Formula	Excel implementation
Financing annuity (=Annuity_Method !F18)	=PMT (Interest rate; Periods; Present value; Ending value; Payment convention)	=PMT('Assumptions Dyn. Inv. Calc.'!$E$14;'Assumptions Dyn. Inv. Calc.'!$E$7;-$E$16;0;0)
Investment annuity (=Annuity_Method !F22)	=PMT (Interest rate; Periods; Present value; Ending value; Payment convention)	=PMT('Assumptions Dyn. Inv. Calc.'!$E$14;'Assumptions Dyn. Inv. Calc.'!$E$7;-SUM($F$11:$J$11);0;0)
Profit annuity (=Annuity_Method !F23)	=Investment annuity – Financing annuity	=F22-F18

Fig. 8.40 Calculating the annuity (financing plan III)

Financing plan III	t_0	t_1	t_2	t_3	t_4	t_5
Loan	1,500					
Loan at the beginning of the year		1,500	1,254	984	687	360
Annuity A_F		396	396	396	396	396
Interest		150	125	98	69	36
Repayment		246	270	297	327	360
Loan at the end of the year	1,500	1,254	984	687	360	0
Annuity A_I		504	504	504	504	504
Profit = A_I - A_F		108	108	108	108	108

Fig. 8.41 Using the net cash flows from the example for interest and repayment to calculate the annuity (Excel File Investment, Worksheet Annuity_Method)

The investment annuity A_I is calculated by multiplying the sum of the present values of the net cash flows with the annuity factor:

$$A_I = \left[\frac{380}{(1+0.1)^1} + \frac{500}{(1+0.1)^2} + \frac{500}{(1+0.1)^3} + \frac{500}{(1+0.1)^4} + \frac{700}{(1+0,1)^5}\right] \cdot \left[\frac{(1+0.1)^5 \cdot 0,1}{(1+0.1)^5 - 1}\right] = 504$$

Subtracting the financing annuity from the investment annuity yields the annuity A:

$$A = A_I - A_F = 504 - 396 = 108$$

The investment is profitable since $A_I = 504 > A_F = 396$. If implemented, it will return over the next five years an average annual profit of 504 – 396 = 108.

Figure 8.41 shows the calculation of the annuity with the help of a financing plan.

5.4 Comparison and Assessment of the Methods of Dynamic Investment Appraisal

The net present value method provides the clearest results.

The listed criteria of net present value, internal rate of return and annuity are specific and consistent features of the net present value function and are thus interdependent. The net present value method and the annuity method are directly related. The net present value method defines an investment as profitable if the net present value is greater than zero. The annuity method defines an investment as profitable, if the annuity is positive. For a given discount rate, the annuity of an investment is identical to the net present value spread out over several periods. Thus a positive net present value also always implies a positive profit annuity. It can be concluded that the net present value method and the annuity method – assuming an identical duration of the project – will always support an identical decision.

The relationship between net present value and internal rate of return is not as clear. The net present value function of a *normal investment* (which has only one sign change, typically between period 0, which is characterized by an outflow and the following periods, which witness payment surpluses) is falling monotonically and has at most one zero point in the range $i > 0$. Therefore, it always holds that a positive (negative) net present value implies an internal rate of return greater (smaller) than the discount rate. It can be concluded that net present value method and internal rate of return lead to the same conclusion. For *non-normal investments* (several sign changes of the cash flows), however, net present value method and internal rate of return are not equivalent, since the latter method is not applicable due to the lack of a unique solution. The net present value method can also be used in the case of non-normal investments and will correctly signal whether a project is favorable or not.

If investment projects are characterized by differences in the investment outlays or project duration, the conclusions derived with the three methods – net present value, internal rate of return, and annuity – can differ. This possibility is illustrated using the example in Fig. 8.42.

Investments of different volume and length				
	t_0	t_1	t_2	t_3
Year	0	1	2	3
Investment A	-200	50	100	150
Investment B	-100	70	80	
Investment C	-100	50	50	50
Relevant interest rate	10%			

Fig. 8.42 Illustration of the problem of selecting among investment alternatives (Excel File In-vestment, Worksheet Assumptions_Dyn._Invest.Valuation)

Investments of different volume and duration	Investment A	Investment B	Investment C	Decision
Present value	40.80	29.75	24.34	Investment A
Internal rate of return	19.44%	31.05%	23.38%	Investment B
Annuity	16.40	11.96	9.79	Investment A

Fig. 8.43 Comparing net present value, internal rate of return and annuity (Excel File Invest-ment, Worksheet Comparison_(2))

The investment alternatives A, B and C differ with regard to required investment outlay, project duration and cash flows. Figure 8.43 provides net present values, internal rates of return and annuities for the three scenarios. This leads to the following rankings:

Net present value: $A > B > C$

Internal rate of return: $B > C > A$

Annuity: $A > B > C$

The decision concerning the ranking of the investments (cells `F7` to `F9`) can be supported in Excel by the *INDEX* function. The *INDEX* function allows the quick and comfortable selection of the best investment alternative.

The *INDEX* function returns a value or the reference to a value from a table or a range. Two versions of the function *INDEX* are available: the matrix version and the reference version. We will utilize the matrix version in our example.

The syntax of the *INDEX* function is: `=INDEX(Matrix;Row;Column)`

The *INDEX* function can be explained as follows:

- `Matrix` is the cell range where the search should take place. In our example: `C5:E6`

- `Row` provides the position of the row in the matrix, from which the value should be taken. In our example: `1` stands for the first row of the matrix, which only consists of one row.
- `Column` indicates the column from which the target value is returned. The target value is identified with the function *MATCH*. The function *MATCH* conducts a search in a specific cell range and provides the relative position of that element in the range.

The syntax of the function *MATCH* has the following arguments:

- `Search criterion`: The value used for comparison with the elements in the search matrix. If you are looking for the optimum investment in our example, use the present value as the search criterion, even though the optimum investment alternative is your ultimate target variable.
- `Search matrix`: The cell range in which the search will be conducted. In our example these are the cells `C7` to `E7`, which are searched for the largest value with the function *MAX*.
- `Match type`: The value -1, 0 or 1. The argument Match type specifies the type of comparison between the value in the search matrix and the value for the search criterion. 0 means that the search focuses on the first value that exactly matches the search criterion.

The formulas for the *INDEX* function and *MATCH* function are shown for the example of cell `F7` (see Fig. 8.44).

Apparently the decision in favor of a specific investment project depends on the underlying method. In order to assure comparability of the alternatives concerning investment volume, project duration and structure of the cash flows, it would be necessary to consider so-called difference investments, supplementary investments, complementary investments or additional investments. But since the specification of complementary investments creates problems in applied work, a complete comparison of advantages is abandoned in favor of a limited

Position	Formula	Excel implementation
Selecting the optimal investment alternative (=`COMPARISON_(2)!F7`)	=INDEX(Matrix; Row; Column)	`=INDEX($C$5:$E$6;1;MATCH(MAX(C7:E7);C7:E7;0))`

Fig. 8.44 Implementation of the INDEX function and the MATCH function

comparison based on broad assumptions. Ultimately the decision will depend on the method selected, since different assumptions are used for the different methods.

The comparison of results from the net present value method assumes a return on the money not needed for the investment equal to the discount rate, while the internal rate of return assumes a return equal to the internal rate of return. Since the two interest rates will normally be different, the two methods can arrive at different conclusions concerning the ranking of the alternatives. If a different assumption about reinvestment of the funds is made in a specific case, explicit assumptions about an auxiliary investment would be needed, which could imply a positive or negative present value or a higher or lower internal rate of return.

The net present value method and the annuity method also do not yield identical results, even though the latter method is based on the present value. The reason for this is the fact that the investments have different durations, which means that the net present values are multiplied with different annuity factors. Apparently the present value of investment A is distributed over three years, while the present value of investment B is only distributed over two years. This leads to a higher annuity for B. If a reinvestment at the discount rate is assumed during the time by which investment B exceeds investment A (and thus an annuity of zero), present value and annuity method will yield the same result. If the longer investment horizon of three years is used for investment B, an annuity of

$$A = 29.75 \cdot \left[\frac{(1 + 0.1)^3 \cdot 0,1}{(1 + 0.1)^3 - 1} \right] = 11.96$$

is obtained. This replicates the ranking from the comparison of net present values: $A > B > C$.

A comparison of the criteria leads to the following assessment:

- A project is favorable if the present value and hence the profit annuity is greater than zero. In this case the internal rate of return exceeds the discount rate. Net present value method and internal rate of return yield the same assessment.
- A comparison of several projects should be done with the net present value method and not the internal rate of return due to differences in the reinvestment assumptions. The reinvestment

assumption of the net present value method is unproblematic, since any reinvestment takes place at the discount rate (alternative return) which is based on data from the capital market.

- Projects of different duration can be compared with the net present value method, but not on the basis of internal rates of return, since the length of the period matters.

6 Summary

In this chapter on investment, the financial modeler has obtained an overview of methods and approaches in investment management:

Investment

- An investment is the use of financial resources with the aim of creating tangible and intangible assets (real investments) as well as financial assets (financial investments).
- The methods of investment appraisal can be broken down into static and dynamic approaches.

Static Methods of Investment Appraisal

- Static methods of investment appraisal are frequently used in applied work due to their simplicity and traceability.
- Static methods of investment appraisal completely or partially neglect the timing differences in inflows and outflows.
- Among the static methods of investment appraisal are the
  - Cost comparison method,
  - Profit comparison method,
  - Average rate of return method and the
  - Static payback period method.
- The cost comparison method is based on a comparison of costs (including all costs of capital such as depreciation and interest) that are allocated to a defined planning or utilization period of two or more alternative investment objects. The alternative with the lowest cost is selected.
- In the profit comparison method, the profit for a representative period is determined for the investment alternatives. The alternative with the highest profit is selected.

- For the average rate of return method, the expected profit of an investment is related to the capital invested. The alternative with the highest return is selected.
- The static payback period method identifies the time period needed to return the initially invested capital to the company in the form of earnings. Selected is the alternative with the shortest payback period.
- The biggest disadvantages of the static investment appraisal are:
  - Short-term focus
  - No consideration of the timing of inflows and outflows

Dynamic Methods of Investment Appraisal

- Dynamic methods of investment appraisal allow a significantly higher precision in determining whether investments are favorable compared to static methods.
- The aim of dynamic investment appraisal is to achieve comparability of payments that occur at different points in time via discounting and compounding.
- Among the most important dynamic methods of investment appraisal are the
  - Net present value method,
  - Method of internal rate of return and
  - Annuity method.
- The net present value method discounts all future payments to the time $t = 0$ (time of the first payment that is related to the investment) and compares them to the initial investment outlay. A project is favorable whenever the net present value is positive.
- The internal rate of return reflects the interest rate that can be obtained with the capital investment. An investor will select a project whenever the internal rate of return exceeds the discount rate.
- An annuity is a payment stream that consists of uniform and equidistant payments. It is derived from an unevenly structured series of cash flows with an identical net present value. An investment is favorable, if the annuity of inflows exceeds the annuity of outflows, which implies a positive profit annuity.

Literature and Suggestions

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9

Financing

1 Executive Summary

Pharma Group intends to invest in lucrative projects, but does not possess a sufficient amount of liquid funds. Thus Pharma Group must seek additional funding. It can choose either internal or external financing (see Fig. 9.1).

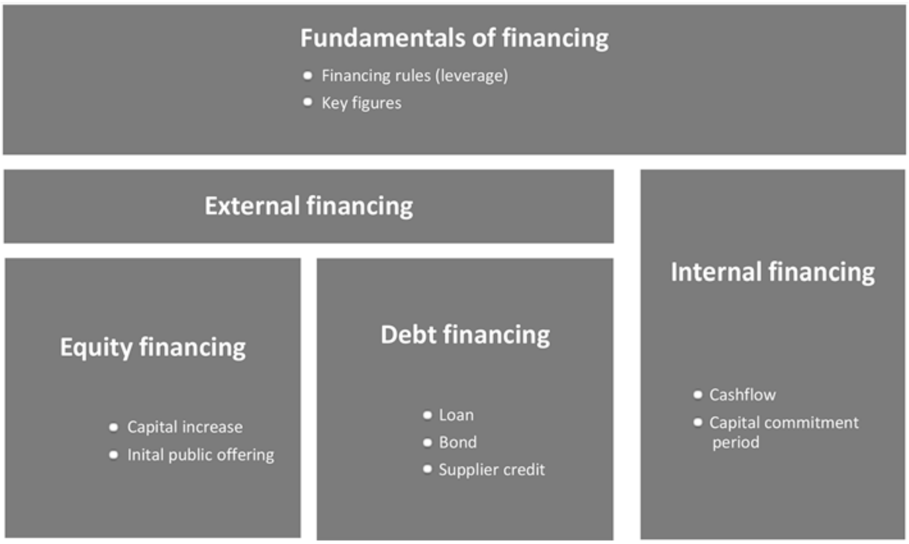


Fig. 9.1 Structure of financing opportunities

J. Häcker and D. Ernst, *Financial Modeling*,
Global Financial Markets, DOI 10.1057/978-1-137-42658-1_9

The main source of internal financing is the cash flow. The positive cash flow which the company is expected to generate over the next five years allows Pharma Group to take on major investment projects. Additionally, Pharma Group can use the method of "financing via reduction of the capital commitment period" in the context of internal financing. This primarily involves a reduction of receivables and inventories.

In addition to internal financing, Pharma Group can also utilize external financing sources. Again a distinction can be made between equity and debt financing. The initial public offering (IPO) of Pharma Group many years ago was a method of equity financing. As is customary for a going public, the Pharma Group had increased its capital at the time. In order to support additional lucrative investment projects, Pharma Group is currently considering a further ordinary capital increase. Compared to debt, this is more expensive, since Pharma Group always faces higher cost of equity than cost of debt. Pharma Group therefore also considers issuing a corporate bond to fund larger investment projects. It could also take on a loan, but this would likely lead to concentration risk at the lending credit institution. In contrast, the corporate bond would be in the hands of numerous, mostly institutional investors. Less relevant in this context is the supplier credit, since it is relatively expensive compared to the other two choices.

In order to reach a solid financing decision, the Pharma Group requires knowledge about the basic rules of financing. In this context, the leverage effect plays a major role. The treasury department of Pharma Group is always interested to replace expensive equity with cheaper debt. However, this measure should not be used too extensively, since an excessive degree of debt raises the insolvency risk of Pharma Group and can result in a lower rating. Thus the treasury department of Pharma Group will always attempt to achieve an optimal mix of debt and equity. This mix is optimal if the weighted average cost of capital (WACC) is minimized. The lower the WACC, the higher the company value and thus Pharma Group's market value at the stock exchange.

Favorable financing decisions are based on a thorough analysis of the income statement, the balance sheet and the cash flow statement. To understand central relationships, Pharma Group works with key ratios. Obviously the financial structure is of primary importance for financing decisions. A decision in favor or against an investment project at the management level will always include considerations such as return, asset structure, capital structure, likely success and cash flow analysis.

2 Learning Outcomes, Definitions, Model Structure and Case Study

Structure

This chapter deals with the topics of financing and provides answers to the following questions:

- Which key ratios are available for the assessment of a company and how is an analysis conducted on the basis of key ratios?
- What are the fundamental financing rules and how are they applied?
- What is meant by an ordinary capital increase and how is it implemented?
- What different types of long-term loans exist and how are they calculated?
- What are bonds, how are interest and prices of bonds calculated and how can interest rate risk be managed?
- What is the essence of short-term financing in the case of supplier credit?
- What is the contribution of the cash flow towards internal financing of a company? What types of cash flow exist and how are they calculated?
- How can financing be assured by reducing the duration of the capital commitment and asset restructuring?

Learning outcomes

The financial modelers are able to:

- Provide an overview of the most important financing instruments.
- Compare the most important methods of financial management, critically discuss advantages and disadvantages and draw conclusions for their use in applied work.
- Relate financing to other chapters, especially investment appraisal and corporate finance.

- Use their knowledge of financial management to develop professional models which can be utilized to assess the viability of financing opportunities on the basis of the financial modeling standards.
- Independently structure complex tasks in financing and to develop independent modules for their solution.
- Critically assess the outcomes of financing measures and explain differences.
- Interpret the outcomes of financing measures and independently draw conclusions for financing decisions.
- Review the structure and results of financing models using Model Review/Audit.
- Manage a project in the field of financing and jointly develop solutions with a group of finance specialists.
- Develop a transparent and complete documentation of assumptions and methods for a given financing project.
- Recognize the linkages among different financing methods and apply the most suitable approach for a given case.
- Structure the process financing decisions and apply the standards of professional financial modeling.
- Apply the knowledge to specific financing projects and modify it to meet the demands of the actual valuation situation.
- Solve new and unfamiliar tasks in the field of financing with the help of financial modeling instruments.
- Critically challenge the assumptions, algorithms and results of every financing decision.
- Present and defend the results of the valuation in front of clients.

Case Study

The financial models for the case studies are found in the download offering in the Excel files "Financing." Use the contents of the download offering as you work through the text:

- The individual learning steps are separated into small units on different worksheets.

- All calculations are done directly in Excel, in order to assure their traceability.
- All input data that are assumptions and needed for the calculations in the financial model are found in the worksheet "Assumptions."
- All input data are marked in the color light orange. These values are assumed by the valuation expert and entered individually.
- All calculations and output data are marked in the color gray. These are values that result from calculations.
- Mixed formulas that contain both numerical values and cell references are highlighted by the font color green.
- Assumptions and calculations are found on different sheets to improve clarity of presentation.
- In the section "Financing" the topics financing rules and ratio analysis are discussed first.
- Next, equity financing is discussed using the example of an ordinary capital increase.
- After that, we will discuss debt financing using the examples of long-term loans, bonds and short-term financing.
- Finally, financing via reducing the duration of the capital commitment and asset restructuring is discussed.

> The applied example of Pharma Group serves as an illustration in the section on financing.

Pharma Group
The financing instruments available to corporations are discussed in the following in the context of the example of Pharma Group, a global leader in the fields of pharmaceuticals, agriculture and high-end materials. The balance sheet of Pharma Group is based on International Financial Reporting Standards (IFRS) and utilizes the cost of sales method.

Pharma Group has the following income statement, balance sheet and cash flow statement (see Figs. 9.2 to 9.5).

Income Statement			
(Absolute numbers in € million)	Actual t_2	Actual t_1	Actual t_0
Total sales	36,528	39,741	40,157
- COGS	17,975	19,070	19,347
Gross profit on sales	18,553	20,671	20,810
- Selling expenses	8,958	9,981	10,080
- Research and development expenses	2,932	3,013	3,190
- General administration expenses	1,713	1,866	1,883
- Other operating expenses	1,660	2,970	1,620
+ Other operating income	859	1,087	897
EBIT	4,149	3,928	4,934
+ Result from associates accounted for using the equity method	-45	-18	-16
+ Financial income	586	503	389
- Financial expenses	1,327	1,237	1,100
Earnings before taxes (EBT)	3,363	3,176	4,207
- Income taxes	891	723	1,021
Earnings after taxes	2,472	2,453	3,186
- of which attributable to non-controlling interest	2	50	-3
Net income	2,470	2,403	3,189
Dividends	1,364	1,571	1,737

Fig. 9.2 Income statement of Pharma Group (Excel File Financing, Worksheet Income_Statement)

Balance Sheet Assets			
(Absolute numbers in € million)	Actual t_2	Actual t_1	Actual t_0
Goodwill	9,148	9,293	9,862
Other intangible assets	10,284	9,464	8,914
Property, plant and equipment	9,887	9,898	10,015
Other financial assets	2,038	2,074	1,902
Deferred taxes	1,312	1,579	1,596
Noncurrent assets	32,669	32,308	32,289
Inventories	6,370	6,991	7,129
Trade accounts receivable	7,060	7,433	7,569
Other financial assets	4,876	2,888	2,668
Cash and cash equivalents	1,771	1,698	1,662
Current assets	20,077	19,010	19,028
Total assets	52,746	51,318	51,317

Fig. 9.3 Balance sheet assets of Pharma Group (Excel File Financing, Worksheet Balance_Sheet_Assets)

Bilance Sheet Equity and Liabilities			
(Absolute numbers in € million)	Actual t_2	Actual t_1	Actual t_0
Subscribed capital of Pharma Group	2,117	2,117	2,117
Capital reserves of Pharma Group	6,167	6,167	6,167
Other reserves	8,442	7,764	9,245
Net income	2,470	2,403	3,189
Equity attributable to non-controlling interest	59	100	86
Equity	**19,255**	**18,551**	**20,804**
Provisions for pensions and other post-employment benefits	7,787	9,246	7,368
Other provisions	1,726	2,111	1,977
Bond			2,960
Other financial liabilities	7,995	6,962	2,630
Other liabilities	474	409	362
Deferred taxes	2,116	935	1,193
Noncurrent debt capital	**20,098**	**19,663**	**16,490**
Other provisions	4,217	4,844	4,727
Financial liabilities	3,683	2,568	3,441
Trade accounts payable	3,785	4,305	4,473
Deferred taxes	76	72	101
Other liabilities	1,632	1,315	1,281
Current debt capital	**13,393**	**13,104**	**14,023**
Total equity and liabilities	**52,746**	**51,318**	**51,317**

Fig. 9.4 Balance sheet liabilities of Pharma Group (Excel File Financing, Worksheet Balance_Sheet_Liabilities)

Pharma Gruppe Cash Flow Statement			
(Absolute numbers in € million)	Actual t_2	Actual t_1	Actual t_0
Earnings after taxes	2,472	2,453	3,186
Taxes	891	723	1,021
Financial result	786	752	727
Taxes on earnings paid or owed	-1,067	-1,560	-1,644
Deprecation on property, plant and equipment and intangible assets	2,769	2,988	2,896
Changes in pension provisions	-504	-581	-249
Profits (–) Losses (+) from the disposal of noncurrent assets	-175	-219	-105
Increase/decrease inventories	-241	-680	-608
Increase/decrease accounts receivable	-389	-455	-751
Increase/decrease accounts payable	245	550	389
Changes in other net assets/Other actiivties that do not involve cash flows	273	559	309
Operating cash flow	**5,060**	**4,530**	**5,171**
Investment in property, plant and equipment and intangible assets	-1,615	-1,929	-2,157
Revenues from the sale of tangible assets and other assets	275	230	153
Revenue from disposals	173	178	79
Revenues/expenses on noncurrent financial assets	-211	-258	204
Expenses for acquisitiona minus cash received	-261	-466	-1,082
Interest and dividend income	75	104	125
Revenues/expenses on current financial assets	-2,326	1,327	97
Investing cash flow	**-3,890**	**-814**	**-2,581**
Dividends and capital gains tax paid	-1,242	-1,366	-1,574
New loans	1,001	1,308	9,078
Repayment of existing loans	-1,398	-3,254	-9,697
Interest expense including expenses for interest rate hedging	-902	-793	-550
Interest income from interest rate hedging transactions	332	325	212
Expenses for the acquisiton of additional shares in subsidiaries	-4	-3	-4
Financing cash flow	**-2,213**	**-3,783**	**-2,535**
Changes resulting from modifications to the group of consolidated companies	0	0	0
Changes from exchange rate changes	-27	-6	-91
Net cash flow	**-1,070**	**-73**	**-36**

Fig. 9.5 Cash flow statement of Pharma Group (Excel File Financing, Worksheet Cash_Flow_Statement)

3 Fundamental Rules of Financing

> Fundamental rules of financing provide a first glimpse at the financial structure of a corporation.

This chapter serves to assess and clarify fundamental rules of financing using the example of Pharma Group. Additionally, the relationship between equity and debt is assessed, which leads to the leverage effect.

3.1 The Golden Rule for Balance Sheets

The golden rule for balance sheets in its narrow interpretation states the following relationship:

$$Equity \geq Noncurrent\ assets$$

To assess this rule, the balance sheet is initially broken down into four sections in the worksheet "Financing rules." This allows setting up a formula involving the =IF() function in Excel, which tests for the golden rule for balance sheets in its narrow interpretation (see Fig. 9.6).

The following situation arises for Pharma Group (see Fig. 9.7).

Position	Formula	Excel implementation
Is the golden rule for balance sheets in its narrow interpretation satisfied? (=Financing_Rules!E11)	=If the equity is at least as high as noncurrent assets, then "Yes," otherwise "No"	=IF(D7>=C7;"Yes";"No")

Fig. 9.6 Checking for the golden rule for balance sheets in its narrow interpretation

	A	B	C	D	E
3					
4		**The golden rule: Narrow interpretation**			
5					
6			Assets	Equity & Liabilities	
7		Noncurrent Assets	32,289	20,804	Equity
8		Current Assets	19,028	30,513	Debt
9					
10					
11		Is the golden rule in the narrow interpretation satisfied?			**No**
12					

Fig. 9.7 The golden rule for balance sheets in its narrow interpretation (Excel File Financing, Worksheet Financing_Rules)

It is apparent that noncurrent assets exceed the equity and therefore the golden rule for balance sheets does not apply. Bar graphs can be used to illustrate the balance sheet structure (Fig. 9.8).

For the weaker form of the golden rule of balance sheets it is also allowed to use noncurrent debt to cover fixed assets. This implies that:

$$Equity + Noncurrent\ debt \geq noncurrent\ assets$$

To provide a clear overview, the balance sheet is again broken down into relevant sections (see Fig. 9.9).

The formula to test the relationship can then be written as follows (see Figs. 9.10 and 9.11):

We see that the noncurrent assets of Pharma Group are sufficiently covered with long-term capital according to the golden rule for balance sheets in its weaker form. Thus the golden rule for balance sheets in its weaker form is satisfied. This is shown graphically with the help of bar charts in Fig. 9.12.

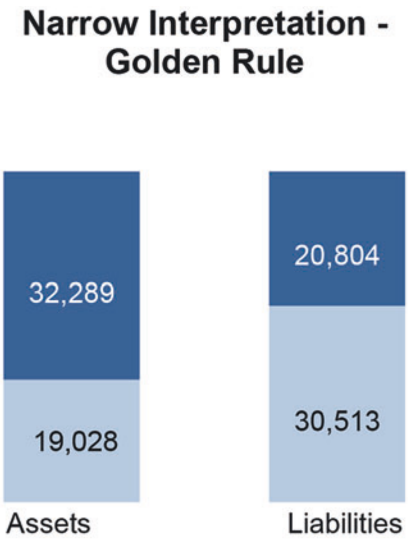


Fig. 9.8 Graphical display of the golden rule of balance sheets in its narrow interpretation (Excel File Financing, Worksheet Financing_Rules)

Position	Formula	Excel implementation
Noncurrent assets (`Financing_Rules!C33`)	=Noncurrent assets	`=Assets!E13`
Current assets (`Financing_Rules!C34`)	=Current assets	`=Assets!E20`
Equity and noncurrent liabilities (`Financing_Rules!D33`)	=Equity + Noncurrent liabilities	`='Equity and Liabilities'!E13+'Equity and Liabilities'!E22`
Current liabilities (`Financing_Rules!D34`)	=Current liabilities	`='Equity and Liabilities'!E30`

Fig. 9.9 The various components of the balance sheet

Position	Formula	Excel implementation
Is the golden rule for balance sheets in its weaker form satisfied? (`Financing_Rules!E37`)	=If the equity plus the noncurrent liabilities are at least as high as the noncurrent assets, then "Yes," otherwise "No"	`=IF(D33>=C33;"Yes";"No")`

Fig. 9.10 Checking for the golden rule for balance sheets in its weaker form

The golden rule: Broad interpretation

	Assets	Equity & Liabilities	
Noncurrent Assets	32,289	37,294	Equity and Noncurrent Liabilities
Current Assets	19,028	14,023	Current Liabilities

Is the golden rule in the broad interpretation satisfied?	Yes

Fig. 9.11 The golden rule for balance sheets in its weaker form (Excel File Financing, Worksheet Financing_Rules)

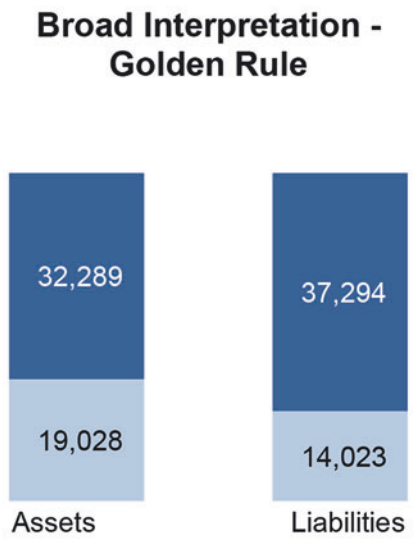


Fig. 9.12 Graphical representation of the golden rule for balance sheets in its weaker form (Ex-cel File Financing, Worksheet Financing_Rules)

3.2 The Relationship between Equity and Debt and the Leverage Effect

> The relationship between equity and debt is usually analyzed in the context of an equal contribution of owners and providers of debt.

Position	Formula	Excel implementation
Is the vertical capital structure rule (1:1-Rule) satisfied? `(Financing_Rules!E60)`	=If the ratio of equity and the sum of current and noncurrent liabilities is 1 at a minimum, then: "Yes," else "No".	`=IF('Equity and Liabilities'!E13/('Equity and Liabilities'!E22+'Equity and Liabilities'!E30)>=1;"Yes";"No")`

Fig. 9.13 Checking the relationship between equity and debt

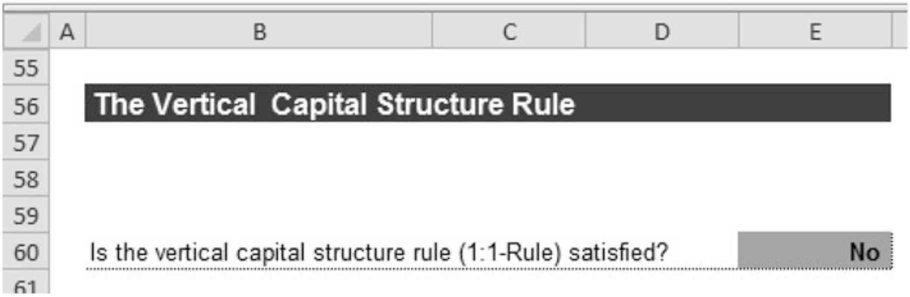


Fig. 9.14 Checking the relationship between equity and debt (Excel File Financing, Worksheet Financing_Rules)

Initially the relationship between equity and debt (1:1-rule) on the liability side of the balance sheet of Pharma Group is checked (see Figs. 9.13 and 9.14). The capital structure is considered to be stable if it holds that:

$$\frac{Equity}{Debt} \geq 1$$

Since debt clearly exceeds equity on the balance sheet, the required relationship between equity and debt of at least 1 is not fulfilled.

3.2.1 Assumptions about the Leverage Effect

To illustrate the leverage effect, the example of an investment that is partially equity financed and partially debt financed will be used. The composition of debt and equity will have a decisive influence on the return on equity of the investment (leverage effect). Initially the required input data for the investment must be provided in the worksheet `Assumptions_Financing_Rules` (see Figs. 9.15 and 9.16).

Position	Formula	Excel implementation
Total capital `(Assumptions_Financing_Rules!D9)`	Total capital here specifies the total investment amount.	**Data check:** Allowed are only positive values. **User input:** `100,000`
Investment return `(Assumptions_Financing_Rules!D11)`	Profit from the investment.	**Data check:** Allowed are only positive values. **User input:** `10,000`
Return on total capital `(Assumptions_Financing_Rules!D13)`	The return on total capital is calculated as the ratio of return of the investment and total capital	**Formula:** `=D11/D9`
Interest rate on debt `(Assumptions_Financing_Rules!D15)`	This requires the input of the interest rate on debt.	**Data check:** Allowed are only positive values. **User input:** `7%`
Gearing `(Assumptions_Financing_Rules!C19:F19)`	The gearing (degree of indebtedness) assumed for the analysis.	**User input:** `0; 0.5; 1; 2`

Fig. 9.15 Input data for the investment under consideration

	A	B	C	D	E	F
3						
4		Assumptions Investment Object				
5						
6				Actual		
7		(Absolute numbers in € million)		t_0		
8						
9		Total capital		100,000		
10						
11		Investment return		10,000		
12						
13		Return on total capital		10%		
14						
15		Interest rate on debt		7%		
16						
17						
18			Case 1	Case 2	Case 3	Case 4
19		Gearing	-	0.50	1.00	2.00

Fig. 9.16 Assumptions that imply a positive leverage effect (Excel File Financing, Worksheet Assumptions_Financing_Rules)

3.2.2 Calculations Concerning the Leverage Effect

> Leverage in general describes how small changes in an input variable can lead to major changes in the result.

Given the input data, it is possible to calculate the leverage effect for different gearing (see Figs. 9.17 and 9.18). The calculations are shown for the first case (gearing 0).

The example demonstrates that a higher level of gearing (meaning a higher percentage of debt) can increase the return on equity. This is the leverage effect. But for a project return below the interest rate on the debt, this effect is reversed. To illustrate this relationship in the Excel model, a lower return on the investment is entered into the worksheet `Assumptions_Financing_Rules`. It needs to be below the interest rate on debt. For example, if a profit in the amount of €3,500 is assumed, the following situation arises (see Figs. 9.19 and 9.20):

As the gearing exceeds one, the equity return becomes negative.

Position	Formula	Excel implementation
Gearing `(Financ-ing_Rules!C70)`	=Gearing	`='Assumptions Financing Rules'!C19`
Total capital `(Financ-ing_Rules!C72)`	=Total capital	`='Assumptions Financing Rules'!D9`
Equity `(Financ-ing_Rules!C73)`	=Total capital / (Gearing + 1)	`=C72/(C70+1)`
Debt `(Financ-ing_Rules!C74)`	=Total capital – Equity	`=C72-C73`
Profit before interest on debt `(Financ-ing_Rules!C76)`	=Investment return	`='Assumptions Financing Rules'!D11`
Interest on debt `(Financ-ing_Rules!C77)`	=Debt * Interest rate on debt	`=C74*'Assumptions Fi-nancing Rules'!$D$15`
Profit `(Financ-ing_Rules!C78)`	=Profit before interest on debt - Interest on debt	`=C76-C77`
Return on equity `(Financ-ing_Rules!C80)`	=If debt is equal to zero, then: Profit before interest on debt / Total capital; else: (Profit before interest on debt / Total capital) + ((Profit before interest on debt / Total capital) - (Interest on debt / Debt)) * (Debt / Equity).	`=IF(C74=0;C76/C72;(C76/C72)+((C76/C72)-(C77/C74))*(C74/C73))`

Fig. 9.17 Calculating the leverage effect for different gearing

(Absolute numbers in € million)	Case 1	Case 2	Case 3	Case 4
Gearing	0	0.5	1	2
Total capital	100,000	100,000	100,000	100,000
Equity	100,000	66,667	50,000	33,333
Debt	0	33,333	50,000	66,667
Profit before interest on debt	10,000	10,000	10,000	10,000
./. Interest on debt	0	2,333	3,500	4,667
Profit	10,000	7,667	6,500	5,333
Return on equity capital	10%	12%	13%	16%

Fig. 9.18 Relationship between leverage effect and return on equity (Excel File Financing, Worksheet Financing_Rules)

(Absolute numbers in € million)	Actual t_0
Total capital	100,000
Investment return	3,500
Return on total capital	4%
Interest rate on debt	7%

Fig. 9.19 Assumptions which imply a negative leverage effect (Excel File Financing, Worksheet Assumptions_Financing_Rules)

(Absolute numbers in € million)	Case 1	Case 2	Case 3	Case 4
Gearing	0	0.5	1	2
Total capital	100,000	100,000	100,000	100,000
Equity	100,000	66,667	50,000	33,333
Debt	0	33,333	50,000	66,667
Profit before interest on debt	3,500	3,500	3,500	3,500
./. Interest on debt	0	2,333	3,500	4,667
Profit	3,500	1,167	0	-1,167
Return on equity capital	4%	2%	0%	-4%

Fig. 9.20 Negative effect of leverage on the return on equity (Excel File Financing, Worksheet Financing_Rules)

4 Analysis of Key Figures

> Key figures provide quantitative information about the business situation.

An important tool to evaluate corporations is the calculation of key figures. They compress the information contained in annual reports and thus provide a quick overview of the financial situation of a company. In this section, important key figures concerning

- Return,
- Financial structure,
- Asset structure and
- Capital structure

are calculated in the Excel model using the example of Pharma Group.

4.1 Key Return Figures

> The return of a company, stated as a percentage, can be measured with the help of different key figures.

All key return figures share the commonality that a figure from the income statement is related to a figure from the balance sheet or another earnings figure.

Initially, the following important key return figures will be derived:

- Return on total capital
- Return on equity
- Return on sales
- Capital turnover

All values are calculated for the three periods covered by the balance sheet and the income statement. The following formulas are used:

$$Return\ on\ total\ capital = \frac{EBIT}{Total\ assets}$$

$$Return\ on\ equity = \frac{EAT}{Equity}$$

$$Return\ on\ sales = \frac{EBIT}{Total\ sales}$$

$$Capital\ turnover = \frac{Total\ sales}{Total\ assets}$$

The implementation in Excel can be seen in Figs. 9.21 and 9.22. The calculations are shown for the example of period t_{-2}.

Position	Formula	Excel implementation
Return on total capital (Analysis_of_Key_Figures!C7)	=EBIT / Total assets	='Income Statement'!C19/Assets!C22
Return on equity (Analysis_of_Key_Figures!C9)	=Earnings after taxes / Equity	='Income Statement'!C29/'Equity and Liabilities'!C13
Return on sales (Analysis_of_Key_Figures!C11)	=EBIT / Total sales	='Income Statement'!C19/'Income Statement'!C7
Capital turnover (Analysis_of_Key_Figures!C13)	=Total sales / Total assets	='Income Statement'!C7/Assets!C22

Fig. 9.21 Calculating the key return figures

	Key return figures	t_2	t_1	t_0
	Return on total capital	7.9%	7.7%	9.6%
	Return on equity	12.8%	13.2%	15.3%
	Return on sales	11.4%	9.9%	12.3%
	Capital turnover	0.7	0.8	0.8

Fig. 9.22 Key return figures (Excel File Financing, Worksheet Analysis_of_Key_Figures)

4.2 Key Figures about Financial Structure

> The key figures about financial structure help to identify relationships between assets and capital as well as investments and financing.

The key figures concerning the financial structure show the relationship between sources (liabilities) and uses (assets) of funds.

To calculate the key figures (see Figs. 9.23 and 9.24) for the financial structure, the following formulas are used:

Position	Formula	Excel implementation
Plant coverage ratio I (Analysis_of_Key_Figures!C18)	=Equity / Noncurrent assets	='Equity and Liabilities'!C13/Assets!C13
Plant coverage ratio II (Analysis_of_Key_Figures!C20)	=(Equity + Noncurrent liabilities) / Noncurrent assets	=('Equity and Liabilities'!C13+'Equity and Liabilities'!C22)/Assets!C13
Liquidity first grade (Analysis_of_Key_Figures!C22)	=Cash and cash equivalents / Current liabilities	=Assets!C18/'Equity and Liabilities'!C30
Quick ratio (Analysis_of_Key_Figures!C24)	=(Current assets - Inventories) / Current liabilities	=(Assets!C20-Assets!C15)/'Equity and Liabilities'!C30
Current ratio (Analysis_of_Key_Figures!C26)	= Current assets / Current liabilities	=Assets!C20/'Equity and Liabilities'!C30

Fig. 9.23 Calculating the key figures about the financial structure

Key figures on the financial structure	t_2	t_1	t_0
Plant coverage ratio I	58.9%	57.4%	64.4%
Plant coverage ratio II	120.5%	118.3%	115.5%
Liquidity first grade	13.2%	13.0%	11.9%
Quick ratio	102.3%	91.7%	84.9%
Current ratio	149.9%	145.1%	135.7%

Fig. 9.24 Key figures about the financial structure (Excel File Financing, Worksheet Analy-sis_of_Key_Figures)

- Plant coverage ratio I
- Plant coverage ratio II
- Liquidity first grade
- Quick ratio
- Current ratio

$$Plant\ coverage\ ratio\ I = \frac{Equity}{Noncurrent\ assets}$$

$$Plant\ coverage\ ratio\ II = \frac{Equity + Noncurrent\ liabilities}{Total\ assets}$$

$$Liquidity\ first\ grade = \frac{Cash\ and\ cash\ equivalents}{Current\ liabilities}$$

$$Quick\ ratio = \frac{Current\ assets - Inventories}{Current\ liabilities}$$

$$Current\ ratio = \frac{Current\ assets}{Current\ liabilities}$$

When calculating the liquidity figures, the item “Cash and cash-equivalents” is used for liquid funds. This leads to the following calculations for the relevant figures (using the example of period t_{-2}):

The key figures for liquidity appear low relative to the recommendations made in the literature. But these are only indications, and in applied work, significant deviations can be observed. Especially the first level liquidity ratio can be significantly below 100% for companies that follow IFRS.

4.3 Key Figures on the Asset Structure

> The key figures on the asset structure inform about type, composition, structure and duration of the assets.

From the analysis of the asset structure, we obtain information about type, composition, structure and duration of the assets. The analysis of the asset structure is also called vertical balance sheet analysis.

4.3.1 The Ratio of Fixed Assets to Current Assets

> The ratio of fixed assets to current assets shows the relationship between long-term and short-term property.

Initially it is helpful to get an overview of the structure of assets. The relevant key figures are

- Circulating intensity,
- Investment intensity,
- Asset composition.

They can be calculated with the following formulas (see Figs. 9.25 and 9.26):

$$\text{Circulating intensity} = \frac{\text{Current assets}}{\text{Total assets}}$$

$$\text{Investment intensity} = \frac{\text{Noncurrent assets}}{\text{Total assets}}$$

$$\text{Asset composition} = \frac{\text{Noncurrent assets}}{\text{Current assets}}$$

Position	Formula	Excel implementation
Circulating intensity (Analysis_of_Key_Figures!C33)	=Current assets / Total assets	=Assets!C20/Assets!C22
Investment intensity (Analysis_of_Key_Figures!C35)	=Noncurrent assets / Total assets	=Assets!C13/Assets!C22
Asset composition (Analysis_of_Key_Figures!C37)	=Noncurrent assets / Current assets	=Assets!C13/Assets!C20

Fig. 9.25 Calculating the key figures on the asset structure

	A	B	C	D	E
30					
31		Ratio of fixed assets to current assets	t_2	t_1	t_0
32					
33		Circulating intensity	38.1%	37.0%	37.1%
34					
35		Investment intensity	61.9%	63.0%	62.9%
36					
37		Asset composition	162.7%	170.0%	169.7%

Fig. 9.26 Key figures on the asset structure (Excel File Financing, Worksheet Analysis_of_Key_Figures)

4.3.2 Key Figures to Study the Investment and Depreciation Policy

Key figures to Study the Investment and Depreciation Policy highlight the requirements for sustainable positive corporate development concerning fixed assets.

The analysis of the investment and depreciation policy allows specific insights about the relationship between fixed assets and sustainable corporate growth. The relevant key figures in this regard are

- Investment grade wear,
- Investment ratio,
- Depreciation rate and
- Growth ratio.

All key figures work with tangible assets (see Figs. 9.27 and 9.28).

$$\textit{Investment grade wear} = \frac{\textit{Depreciation on tangible assets}}{\textit{Property, plant and equipment}}$$

$$\textit{Investment ratio} = \frac{\textit{Investment in tangible assets}}{\textit{Total sales}}$$

$$\textit{Depreciation rate} = \frac{\textit{Depreciation on tangible assets}}{\textit{Total sales}}$$

$$\textit{Growth ratio} = \frac{\textit{Investment in tangible assets}}{\textit{Depreciation on tangible assets}}$$

Position	Formula	Excel implementation
Investment grade wear (Analy-sis_of_Key_Figures!C41)	=Depreciation tangible assets / Property, plant and equipment	='Assumptions Key Fig-ures'!C8/Assets!C9
Investment ratio (Analy-sis_of_Key_Figures!C43)	=Investment tangible assets / Total sales	=('Assumptions Key Fig-ures'!C6)/'Income State-ment'!C7
Depreciation rate (Analy-sis_of_Key_Figures!C45)	=Depreciation tangible assets / Total sales	='Assumptions Key Fig-ures'!C8/'Income State-ment'!C7
Growth ratio (Analy-sis_of_Key_Figures!C47)	=Investments tangible assets / De-preciation tangible assets	='Assumptions Key Fig-ures'!C6/'Assumptions Key Figures'!C8

Fig. 9.27 Calculating the key figures on investment and depreciation policy

	A	B	C	D	E
38					
39		**Key figures to study the investment and depreciation policy**	t_2	t_1	t_0
40					
41		Investment grade wear	23.1%	16.8%	13.3%
42					
43		Investment ratio	1.1%	1.1%	4.4%
44					
45		Depreciation rate	6.2%	4.2%	3.3%
46					
47		Growth ratio	17.9%	26.7%	132.5%
48					

Fig. 9.28 Key figures on investment and depreciation policy (Excel File Financing, Analy-sis_of_Key_Figures)

4.3.3 Analysis of Net Working Capital

> The defining criteria for net working capital are limited retention period at the corporation and absence of interest payments.

Net working capital is defined as the surplus of operating current assets over non-interest bearing current liabilities. We will work with the following simplified calculation:

$$\begin{aligned} \textit{Net Working Capital} &= \textit{Inventories} + \textit{Trade accounts receivable} \\ &\quad + \textit{Other receivables} - \textit{Trade accounts payable} \\ &\quad - \textit{Other liabilities} \end{aligned}$$

The intensity of the net working capital can be derived with the help of the following formula. Also calculated are days sales outstanding, days payables outstanding and inventory turnover (see Figs. 9.29 and 9.30):

$$\textit{Net working capital intensity} = \frac{\textit{Net working capital}}{\textit{Total sales}}$$

$$\textit{Days sales outstanding} = \frac{\textit{Trade accounts receivable}}{\textit{Total sales}} * 360$$

Position	Formula	Excel implementation
Working capital intensity (Analysis_of_Key_Figures!C51)	=(Inventories + Trade accounts receivable + Other financial assets – Trade accounts payable – Other liabilities) / Total sales	=(Assets!C15+Assets!C16+Assets!C17-'Equity and Liabilities'!C26-'Equity and Liabilities'!C28)/'Income Statement'!C7
Days sales outstanding (Analysis_of_Key_Figures!C53)	=Trade accounts receivable / Total sales * Days per year	=Assets!C16/'Income Statement'!C7*'Assumptions General'!C8
Days payables outstanding (Analysis_of_Key_Figures!C55)	=Trade accounts payable / Cost of goods sold * Days per year	='Equity and Liabilities'!C26/'Income Statement'!C9*'Assumptions General'!C8
Inventory turnover (Analysis_of_Key_Figures!C57)	=Inventories / Cost of goods sold * Days per year	=Assets!C15/'Income Statement'!C9*'Assumptions General'!C8

Fig. 9.29 Calculating the key figures for the net working capital analysis

Analysis of net working capital	t_2	t_1	t_0
Working capital intensity	35.3%	29.4%	28.9%
Days sales outstanding	69.6	67.3	67.9
Days payables outstanding	75.8	81.3	83.2
Inventory turnover	127.6	132.0	132.7

Fig. 9.30 Key figures for the net working capital analysis (Excel File Financing, Worksheet Analysis_of_Key_Figures)

$$Days\ payables\ outstanding = \frac{Trade\ accounts\ payable}{Cost\ of\ goods\ sold} * 360$$

$$Inventory\ turnover = \frac{Inventories}{Cost\ of\ goods\ sold} * 360$$

4.4 Key Figures for the Capital Structure

> The analysis of the capital structure considers type, composition and duration of the sources of capital.

The key figures that deal with the capital structure help to assess the stability of the financing structure (see Figs. 9.31 and 9.32). Main figures are

Position	Formula	Excel implementation
Equity ratio (Analysis_of_Key_Figures!C62)	=Equity / Total equity and liabilities	='Equity and Liabilities'!C13/'Equity and Liabilities'!C32
Debt ratio (Analysis_of_Key_Figures!C64)	=(Noncurrent liabilities + Current liabilities) / Total equity and liabilities	=('Equity and Liabilities'!C22+'Equity and Liabilities'!C30)/'Equity and Liabilities'!C32
Gearing (Analysis_of_Key_Figures!C66)	=(Noncurrent liabilities + Current liabilities) / Equity	=('Equity and Liabilities'!C22+'Equity and Liabilities'!C30)/'Equity and Liabilities'!C13

Fig. 9.31 Calculating the key figures for the capital structure

Key figures for the capital structure	t_{-2}	t_{-1}	t_0
Equity ratio	36.5%	36.1%	40.5%
Debt ratio	63.5%	63.9%	59.5%
Gearing	1.7	1.8	1.5

Fig. 9.32 Key figures for the capital structure (Excel File Financing, Worksheet Analysis_of_Key_Figures)

- Equity ratio,
- Debt ratio and
- Gearing.

$$\textit{Equity ratio} = \frac{\textit{Equity}}{\textit{Total equity and liabilities}}$$

$$\textit{Debt ratio} = \frac{\textit{Debt}}{\textit{Total equity and liabilities}}$$

$$\textit{Gearing} = \frac{\textit{Debt}}{\textit{Equity}}$$

4.5 Key Figures for the Structure of Earnings

> The analysis of costs and revenues splits the overall result into the different contributing factors.

The following fundamental key figures concerning the structure of earnings will be analyzed:

- Cost of materials ratio,
- Gross profit ratio,
- Other operating income ratio,
- Research and development ratio,
- Financial result ratio and

- Interest expense ratio

(see Figs. 9.33 and 9.34):

Position	Formula	Excel implementation
Cost of materials ratio (Analysis_of_Key_Figures!C71)	=Cost of goods sold / Total sales	='Income Statement'!C9/'Income Statement'!C7
Gross profit ratio (Analysis_of_Key_Figures!C73)	=Gross profit on sales / Total sales	='Income Statement'!C11/'Income Statement'!C7
Other operating income ratio (Analysis_of_Key_Figures!C75)	=(Other operating income – Other operating expenses) / Total sales	=('Income Statement'!C17-'Income Statement'!C16)/'Income Statement'!C7
Research and development ratio (Analysis_of_Key_Figures!C77)	=Research and development expenses / Total sales	='Income Statement'!C14/'Income Statement'!C7
Financial result ratio (Analysis_of_Key_Figures!C79)	=-(Result from associates accounted for using the equity method + Financial income – Financial expenses)/ EBIT	=-('Income Statement'!C21+'Income Statement'!C22-'Income Statement'!C23)/'Income Statement'!C19
Interest expense ratio (Analysis_of_Key_Figures!C81)	=Financial expenses / Total sales	='Income Statement'!C23/'Income Statement'!C7

Fig. 9.33 Calculating the key figures for the structure of earnings

	A	B	C	D	E
68					
69		**Key figures for the structure of earnings**	t_2	t_1	t_0
70					
71		Cost of materials ratio	49.2%	48.0%	48.2%
72					
73		Gross profit ratio	50.8%	52.0%	51.8%
74					
75		Other operating income ratio	-2.2%	-4.7%	-1.8%
76					
77		Research and development ratio	8.0%	7.6%	7.9%
78					
79		Financial result ratio	18.9%	19.1%	14.7%
80					
81		Interest expense ratio	3.6%	3.1%	2.7%

Fig. 9.34 Key figures for the structure of earnings (Excel File Financing, Worksheet Analysis_of_Key_Figures)

$$\textit{Cost of materials ratio} = \frac{\textit{COGS}}{\textit{Total sales}}$$

$$\textit{Gross profit ratio} = \frac{\textit{Gross profit on sales}}{\textit{Total sales}}$$

$$\textit{Other operating income ratio} = \frac{\textit{Other operating income - Other operating expenses}}{\textit{Total sales}}$$

$$\textit{Research and development ratio} = \frac{\textit{Research and development expenses}}{\textit{Total sales}}$$

$$\textit{Financial result ratio} = \frac{\textit{Financial result}}{\textit{EBIT}}$$

$$\textit{Interest expense ratio} = \frac{\textit{Financial expenses}}{\textit{Total sales}}$$

For the implementation we assume that the cost of materials is equal to the variable costs of goods sold (COGS) from the income statement.

4.6 Cash Flow Key Figures

> Cash flow key figures help to analyze the earnings power, ability to finance out of earnings and the ability to service debt.

The most important key figures in this area are:

- Cash flow margin,
- Capital serving capacity (which in turn can be separated into the debt capacity and the dynamic gearing ratio),
- Internal financing power as well as
- Investment grade.

These key figures are calculated as follows (see Figs. 9.35 and 9.36):

$$\textit{Cash flow margin} = \frac{\textit{Operating cash flow}}{\textit{Total sales}}$$

$$\textit{Capital serving capacity} = \frac{\textit{Operating cash flow}}{\textit{Net financial liabilities}}$$

$$\textit{Dynamic gearing ratio} = \frac{\textit{Net financial liabilities}}{\textit{Operating free cash flow}}$$

$$\textit{Internal financing power} = \frac{\textit{Operating cash flow}}{\text{Investment in PPE and intangible assets}}$$

$$\textit{Investment grade} = \frac{\textit{Investing cash flow}}{\textit{Operating cash flow}}$$

Position	Formula	Excel implementation
Cash flow margin `(Analysis_of_Key_Figures!C86)`	=Operating cash flow / Total sales	`='Cash Flow Statement'!C19/'Income Statement'!C7`
Capital serving capacity `(Analysis_of_Key_Figures!C88)`	=Operating free cash flows / (Provisions for pensions and other post-employment benefits + Financial liabilities (non-current) + Financial liabilities (current) – Cash and cash equivalents)	`='Cash Flow'!C43/('Equity and Liabilities'!C15+'Equity and Liabilities'!C17+'Equity and Liabilities'!C18+'Equity and Liabilities'!C25-Assets!C18)`
Dynamic gearing ratio `(Analysis_of_Key_Figures!C90)`	=(Provisions for pensions and other post-employment benefits + Financial liabilities (non-current) + Other financial liabilities (non-current) + Financial liabilities (current) – Cash and cash equivalents) / Operating free cash flow	`=('Equity and Liabilities'!C15+'Equity and Liabilities'!C17+'Equity and Liabilities'!C18+'Equity and Liabilities'!C25-Assets!C18)/'Cash Flow'!C43`
Internal financing power `(Analysis_of_Key_Figures!C92)`	=–(Operating cash flow / Investment in property, plant and equipment and intangible assets)	`=-('Cash Flow Statement'!C19/'Cash Flow Statement'!C21)`
Investment grade `(Analysis_of_Key_Figures!C94)`	=–(Investing cash flow/ Operating cash flow)	`=-('Cash Flow Statement'!C29/'Cash Flow Statement'!C19)`

Fig. 9.35 Calculating cash flow key figures

	A	B	C	D	E
83					
84		**Cash flow key figures**	t_2	t_1	t_0
85					
86		Cash flow margin	13.9%	11.4%	12.9%
87					
88		Capital serving capacity	19.5%	15.2%	20.5%
89					
90		Dynamic gearing ratio	5.14	6.57	4.89
91					
92		Internal financing power	3.1	2.3	2.4
93					
94		Investment grade	76.9%	18.0%	49.9%

Fig. 9.36 Cash flow key figures (Excel File Financing, Worksheet Analysis of Key Figures)

5 The Ordinary Capital Increase

> An ordinary capital increase is defined as a capital increase which relies on issuing new shares.

A capital increase is defined as an increase of the equity of a company by issuing new shares. Existing shareholders can maintain their existing ownership percentage in the company via subscription rights. If they acquire additional subscription rights, they can even increase their holdings.

Using the applied example of Pharma Group, we will simulate an ordinary capital increase in the Excel model. New shares are issued during an ordinary capital increase and in principle cash or physical resources can be provided.

Several assumptions are needed in order to build the financial model of the capital increase. All assumptions are entered into the worksheet `Assumptions_Capital_Increase` in the Excel sheet. Since these assumptions determine the magnitude of the capital transaction, they should be known at the beginning. Initially a few basic values must be provided (see Figs. 9.37 and 9.38).

Position	Formula	Excel implementation
Subscribed capital (in million €) (Assumptions_Capital_Increase!E7)	=Subscribed capital at time t_0 (before the capital transaction)	='Equity and Liabilities'!E7
Number of old shares (in million) (Assumptions_Capital_Increase!E9)	Number of shares in million, which account for the subscribed capital at time t_0.	**Data check:** Only positive integers are accepted. **User input:** 827
Nominal value or calculated value of old shares (Assumptions_Capital_Increase!E11)	Nominal value of old shares in case of par value shares respectively calculated value of old shares in case of unit shares at time t_0. This value is obtained by dividing the share capital by the number of old shares. Since the number of shares is increased in line with the share capital in the case of unit shares, it is recommended to round the calculated share to two decimals. This facilitates the user input of the calculated value of new shares during a capital increase, since the exact decimal value is not required. Therefore the function =ROUND () is used to round to two decimal places.	=ROUND(E7/E9;2)
Price of old shares (Assumptions_Capital_Increase!E13)	The current share price of the old shares.	**Data check:** Only positive values are accepted. **User input:** 102
Tax rate (Assumptions_Capital_Increase!E15)	Tax rate which the company is required to pay on its earnings. Pharma Group works with a tax rate of 24.3% in year t_0.	**Data check:** Only values between 0 and 100% are accepted. **User input:** 24.3%

Fig. 9.37 Starting values for the capital transactions

(Absolute numbers in € million)	Acutal t_0
Subscribed capital	2,117
Number of old shares (in million)	827
Nominal value or calculated value of old shares	2.56
Price of old shares	102.00
Tax rate	24.3%

Fig. 9.38 Starting values for the capital transactions (Excel File Financing, Worksheet Assumptions_Capital increase)

5.1 Assumptions Concerning the Ordinary Capital Increase

Several additional assumptions must be made in order to model the capital increase. For the most part, these can be derived from the intended outcome of the measures. For example, the assumptions directly determine the amount of the additional equity and the theoretical value of the subscription right.

The explanations concerning the required input data can be seen in Figs. 9.39 and 9.40. In order to prevent errors, the fields are formatted in a way that only allows meaningful input.

Position	Formula	Excel implementation
Type of shares (Assumptions_Capital increase!E25)	Two main types of shares can be distinguished. **Nominal value shares:** These shares always have a nominal value. The sum of all nominal values determines the share capital of a stock corporation. **Unit shares:** In contrast to nominal value shares, unit shares do not have a nominal value but represent the theoretical fractional right in the share capital. Its value is calculated by dividing the share capital by the number of unit shares.	**Control element** (E25): Defined under: *Developer tools ➲ Attributes (Control elements) ➲ Control* Input Ranke: $B$45:$B$46 Cell reference: $D$44 Dropdown rows: 2 **User input:** Nominal value shares
Number of new shares (in million shares) (Assumptions_Capital increase!E27)	Number of new shares (in million shares) that the company is planning to issue during the capital increase.	**Data check:** Only positive values are allowed. **User input:** 165
Nominal value or calculated value of new shares (Assumptions_Capital increase!E29)	**Nominal value shares:** Nominal value of the shares to be issued. In the case of nominal value shares, the nominal value of new shares cannot be below the nominal value of old shares. **Unit shares:** Value of one unit share in the share capital (Subscribed capital / Number of unit shares). If unit shares are newly issued, the number of shares must be increased in line with the share capital.	**User input:** 2.56
Price of new shares (Assumptions_Capital increase!E31)	Is equal to the price of the shares to be issued. This is normally below the share price of old shares, in order to achieve a successful placement with investors.	**Data check:** Only positive values are allowed. **User input:** 84
Subscription ratio of old for new shares (Assumptions_Capital increase!C33)	The subscription ratio allows the existing shareholders to maintain their relative share concerning voting rights and ownership after the capital increase. Utilization of the subscription right protects the shareholder against possible losses as a result of the capital increase.	**Formula:** =(E9*E11)/(E27*E29)
Cost of tcapital increase (Assumptions_Capital increase!E35)	Estimated cost of the capital increase in percent of the volume issued. This is 3% on average, but can be considerably higher in case of smaller volumes.	**Data check:** Only positive values are allowed. **User input:** 3%

Fig. 9.39 Assumptions concerning the ordinary capital increase

	A	B	C	D	E	F
26						
27						Actual
28		(Absolute numbers in € million)				t_0
29		Type of shares				Nominal value shares
30						
31		Number of new shares (in million)				165
32						
33		Nominal value or calculated value of new shares				2.56
34						
35		Price of new shares				84.00
36						
37		Subscription ratio of old for new shares		5	:	1
38		Cost of capital increase				3%

Fig. 9.40 Assumptions concerning the ordinary capital increase (Excel File Financing, Worksheet Assumptions_Capital_Increase)

5.2 Calculating the Values on the Balance Sheet

Given the assumptions it is now possible in a second step to calculate the effects of the capital increase on the balance sheet and the income statement in the worksheet `Capital_Increase`. Initially the new composition of the share capital is calculated (see Figs. 9.41 and 9.42).

Based on this, it is possible to calculate the changes in the balance sheet and the income statement. Since the balance sheet of Pharma Group is based on IFRS, the effects are also analyzed according to these standards. The influence of the capital increase on the affected items "Subscribed capital," "Capital reserve" as well as "Cash and cash equivalents" are shown in Figs. 9.43 and 9.44.

This allows the derivation of the balance sheet and the income statement. To assure a uniform appearance, the individual items from

Position	Formula	Excel implementation
Number of shares t_1 (`Capital_Increase!F5`)	=Number of old shares + Number of new shares	`='Assumptions Capital Increase'!E9+'Assumptions Capital Increase'!E27`
Nominal value t_1 (`Capital_Increase!F7`)	=Subscribed capital t_1 / Number of shares t_1	`=D20/F5`

Fig. 9.41 Calculating the composition of the share capital

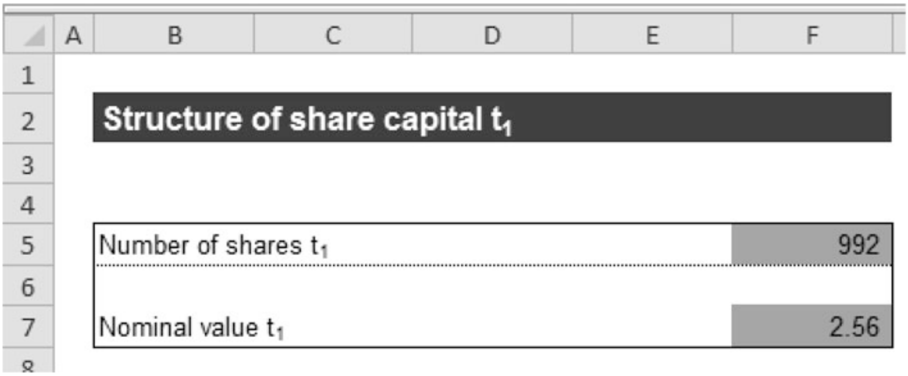


Fig. 9.42 The new composition of the share capital (Excel File Financing, Worksheet Capital_Increase)

Position	Formula	Excel implementation
t_0		
Subscribed capital (Capital_Increase!E16)	=Subscribed capital t_0	='Equity and Liabilities'!E7
Capital reserve (Capital_Increase!G16)	=Capital reserve t_0	='Equity and Liabilities'!E8
Cash and cash equivalents (Capital_Increase!I16)	=Cash and cash equivalents t_0	=Assets!E18
Capital increase		
Increase subscribed capital (Capital_Increase!E18)	=Number of new shares * Nominal value or calculated value of new shares	='Assumptions Capital Increase'!E27*'Assumptions Capital Increase'!E29
Increase capital reserve (Capital_Increase!G18)	=(Number of new shares * (Price of new shares - Nominal value or calculated value of new shares)) - (Cost of capital increase * Number of new shares * Price of new shares)	=('Assumptions Capital Increase'!E27*('Assumptions Capital Increase'!E31-'Assumptions Capital Increase'!E29)-('Assumptions Capital Increase'!E35*'Assumptions Capital Increase'!E27*'Assumptions Capital Increase'!E31))
Increase cash and cash equivalents (Capital_Increase!I18)	=Increase subscribed capital + Increase capital reserve	=D18+F18
t_1		
Subscribed capital (Capital_Increase!E20)	=Subscribed capital t_0 + Increase subscribed capital	=D16+D18
Capital reserve (Capital_Increase!G20)	= Capital reserve t_0 + Increase capital reserve	=F16+F18
Cash and cash equivalents (Capital_Increase!I20)	= Cash and cash equivalents t_0 + Increase cash and cash equivalents	=H16+H18

Fig. 9.43 Calculating the effects of the capital increase on the relevant balance sheet items

Time	Subscribed capital	Capital reserves	Cash and cash equivalents
t_0	2,117	6,167	1,662
Capital increase	422	13,022	13,444
t_1	2,539	19,189	15,106

Fig. 9.44 Effects of the capital increase on the relevant balance sheet items (Excel File Financing, Worksheet Capital_Increase)

Position	t_0 Formulas	Excel implementation	t_1 Formulas	Excel implementation
Cash and cash equivalents (Capital_Increase!E35 and F35)	=Cash and cash equivalents t_0	=Assets!E18	=Cash and cash equivalents t_1	=H20
Subscribed capital of Pharma Group (Capital_Increase!E46 and F46)	=Subscribed capital t_0	='Equity and Liabilities'!E7	=Subscribed capital t_1	=D20
Capital reserves of Pharma Group (Capital_Increase!E47 and F47)	=Capital reserve t_0	='Equity and Liabilities'!E8	=Capital reserve t_1	=F20

Fig. 9.45 Calculating assets before and after the capital increase

the worksheets “Balance sheet assets” and “Balance sheet liabilities” are linked with the new tables. This also reduces the probability of errors in the model. Since the income statement is unaffected according to IFRS, it is not modeled separately. Only those balance sheet items are listed that are affected by the capital increase (see Figs. 9.45 to 9.47).

(Absolute numbers in € million)	Actual t_0	Planned t_1
Noncurrent assets	32,289	32,289
Inventories	7,129	7,129
Receivables	7,569	7,569
Other financial assets	2,668	2,668
Cash and cash equivalents	1,662	15,106
Current assets	19,028	32,472
Total assets	51,317	64,761

Fig. 9.46 Assets before and after the capital increase (Excel File Financing, Worksheet Capital_Increase)

(Absolute numbers in € million)	Actual t_0	Planned t_1
Subscribed capital of Pharma Group	2,117	2,539
Capital reserves of Pharma Group	6,167	19,189
Other reserves	9,245	9,245
Net income	3,189	3,189
Equity attributable to non-controlling i	86	86
Equity capital	20,804	34,248
Provisions for pensions and other po	7,368	7,368
Other provisions	1,977	1,977
Bond	2,960	2,960
Other financial liabilities	2,630	2,630
Other liabilities	362	362
Deferred taxes	1,193	1,193
Noncurrent debt capital	16,490	16,490
Other provisions	4,727	4,727
Financial liabilities	3,441	3,441
Trade accounts payable	4,473	4,473
Deferred taxes	101	101
Other liabilities	1,281	1,281
Current debt capital	14,023	14,023
Total liabilities	51,317	64,761

Fig. 9.47 Liabilities before and after the capital increase (Excel File Financing, Worksheet Capital_Increase)

5.3 Calculating the Value of the Subscription Rights

A subscription right provides existing shareholders with the opportunity to obtain new shares during an ordinary capital increase.

Now we will determine the value of the subscription rights which belong to the existing shareholder. It is calculated as follows:

$$\text{Value of subscription right} = \frac{\text{Price of old shares} - \text{Price of new shares}}{\text{Subscription ratio} + 1}$$

The subscription right is introduced to give existing shareholders the opportunity to keep constant their relative share in the company following the capital increase. Additionally, possible wealth reductions as a result of the transaction must be compensated. These wealth reductions follow from the fact that the average price after the issuance of new shares is mostly below the previous price. The new price can be determined with the help of the formula

$$\text{New price} = \frac{\text{Price of old shares} + \text{Price of new shares}}{\text{Number of old shares} + \text{Number of new shares}}.$$

The shareholder can compensate this loss by selling his subscription rights. If instead new shareholders want to participate in the capital increase, they need to buy the subscription rights necessary for the purchase of new shares. For example, if the subscription ratio is 5:1 as in this case, a new shareholder needs to acquire five subscription rights from an existing shareholder in order to obtain the right to purchase one new share.

The modeling in Excel confirms that the existing shareholder does not suffer any financial damages if he sells his subscription rights (see Figs. 9.48 and 9.49):

Position	Calculation	Excel implementation
Subscription right		
Value of the subscription right (Capital_Increase!F80)	=(Price of the old shares - Price of new shares) / (Subscription ratio + 1)	=('Assumptions Capital Increase'!E13-'Assumptions Capital Increase'!E31)/(('Assumptions Capital Increase'!C33/'Assumptions Capital Increase'!E33)+1)
Existing shareholders		
Number of existing shares (Capital_Increase!E84)	=Number of old shares required to acquire one new share. This follows from the subscription ratio. 5 old shares are needed in case of a subscription ratio of 5:1.	='Assumptions Capital Increase'!C33
Old share price (Capital_Increase!E86)	=Price of old shares	='Assumptions Capital Increase'!E13
Asset value prior to capital increase (Capital_Increase!E88)	=Number of existing shares * Old share price	=E84*E86
New share price (Capital_Increase!E90)	=(Price of old shares + Price of new shares) / (Number of old shares + Number of new shares)	=('Assumptions Capital Increase'!E13*'Assumptions Capital Increase'!E9+'Assumptions Capital Increase'!E31*'Assumptions Capital Increase'!E27)/('Assumptions Capital Increase'!E9+'Assumptions Capital Increase'!E27)
New asset value (Capital_Increase!E92)	=Number of existing shares * New share price	=E84*E90
Loss (Capital_Increase!E94)	=New asset value – Asset value prior to capital increase	=E92-E88
Sale of subscription rights (Capital_Increase!E96)	=Value of the subscription right * Number of existing shares	=F80*E84
Asset value after capital increase (Capital_Increase!E98)	=New asset value + Sale of subscription rights	=E92+E96
New shareholders		
Price of one new share (Capital_Increase!J84)	=Price of new shares	='Assumptions Capital Increase'!E31
Subscription rights needed (Capital_Increase!J86)	=Number of old shares needed to acquire one new share.	='Assumptions Capital Increase'!C33
Cost of acquiring the subscription rights (Capital_Increase!J88)	=Subscription rights needed * Value of the subscription right	=J86*F80
Investment needed for one new share (Capital_Increase!J90)	=Price of one new share + Cost of acquiring the subscription rights	=J84+J88

Fig. 9.48 The sale of the subscription right will protect the value of the holding

Sale of the subscription right to maintain the level of wealth

Value of the subscription right	2.99

Existing shareholder	
Number existing shares	5.01
Old share price	102.00
Asset value prior to capital increase	511.24
New share price	99.01
New asset value	496.23
Loss	-15.01
Sale of subscription rights	15.01
Asset value after capital increase	511.24

New shareholder	
Price of one new share	84.00
Subscription rights needed	5.01
Cost of acquiring the subscription rights	15.01
Investment needed for one new share	99.01

Fig. 9.49 The sale of the subscription right will protect the value of the (Excel File Financing, Worksheet Capital_Increase)

6 The Long-Term Loan

A long-term loan has a maturity greater than one year.

As a type of external financing, the loan is an example of debt financing. For the three different types of loans

- Annuity loan,
- Amortizable loan,
- Bullet loan,

which differ with regard to the repayment terms, we will provide one example each in the Excel file. We will work with the following basic assumptions:

- Annual payment of the annuity
- Term of the loan between 5 and 10 years
- Payments occur at the end of the period

6.1 Assumptions Concerning the Long-Term Loan

In a first step, the required input data is provided. The input is independent of the type of loan (see Figs. 9.50 and 9.51).

Position	Description	Limitations/Excel implementation
Loan value (=Assumptions_Long-term_Loan!E7)	Nominal loan amount in Euro.	**Data check:** Only positive values are allowed. **User input:** 500,000
Term (in years) (=Assumptions_Long-term_Loan!E9)	The term of the loan in years. A long-term loan must have a term of at least five years. The selection allows a term between 5 and 10 years.	**Control element (E9):** Input Ranke: \$B\$29:\$B\$34 Cell reference: \$E\$28 Dropdown rows: 6 **User input:** 8
Nominal interest rate (=Assumptions_Long-term_Loan!E11)	The nominal interest rate of the loan.	**Data check:** Only positive values less than 50% are allowed. Imposing the upper limit protects the user against entering incorrect input values. **User input:** 10 %
Discount (=Assumptions_Long-term_Loan!E13)	The discount is the difference between nominal value of the loan and actual loan payment.	**Data check:** Only positive values less than 20% are allowed. Imposing the upper limit protects the user against entering unrealistically high values for the discount. **User input:** 3 %
Repayment rate (=Assumptions_Long-term_Loan!E15)	Input of the initial repayment rate on the annuity loan.	**Data check:** Only positive values are allowed. **User input:** 8%
Present value factor (=Assumptions_Long-term_Loan!E17)	The Present value factor is an important variable in the context of an annuity loan. In the absence of a spreadsheet, it is possible to determine the annuity from the present value of the payment stream and the annuity present value factor (it holds that Annuity = Present value / Annuity present value factor). The annuity present value factor is defined as $\frac{(1+i)^n-1}{i(1+i)^n}$, with i = nominal interest rate and n the term to maturity. We use the Excel formula =PV().	**Formula:** =PV(E11;E29;-1)
Recovery factor (=Assumptions_Long-term_Loan!E19)	The recovery factor is the reciprocal of the present value factor of an annuity	**Formula:** =1/E17

Fig. 9.50 Assumptions concerning the long-term loan

Loan	
Loan value	500,000
Term (in years)	8
Nominal interest rate	10.0%
Discount	3.0%
Repayment rate	8.0%
Present value factor	5.3349
Recovery factor	0.1874

Fig. 9.51 Assumptions concerning the long-term loan (Excel File Financing, Worksheet Assumptions_Long-term_Loan)

6.2 The Annuity Loan

An annuity loan involves constant installments consisting of interest payment and repayment.

The annuity is the sum of interest payments and repayment in a period. This amount is constant over the life of the loan. Over time, interest payments are decreasing while repayment is increasing. In the first step, important features of the loan are calculated (see Figs. 9.52 and 9.53).

Position	Formula	Excel implementation
Nominal value paid out (=Long-term_Loan!F7)	=Loan value * (1 – Discount)	='Assumptions Long-term Loan'!E7*(1-'Assumptions Long-term Loan'!E13)
Term (in years) (=Long-term_Loan!F9)	=Term	='Assumptions Long-term Loan'!E29
Annuity (=Long-term_Loan!F11)	=Annuity, calculated with the Excel formula =PMT(nominal interest rate; Term; Loan amount). PMT stands for regular payments, in other words the annuity.	=PMT('Assumptions Long-term Loan'!E11;F9;-'Assumptions Long-term Loan'!E7)
Effective interest rate (rule of thumb) (=Long-term_Loan!F13)	=(Nominal interest rate + Discount / Term) / (100% - Discount)	=('Assumptions Long-term Loan'!E11+'Assumptions Long-term Loan'!E13/F9)/(1-'Assumptions Long-term Loan'!E13)
Effective interest rate (internal rate of return) (=Long-term_Loan!F15)	=Exact effective interest rate, which is equivalent to the internal rate of return from the perspective of the loan provider.	=C169

Fig. 9.52 Calculating important values for the annuity loan

	A	B	C	D	E	F
4						
5		Values annuity loan				
6						
7		Nominal value paid out				485,000.00
8						
9		Term (in years)				8
10						
11		Annuity				93,722.01
12						
13		Effective interest rate (rule of thumb)				10.70%
14						
15		Effective interest rate (internal rate of return)				10.84%
16						

Fig. 9.53 Important values for the annuity loan (Excel File Financing, Worksheet Long-term_Loan)

The internal rate of return of the cash flows (considering the discount) must be determined in order to calculate the precise effective interest rate for a loan with a discount (see Fig. 9.54). The same procedure is needed in the case of an amortizable loan.

Position	Formula	Excel implementation
Effective interest rate (internal rate of return) (=Long-term_Loan!C169)	=IRR(Values;[Estimated value])	=IRR(C158:C168;'Assumptions Long-term Loan'!E11)

Fig. 9.54 Calculating effective interest rates

Position	Formula	Excel implementation
Year 1...5 (using the example t_1)		
Loan value at the beginning of the year (=Long-term_Loan!C23)	=Loan value	='Assumptions Long-term Loan'!E7
Annuity (total amount) (=Long-term_Loan!D23)	=Annuity	=$F$11
Interest (=Long-term_Loan!E23)	=Loan value at the beginning of the year * Nominal interest rate	=C23*'Assumptions Long-term Loan'!$E$11
Repayment (=Long-term_Loan!F23)	=Annuity – Interest	=D23-E23
Loan value at the end of the year (=Long-term_Loan!G23)	=Loan value at the beginning of the year – Repayment	=C23-F23

Fig. 9.55 Setting up the repayment schedule

Based on this preliminary work it is possible to set up the so-called repayment schedule. It summarizes all payments for interest and repayment in each period in the form of a table. The formulas used are (see Fig. 9.55):

The calculations in the periods 6...10 are identical in principle to those in the years 2...5. Additional IF-functions assure that values are calculated only for the case that the loan is still outstanding at that time. If that is not the case, the cell remains empty (see Figs. 9.56 and 9.57).

Up to this point, the discount was not considered. If a loan includes a discount, the amount that is paid out is reduced accordingly. Nonetheless, the full loan amount must be repaid. This means that the effective interest rate exceeds the nominal interest rate. From the perspective of the provider of the loan, the effective interest rate is equal

Year 6...10 (using the example t_6)		
Loan value at the beginning of the year (=Long-term_Loan!C28)	=If the loan balance is still greater zero, then: Loan value at the end of the previous year; otherwise: Empty cell	`=IF(B28<>"";G27;"")`
Annuity (total amount) (=Long-term_Loan!D28)	=If the loan balance is still greater zero, then: Annuity; otherwise: Empty cell	`=IF(B28<>"";$F$11;"")`
Interest (=Long-term_Loan!E28)	=If the loan balance is still greater zero, then: Loan at the beginning of the year * Nominal interest rate; otherwise: Empty cell	`=IF(B28<>"";C28*'Assumptions Long-term Loan'!$E$11;"")`
Repayment (=Long-term_Loan!F28)	= If the loan balance is still greater zero, then: Annuity - Interest; otherwise: Empty cell	`=IF(B28<>"";D28-E28;"")`
Loan value at the end of the year (=Long-term_Loan!G28)	= If the loan balance is still greater zero, then: Loan value at the beginning of the year – Repayment; otherwise: Empty cell	`=IF(B28<>"";C28-F28;"")`

Fig. 9.56 Setting up the repayment schedule

Schedule of interest payment and repayment considering loan discount

Year	Loan value at the beginning of the year	Annuity (Total payment)	Interest	Repayment	Loan value at the end of the year
1	500,000.00	93,722.01	50,000.00	43,722.01	456,277.99
2	456,277.99	93,722.01	45,627.80	48,094.21	408,183.78
3	408,183.78	93,722.01	40,818.38	52,903.63	355,280.15
4	355,280.15	93,722.01	35,528.02	58,193.99	297,086.16
5	297,086.16	93,722.01	29,708.62	64,013.39	233,072.76
6	233,072.76	93,722.01	23,307.28	70,414.73	162,658.03
7	162,658.03	93,722.01	16,265.80	77,456.21	85,201.83
8	85,201.83	93,722.01	8,520.18	85,201.83	0.00
∑		749,776.07	249,776.07	500,000.00	

Fig. 9.57 Interest payment and repayment in the case of an annuity loan (Excel File Financing, Worksheet Long-term_Loan)

to the internal rate of return of his investment. The effective interest rate can be approximated with the formula

$$i_{eff} = \frac{i_{nom} + \frac{d}{n}}{100\% - d}$$

Position	Formula	Excel implementation
Year 1		
Actual loan value at the beginning of the year (=Long-term_Loan!C41)	=Loan value	=F7
Interest (=Long-term_Loan!E41)	= The amount paid out * effective interest rate	=C41*$F$15

Fig. 9.58 Repayment schedule for the annuity loan (Excel File Financing, Worksheet Long-term Loan)

Schedule of interest payment and repayment considering discount

Year	Loan value at the beginning of the year	Annuity (Total payment)	Interest	Repayment	Loan value at the end of the year
1	485,000.00	93,722.01	52,593.39	41,128.62	443,871.38
2	443,871.38	93,722.01	48,133.40	45,588.61	398,282.77
3	398,282.77	93,722.01	43,189.77	50,532.24	347,750.54
4	347,750.54	93,722.01	37,710.06	56,011.95	291,738.59
5	291,738.59	93,722.01	31,636.12	62,085.88	229,652.70
6	229,652.70	93,722.01	24,903.53	68,818.48	160,834.23
7	160,834.23	93,722.01	17,440.86	76,281.15	84,553.08
8	84,553.08	93,722.01	9,168.93	84,553.08	0.00
∑		749,776.07	264,776.07	485,000.00	

Fig. 9.59 Repayment schedule for the annuity loan (Excel File Financing, Worksheet Long-term_Loan)

with:

d = Discount

n = Term

i_{nom} = Nominal interest rate.

For a precise determination of this interest rate, the internal rate of return of the cash flows must be determined. Both effective interest rates were already listed above among the important key figures. Due to the difference between nominal and effective interest rate and the reduction in the amount that is paid out, a new repayment schedule is required.

Only a few changes in the formulas, which are identical for all periods, are needed to set up this new repayment schedule (see Fig. 9.58).

The resulting repayment schedule is shown in Fig. 9.59.

6.3 The Amortizable Loan

An amortizable loan (also called redeemable loan) is characterized by a constant (linear) repayment over a fixed time period.

A second possibility is the amortizable loan. The annual repayment is given by the ratio of loan amount and term of the loan. The overall payment goes down steadily due to the reduced interest payment.

The most important key figures of the amortizable loan are as follows (see Figs. 9.60 and 9.61):

With these preliminary calculations, it is possible to determine the repayment schedule (see Figs. 9.62 and 9.63):

Position	Formula	Excel implementation
The amount paid out (=Long-term_Loan!G61)	=Loan value * (1 – Discount)	='Assumptions Long-term Loan'!E7*(1-'Assumptions Long-term Loan'!E13)
Term (in years) (=Long-term_Loan!G63)	=Term	='Assumptions Long-term Loan'!E29
Annual repayment (=Long-term_Loan!G65)	=Loan value / Term	='Assumptions Long-term Loan'!E7/G63
Actual annual repayment (=Long-term_Loan!G67)	=Nominal loan value paid out / Term	=G61/G63
Effective interest rate (rule of thumb) (=Long-term_Loan!G69)	=(Nominal interest rate + Discount / ((Term+1) / 2) / (100% - Discount)	=('Assumptions Long-term Loan'!E11+'Assumptions Long-term Loan'!E13/((G63+1)/2))/(1-'Assumptions Long-term Loan'!E13)
Effective interest rate (internal rate of return) (=Long-term_Loan!G71)	=Exact effective interest rate, equal to the internal rate of return	=C186

Fig. 9.60 Important features of the amortizable loan

Values amortizable loan	
Nominal value paid out	485,000.00
Term (in years)	8
Annual repayment	62,500
Actual annual repayment	60,625
Effective interest rate (rule of thumb)	11.00%
Effective interest rate (internal rate of return)	10.92%

Fig. 9.61 Important features of the amortizable loan (Excel File Financing, Worksheet Long-term_Loan)

Position	Formula	Excel implementation
Year 1...5 (example t_1)		
Loan value at the beginning of the year (=Long-term_Loan!C79)	=Loan value	='Assumptions Long-term Loan'!E7
Annuity (total payment) (=Long-term_Loan!D79)	=Interest + Repayment	=E79+F79
Interest (=Long-term_Loan!E79)	=Loan value at the beginning of the year * Nominal interest rate	=C79*'Assumptions Long-term Loan'!$E$11
Repayment (=Long-term_Loan!F79)	=Repayment	=$G$65
Loan value at the end of the year (=Long-term_Loan!G79)	=Loan value at the beginning of the year – Repayment	=C79-F79
Years 6...10 (example t_6)		
Loan value at the beginning of the year (=Long-term_Loan!C84)	=If the loan balance is still greater zero, then: Loan value at the end of the previous year; otherwise: Empty cell [1]	=IF(B84<>"";G83;"")
Annuity (total payment) (=Long-term_Loan!D84)	= If the loan balance is still greater zero, then: Interest + Repayment; otherwise: Empty cell	=IF(B84<>"";E84+F84;"")
Interest (=Long-term_Loan!E84)	=If the loan balance is still greater zero, then: Loan value at the beginning of the year * Nominal interest rate; otherwise: Empty cell	=IF(B84<>"";C84*'Assumptions Long-term Loan'!$E$11;"")
Repayment (=Long-term_Loan!F84)	=If the loan balance is still greater zero, then: Repayment; otherwise: Empty cell	=IF(B84<>"";$G$65;"")
Loan value at the end of the year (=Long-term_Loan!G84)	=If the loan balance is still greater zero, then: Loan value at the beginning of the year - Repayment; otherwise: Empty cell	=IF(B84<>"";C84-F84;"")

Fig. 9.62 Repayment schedule for the amortizable loan

Schedule of interest payment and repayment

Year	Loan value at the beginning of the year	Annuity (Total payment)	Interest	Repayment	Loan value at the end of the year
1	500,000.00	112,500.00	50,000.00	62,500.00	437,500.00
2	437,500.00	106,250.00	43,750.00	62,500.00	375,000.00
3	375,000.00	100,000.00	37,500.00	62,500.00	312,500.00
4	312,500.00	93,750.00	31,250.00	62,500.00	250,000.00
5	250,000.00	87,500.00	25,000.00	62,500.00	187,500.00
6	187,500.00	81,250.00	18,750.00	62,500.00	125,000.00
7	125,000.00	75,000.00	12,500.00	62,500.00	62,500.00
8	62,500.00	68,750.00	6,250.00	62,500.00	0.00
Σ		725,000.00	225,000.00	500,000.00	

Fig. 9.63 Repayment schedule for the amortizable loan (Excel File Financing, Worksheet Long-term_Loan)

For the amortizable loan it again makes sense to also consider the effective repayment schedule. The effective rate of interest is equal to the internal rate of return from the perspective of the provider of capital. Since this cannot be calculated without tools such as Excel, the approximate formula is again interesting. A slight modification of the equation for the annuity loan is required:

$$i_{eff} = \frac{i_{nom} + \frac{d}{\frac{t+1}{2}}}{100\% - d}$$

The term to maturity t is replaced by the average term to maturity (t+1)/2. When modeling the effective repayment schedule, the internal rate of return is again used as the effective interest rate (see Figs. 9.64 and 9.65).

Position	Formula	Excel implementation
Year 1		
Loan value at the beginning of the year (=Long-term loan!C97)	=Nominal value paid out	=G61
Interest (=Long-term loan!E97)	=Loan value at the beginning of the year * Effective interest rate	=C97*$G$71

Fig. 9.64 Calculating the actual loan balance and the interest paid for the amortizable loan

	A	B	C	D	E	F	G
92							
93		Schedule of interest payment and repayment considering loan discount					
94							
95		Year	Loan value at the beginning of the year	Annuity (Total payment)	Interest	Repayment	Loan value at the end of the year
96							
97		1	485,000.00	113,602.36	52,977.36	60,625.00	424,375.00
98		2	424,375.00	106,980.19	46,355.19	60,625.00	363,750.00
99		3	363,750.00	100,358.02	39,733.02	60,625.00	303,125.00
100		4	303,125.00	93,735.85	33,110.85	60,625.00	242,500.00
101		5	242,500.00	87,113.68	26,488.68	60,625.00	181,875.00
102		6	181,875.00	80,491.51	19,866.51	60,625.00	121,250.00
103		7	121,250.00	73,869.34	13,244.34	60,625.00	60,625.00
104		8	60,625.00	67,247.17	6,622.17	60,625.00	0.00
105							
106							
107							
108		∑		723,398.12	238,398.12	485,000.00	
109							

Fig. 9.65 Repayment schedule for the amortizable loan (Excel File Financing, Worksheet Long-term Loan)

6.4 The Bullet Loan

The bullet loan (also called interest-only-loan) is a loan where the entire loan amount is due only at the end of term to maturity.

Only interest payments are made during the term of the loan and the loan is repaid at the maturity date. In the last period, the loan is fully repaid. Since no specific values are needed for the financial model, the repayment schedule can be determined directly. There is no need to discuss an effective repayment schedule in this case (see Figs. 9.66 and 9.67).

Position	Formula	Excel implementation
Years 1...4 (example t_1)		
Loan value at the beginning of the year (=Long-term_Loan!C127)	=Loan value	='Assumptions Long-term Loan'!E7
Annuity (total payment) (=Long-term_Loan!D127)	=Interest + Repayment	=E127+F127
Interest (=Long-term_Loan!E127)	=Loan value at the beginning of the year * Nominal interest rate	=C127*'Assumptions Long-term Loan'!$E$11
Repayment (=Long-term_Loan!F127)	-	0
Loan value at the end of the year (=Long-term_Loan!G127)	=Loan value at the beginning of the year – Repayment	=C127-F127
Year 5		
Loan value at the beginning of the year (=Long-term_Loan!C131)	=Loan value at the end of the year t_{-1}	=G130
Annuity (total payment) (=Long-term_Loan!D131)	=Interest + Repayment	=E131+F131
Interest (=Long-term_Loan!E131)	=Loan value at the beginning of the year * Nominal interest rate	=C131*'Assumptions Long-term Loan'!$E$11
Repayment (=Long-term_Loan!F131)	=If the loan is repaid in this year, then: Loan value; Else 0	=IF(B131=$G$119;'Assumptions Long-term Loan'!$E$7;0)
Loan value at the end of the year (=Long-term_Loan!G131)	=Loan value at the beginning of the year – Repayment	=C131-F131
Years 6...10 (example t_6)		
Loan value at the beginning of the year (=Long-term_Loan!C132)	=If the loan is not repaid in this year, then: Loan value at the end of the year t_{-1}; Else: empty cell	=IF(B132<>"";G131;"")
Annuity (total payment) (=Long-term_Loan!D132)	=If the loan is not repaid in this year, then: Interest + Repayment; Else: empty cell	=IF(B132<>"";E132+F132;"")
Interest (=Long-term_Loan!E132)	=If the loan is not repaid in this year, then: Loan value at the beginning of the year * Nominal interest rate; Else: empty cell	=IF(B132<>"";C132*'Assumptions Long-term Loan'!$E$11;"")
Repayment (=Long-term_Loan!F132)	=If the loan is repaid in this year, then: Loan value; Else: If the loan is not repaid in this year, then: 0; Else: empty cell	=IF(B132=$G$119;'Assumptions Long-term Loan'!$E$7;IF(B132<>"";0;""))
Loan value at the end of the year (=Long-term_Loan!G132)	=If the loan is not repaid in this year, then: Loan value at the beginning of the year - Repayment; Else: empty cell	=IF(B132<>"";C132-F132;"")

Fig. 9.66 Repayment schedule for the bullet loan

Schedule of interest payment and repayment

Year	Loan value at the beginning of the year	Annuity (Total payment)	Interest	Repayment	Loan value at the end of the year
1	500,000.00	50,000.00	50,000.00	0.00	500,000.00
2	500,000.00	50,000.00	50,000.00	0.00	500,000.00
3	500,000.00	50,000.00	50,000.00	0.00	500,000.00
4	500,000.00	50,000.00	50,000.00	0.00	500,000.00
5	500,000.00	50,000.00	50,000.00	0.00	500,000.00
6	500,000.00	50,000.00	50,000.00	0.00	500,000.00
7	500,000.00	50,000.00	50,000.00	0.00	500,000.00
8	500,000.00	550,000.00	50,000.00	500,000.00	0.00
Σ		900,000.00	400,000.00	500,000.00	

Fig. 9.67 Repayment schedule for the bullet loan (Excel File Financing, Worksheet Long-term_Loan)

6.5 Comparison of the Various Types of Repayment

A graphical analysis is preferable in Excel for the comparison of the various repayment methods. In a stacked diagram with time on the x-axis, that displays interest payments and repayment, the following comparison emerges (see Figs. 9.68 to 9.70):

The graphs clearly display the main advantages and disadvantages. The annuity loan, for example, always involves constant payments. In contrast, the bullet loan minimizes payments in the earlier periods. As an additional decision criterion, the sum of interest expenses during the entire term to maturity is modeled. This is implemented in Excel as follows (see Figs. 9.71 and 9.72):

The result is unsurprising: the amortizable loan is characterized by high interest payments in the beginning, which implies the lowest overall interest burden. The highest cost is associated with the bullet loan, where repayment is reserved for the last period. The annuity loan falls between these two extremes.

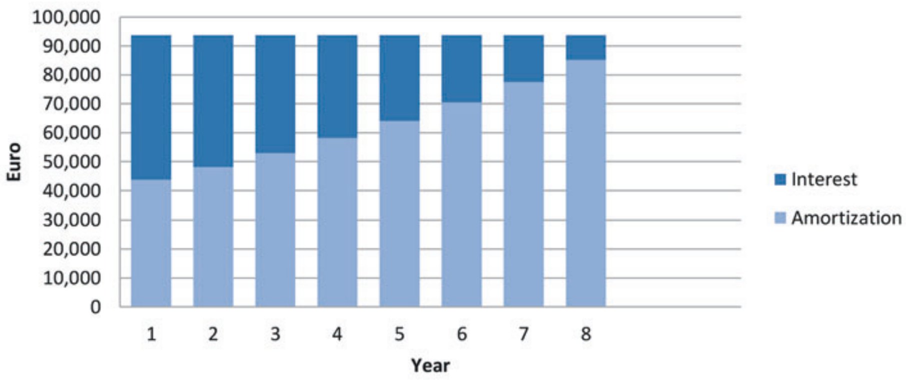


Fig. 9.68 Interest and repayment for the annuity loan (Excel File Financing, Worksheet Long-term_Loan)

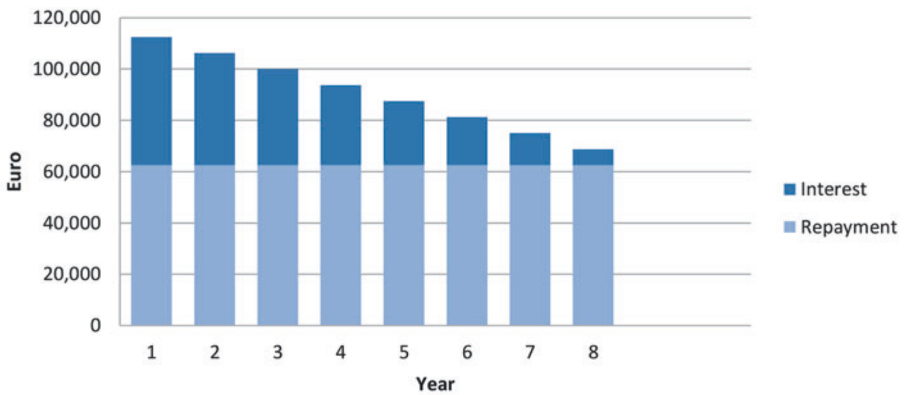


Fig. 9.69 Interest and repayment for the amortizable loan (Excel File Financing, Worksheet Long-term_Loan)

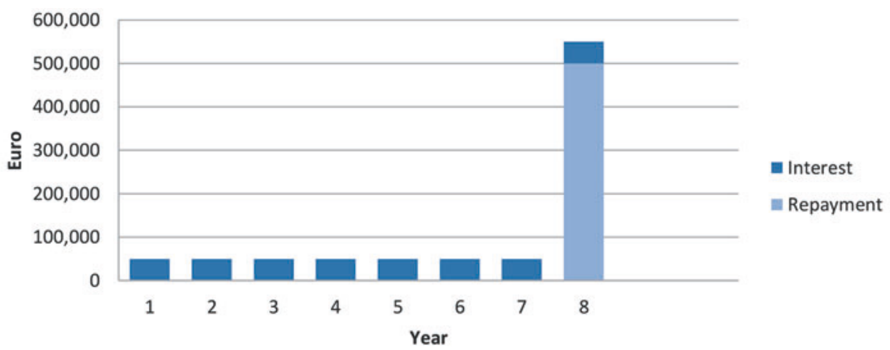


Fig. 9.70 Interest and repayment for the bullet loan (Excel File Financing, Worksheet Long-term_Loan)

Position	Explanation	Excel implementation
Annuity loan		
Rank (=Long-term_Loan!B146)	The rank among the different repayment options is determined with the help of the Excel function =RANK() in ascending order. This means that the loan with the lowest interest payments will be ranked first.	`=RANK(E146;$E$146:$E$148;1))`
Total interest expense (=Long-term_Loan!E146)	= Sum of interest expense	`=E34`
Amortizable loan		
Rank (=Long-term_Loan!B147)	The rank among the different repayment options is determined with the help of the Excel function =RANK() in ascending order. This means that the loan with the lowest interest payments will be ranked first.	`=RANK(E147;$E$146:$E$148;1)`
Total interest expense (=Long-term_Loan!E147)	=Sum of interest expense	`=E90`
Bullet loan		
Rank (=Long-term_Loan!B148)	The rank among the different repayment options is determined with the help of the Excel function =RANK() in ascending order. This means that the loan with the lowest interest payments will be ranked first.	`=RANK(E148;$E$146:$E$148;1)`
Total interest expense (=Long-term_Loan!E148)	=Sum of interest expense	`=E138`

Fig. 9.71 Comparison of interest payments for the long-term loans

	A	B	C	D	E
141					
142		**Comparison of interest payments**			
143					
144		**Rank**	**Type of repayment**		**Total interest expense**
145					
146		2	Annuity loan		249,776.07
147		1	Amortizable loan		225,000.00
148		3	Bullet loan		400,000.00

Fig. 9.72 Comparison of interest payments for the long-term loans (Excel File Financing, Worksheet Long-term_Loan)

7 Bonds

> Bonds are securities which allow the placement of a loan in the capital markets. Bonds are publicly placed exclusively by legal entities.

Bonds are a type of external financing. A provider of capital (creditor) transfers an amount of money to the recipient (debtor) for a specified amount of time. This gives him the right to receive future interest and repayments. In contrast to long-term loans, the amount of the nominal value is usually so large that a single provider of capital is unable – or unwilling – to provide the entire sum. For that reason the loan amount is split up into numerous tranches that have smaller nominal values, which are acquired by private or institutional investors at the time of issuance or via an exchange. In contrast to loans, bonds are securities and can therefore be traded in financial markets.

In the Excel example, the issuance of a bond by Pharma Group is modeled. This requires the determination of several input parameters such as term to maturity, interest payments (coupons), and currency of the bond. These features of the bond are analyzed with regard to their effect on the balance sheet and the profit and loss statement. In addition, the effective interest charged, the accrued interest and the price of the bond will be calculated. In the following, issues of risk management are discussed with reference to key figures such as duration and convexity.

7.1 Assumptions for the Bond

In the first step, general information concerning the nominal amount, the denomination and currency of the bond are entered (see Figs. 9.73 and 9.74).

The next input range covers the specifics concerning interest payment, issuing cost and repayment (see Figs. 9.75 and 9.76):

Finally parameters which are specific to the term to maturity are required as input data for some of the following calculations (see Figs. 9.77 and 9.78).

Position	Explanation	Limitations/Excel implementation
Currency (=Assumptions_Bond!E7)	Here the user can select the currency of the bond. Available currencies are **Euro**, **US-Dollar**, **British Pound** as well as **Swiss Franc**.	**Control element:** Input range: `$B$234:$B$237` Cell reference: `$E$233` Dropdown rows: 4 **User input:** `Euro`
Bond volume (in million) (=Assumptions_Bond!E9)	The bond volume in million monetary units.	**Data check:** In applied work, the total issue volume frequently exceeds 100 million due to high transaction costs **User input:** `2.960`
Face value of bond (=Assumptions_Bond!E11)	The purchase of a bond is based on its nominal denomination. For example, this can be in **1,000**, **50,000**, **100,000** monetary units (depending on the currency).	**Control element (E11):** Input range: `$B$242:$B$244` Cell reference: `$E$241` Dropdown rows: 3 **User input:** `1000`
Nominal value of bond (=Assumptions_Bond!E13)	The nominal value is the amount which the issuer is required to repay to the purchaser. At the end of the term to maturity, this amount is repaid at the nominal value of 100 or above.	**User input:** `100`
Exchange rate (=Assumptions_Bond!E15)	The exchange rate between the Euro (the accounts of Pharma Group are in Euro) and the currency selected in the indirect notation. If the currency is the Euro, the cell turns grey and thus indicates that no input is required.	**Data check** Only positive values are allowed. **User input:** `1,00`

Fig. 9.73 Assumptions about volume, denomination and currency of the bond

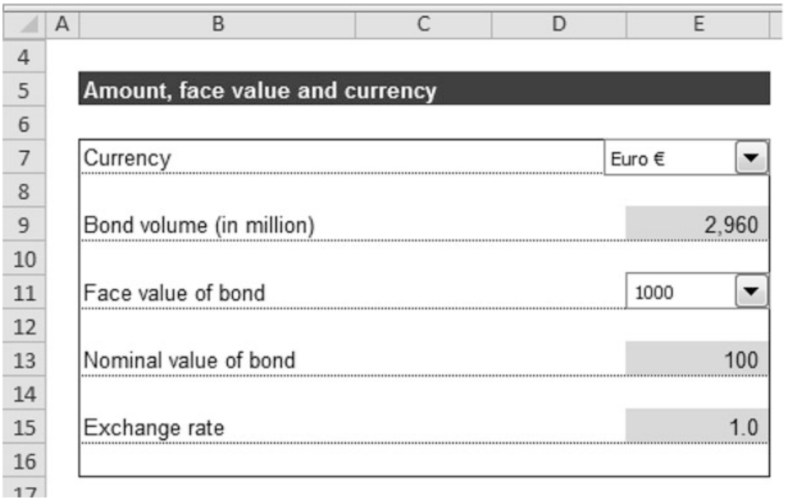


Fig. 9.74 Assumptions about volume, denomination and currency of the bond (Excel File Financing, Worksheet Assumptions_Bond)

Position	Explanations	Limitations/Excel implementation
Type of issue (=Assumptions_Bond!E21)	User selection whether the issue is managed **outside** or **self**. This field is mainly for informational purposes and is not included in the following calculations. Normally it is cheaper to manage the issue internally, since this means that no bank fees are paid.	**Control element:** Input range: $B$249:$B$250 Cell reference: $E$248 Dropdown rows: 2 **User input:** output
Rating of Pharma Group (=Assumptions_Bond!E23)	AA	**User input:** AA
Capital market yield on 01.01.2013 (=Assumptions_Bond!E25)	Based on the rating of Pharma Group, the return of a comparable bond is selected.	**User input:** 6.51%
Equivalent period yield (=Assumptions_Bond!E27)	Since coupon payments are semi-annually, the annual return is converted into a semi-annual return.	=(1+E25)^(1/E35)-1
Issuing cost (in % of nominal value) (=Assumptions_Bond!E29)	Issuing costs are paid only once, namely at the time of issue. It includes banking and listing fees, costs of providing collateral, as well as marketing and printing costs.	**User input:** 3.0%
Coupon rate (nominal interest rate) (=Assumptions_Bond!E31)	The nominal interest rate of the bond.	**Data check:** Only values between 0 and 15% are allowed. **User input:** 6%
Frequency of coupon payment (=Assumptions_Bond!E33)	User needs to select whether coupon payments are **annual** or **semi-annual**.	**Control element:** Input range: $B$255:$B$256 Cell reference: $E$254 Dropdown rows: 2 **User input:** semi-annual
Frequency of coupon payment (=Assumptions_Bond!E35)	Indicates the frequency of coupon payments.	=E254
Capital market yield (for a term to maturity of 8.625 years) (=Assumptions_Bond!E37)	Indicates the yield to maturity of 8.625 years.	**User input:** 7.0%

Fig. 9.75 Assumptions concerning interest payment and cost of the bond

19	**Interest paymentand cost**	
21	Type of issue	outside
23	Rating of Pharma Group	AA
25	Capital market yield on 01.01.2013	6.51%
27	Equivalent period yield	3.21%
29	Issue cost in % of nominal value	3.0%
31	Coupon rate (nominal interest rate)	6.0%
33	Frequency of coupon payment	semi-annual
35	Frequency of coupon payment	2
37	Capital market yield (for a term to maturity of 8.625 years)	7.00%

Fig. 9.76 Assumptions concerning interest payment and cost of the bond (Excel File Financing, Worksheet Assumptions_Bond)

Position	Explanation	Limitations/Excel implementation
Date of issue (=Assumptions_Bond!E43)	The date on which Pharma Group issues the bond.	**Data check:** Input must follow the date format and be between 01.01.2000 and 01.01.2022. **User input:** 01.01.2013
Term (in years) (=Assumptions_Bond!E45)	The term of the bond in years.	**Data check:** Only integers in the range 1 to 20 are accepted. **User input:** 10
Term (in semi-annual periods) (=Assumptions_Bond!E47)	The term as measured by the frequency of coupon payments.	=E45*E35
Repayment date (=Assumptions_Bond!E49)	The repayment date follows from the issue date and the term to maturity. For the automatic determination of this date, the Excel functions =DATE(), =YEAR(), =MONTH() and =DAY() are used.	=DATE(YEAR(E43)+E45;MONTH(E43);DAY(E43)-1)
Purchase date of bond (=Assumptions_Bond!E51)	The analysis of the bond characteristics is also conducted from the perspective of the investor. Since the bond is frequently purchased on the exchange after the issue date, this input is required.	**Data check:** The input is in the format of a date and must lie between issue date and repayment date. **User input:** 15.05.2014

Fig. 9.77 Assumptions about the maturity of the bond

	A	B	C	D	E
40					
41		Term			
42					
43		Date of issue			01.01.2013
44					
45		Term (in years)			10
46					
47		Term (in semi-annual periods)			20
48					
49		Repayment date			31.12.2022
50					
51		Purchase date of bond			15.05.2014
52					

Fig. 9.78 Assumptions about the maturity of the bond (Excel File Financing, Worksheet Assumptions_Bond)

7.2 Analyzing the Bond from the Issuer Perspective

Cash flow and discount rate determine the price of a bond.

The purchase of a bond is a financial investment and the price determination follows the typical methods which are familiar from investment appraisal. If the discount rate is known and the payment stream is certain, the present value of the future payments (interest and repayment of principal) is equal to the market value of the bond.

If additionally the term structure of interest rates is flat, the value of a coupon bond when the next coupon payment is exactly one year away and repaid at par at the maturity date (straight bond) can be calculated as

$$P = \frac{C}{1+r} + \frac{C}{(1+r)^2} + \ldots + \frac{C+M}{(1+r)^n} = \sum_{t=1}^{n} C \cdot (1+r)^{-t} + M \cdot (1+r)^{-n}$$

Since the coupon payments can also be interpreted as an annuity which is paid at the end of the period, it is possible to write:

$$P = C \cdot \left[\frac{(1+r)^n - 1}{r \cdot (1+r)^n} \right] + \frac{M}{(1+r)^n}$$

with

P = Present value (price) of the bond at $t = 0$
M = Nominal value of the bond (maturity value)
c = Coupon rate (nominal interest rate)
C = Coupon payment, $C = c \cdot M$
r = Market interest rate p.a. (effective interest rate, required rate of return, yield to maturity are used synonymously)
r_e = Effective interest rate when considering the cost of issuing the bond
n = (Remaining) term to maturity

The first term of the present value equation shows the present value of the coupon payments reinvested at the interest rate of r (underlying the present value approach is the reinvestment assumption), the second term is the present value of the amount which is repaid at maturity, that is, the maturity value, face value, par value or simply par.

For a given price, the relationship

$$P = \frac{C}{1+r} + \frac{C}{(1+r)^2} + \ldots + \frac{C+M}{(1+r)}$$

can be used to derive the effective annual interest rate r (yield to maturity) via an approximation method (such as linear interpolation) or with the Excel function *IRR*.

Pharma Group makes semi-annual coupon payments. If the next coupon payment occurs exactly in half a year, the coupon payment, the market interest rate and the term to maturity need to be adjusted. The amount of the semi-annual coupon payments is $C/2$, the annual market interest rate becomes the period interest rate $r/2$ and the term to maturity is $2n$. This leads to a price of the bond in the case of semi-annual interest payments of:

$$P = \frac{C/2}{1+r/2} + \frac{C/2}{(1+r/2)^2} + \ldots + \frac{C/2+M}{(1+r/2)^{2\cdot n}} = \sum_{t=1}^{2\cdot n} C \cdot (1+r/2)^t + \frac{M}{(1+r/2)^{2\cdot n}}$$

or

$$P = C/2 \cdot \left[\frac{(1 + r/2)^{2 \cdot n} - 1}{r/2 \cdot (1 + r/2)^{2 \cdot n}} \right] + \frac{M}{(1 + r/2)^{2 \cdot n}}$$

According to the market convention, annual interest rates (market interest rate) are transformed into period interest rates. This results in an effective interest rate which exceeds the nominal annual interest rate. Given the price P, from

$$P = \frac{C/2}{1 + r/2} + \frac{C/2}{(1 + r/2)^2} + \ldots + \frac{C/2 + M}{(1 + r/2)^{2n}}$$

the effective semi-annual interest rate $r/2$ follows, which can be transformed into an effective annual interest rate as follows:

$$r = (1 + r/2)^2 - 1$$

The aim of the next step is to find an issue price that is accepted in the market. It is determined mainly by capital market interest rates, which in turn are driven by the overall level of riskless interest rates, the (remaining) term to maturity and the risk premium of the issuer. The main challenge is to find the appropriate capital market interest rate (discount rate), so that the bond is neither overvalued nor undervalued when issued.

In principle it holds that bonds should yield a return that is aligned with their risk. This means that bonds with higher (lower) risk should also have higher (lower) interest rates.

The correct discount rate can be derived from comparable securities that are already traded in the market. Comparable means that the bond is in the same risk category as Pharma Group (namely a bond with a rating of AA) and has an identical term to maturity. This interest rate can be used for discounting the coupon payments and the nominal value. The sum of the discounted cash flows can be interpreted as the issue price for Pharma Group.

The interest rate derived from market data (discount rate) of 6.51% is the effective interest rate excluding any issue costs, which is relevant for the investor. Pharma Group bases the valuation of its bonds on this interest rate. This yields an issue price of 97.00.

Position	Formula	Excel implementation
Coupon payments using the example t_1 (=Bond!C14)	=IF(Period under consideration=no value); No value; IF(Period under consideration = Term (in semi-annual periods); Nominal value + Annual coupon/Frequency of coupon payments; Annual coupon/ Frequency of coupon payments)	=IF(B14="";"";IF(B14='Assumptions Bond'!$E$72;'Assumptions Bond'!$E$58+'Assumptions Bond'!$E$62/'Assumptions Bond'!$E$64;'Assumptions Bond'!$E$62/'Assumptions Bond'!$E$64))
Present value of the payments using the example t_1 (=Bond!D14)	=IF(Period under consideration > Term in semi-annual periods; No value; Coupon payment/(1+ Equivalent period yield) ^ Period under consideration)	=IF(B14>'Assumptions Bond'!$E$72;"";C14/(1+'Assumptions Bond'!$E$76)^B14)

Fig. 9.79 Payment stream excluding issue costs

Modeling of the issue price for a given return is based on the following stream of payments which does not include any issue costs (see Figs. 9.79 and 9.80).

The following formula (see Figs. 9.81 and 9.82) is used to calculate the issue price excluding issue costs:

As a quality check, it is possible to calculate the rate of return of the payment stream considering the issue price in t_0 (see Figs. 9.83 and 9.84). It is apparent that the effective annual interest rate based on the function *IRR* is equal to the rate of return of the comparable bond.

The calculation of the rate of return is also possible with the Excel function *YIELD*. Using this function, an annual interest rate of 6.41% is obtained. The difference is due to the fact that the *YIELD* function uses an imprecise method to annualize the interest rate.

But the decision criterion for implementing the bond issue from the perspective of Pharma Group is all-in costs, namely the effective interest rate which considers all cash flows, including the costs of issuing the bond. Considering the fact that:

$$\text{Net amount received } = \text{Present value of all future payments,}$$

the effective interest rate that needs to be determined is the rate with which the future payments are discounted.

The precise determination of the effective interest rate of Pharma Group considering the issue costs r_e follows from this equation:

$$97 - 3 = 94 = \frac{3}{1 + r_e/2} + \frac{3}{(1 + r_e/2)^2} + \ldots + \frac{103}{(1 + r_e/2)^{20}}$$

The function *IRR* determines an effective semi-annual interest rate of 3.42%, which implies an effective annual rate of 6.96%.

	A	B	C	D
11				
12		Periods	Coupon payments	Present value of coupon payments
13		0		
14		1	3	2.91
15		2	3	2.82
16		3	3	2.73
17		4	3	2.64
18		5	3	2.56
19		6	3	2.48
20		7	3	2.41
21		8	3	2.33
22		9	3	2.26
23		10	3	2.19
24		11	3	2.12
25		12	3	2.05
26		13	3	1.99
27		14	3	1.93
28		15	3	1.87
29		16	3	1.81
30		17	3	1.75
31		18	3	1.70
32		19	3	1.65
33		20	103	54.80

Fig. 9.80 Payment stream excluding issue costs (Excel File Financing, Worksheet Bond)

Position	Formula	Excel implementation
Issue price for given yield (=Bond!G6)	=Sum (Present value of the payments)	=SUM(D14:D33)

Fig. 9.81 Calculating the issue price excluding issue costs

Issue price not considering the cost of issuing the bond	
Issue price for given yield	97.00

Fig. 9.82 Calculating the issue price excluding issue costs (Excel File Financing, Worksheet Assumptions_Bond)

Position	Formula	Excel implementation
Rate of return (IRR function) semi-annually (=Bond!G38)	=IRR(Present value of the payments)	=IRR(D49:D69)
Rate of return (IRR function) annually (=Bond!G40)	=(1+ Rate of return (IRR function) semi-annually)^ (Frequency of coupon payments)-1	=(1+G38)^'Assumptions Bond'!E64-1
Rate of return (return function) annually (=Bond!G42)	=Yield(Date of issue; Repayment date; Coupon; Issue price; Nominal value; Frequency of coupon payments)	=YIELD('Assumptions Bond'!E66;'Assumptions Bond'!E68;'Assumptions Bond'!E60;G6;'Assumptions Bond'!E58;'Assumptions Bond'!E64)

Fig. 9.83 Different ways of calculating the rate of return (Excel File Financing, Worksheet Bond)

Rate of return	
Rate of return (IRR function) semi-annually	3.21%
Rate of return (IRR function) annually	6.51%
Rate of return (return function) annually	6.41%

Fig. 9.84 Different ways of calculating the return (Excel File Financing, Worksheet Bond)

Starting from this effective interest rate, Pharma Group will now assess whether different types of bonds or a loan will result in cheaper financing. If this is not the case, Pharma Group will issue the bond and after all costs an amount of €278,240,000 (€94 × 2,960,000) will be available.

The issue price considering the issue costs of 3% of the nominal value can be calculated using the following formula (see Figs. 9.85 and 9.86).

Position	Formula	Excel implementation
Issue price considering the cost of issuing the bond (=Bond!G76)	=Issue price – Issue costs	=G6-'Assumptions Bond'!E58*'Assumptions Bond'!E78

Fig. 9.85 Calculating the issue price including issue costs

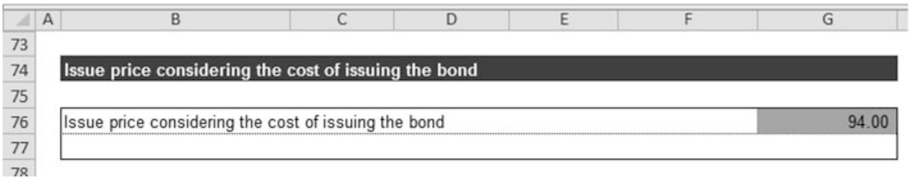


Fig. 9.86 Calculating the issue price including issue costs (Excel File Financing, Worksheet Bond)

Position	Formula	Excel implementation
Rate of return (IRR function) semi-annually (=Bond!G82)	=IRR(Present value of payments)	=IRR(D93:D113)
Rate of return (IRR function) annually (=Bond!G84)	=(1+ Return (IRR function) semi-annually)^(Number of periods within one year)-1	=(1+G82)^'Assumptions Bond'!E64-1
Rate of return (return function) annually (=Bond!G86)	=Yield(Date of issue; Repayment date; Coupon; Issue price; Nominal value; Frequency of coupon payments)	=YIELD('Assumptions Bond'!E66;'Assumptions Bond'!E68;'Assumptions Bond'!E60;G6;'Assumptions Bond'!E58;'Assumptions Bond'!E64)

Fig. 9.87 Different ways of calculating the rate of return

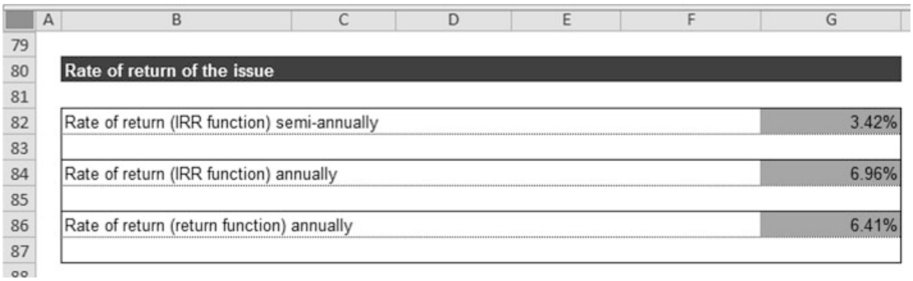


Fig. 9.88 Different ways of calculating the rate of return (Excel File Financing, Worksheet Bond)

In the next step it is possible to calculate the effective annual interest rate on the basis of the *IRR* function. The following formulas are used when calculating the rate of return on the basis of the *IRR* function and the *YIELD* function (see Figs. 9.87 and 9.88).

It becomes apparent that the interest cost of the company exceeds the required rate of return of investors of 6.51% (calculated using the IRR function) due to the incorporation of issue costs.

7.3 Analyzing the Bond from the Investor Perspective

> The bond can be traded between investors in the secondary market.

Once the bond is issued, it trades in the secondary market. It is acquired on May 15, 2014 by an investor. At that time it has a remaining term to maturity of 8 years and 225 days (8.625 years) respectively 17.25 semi-annual periods. Since this remaining term to maturity cannot be expressed in full years, the formula for the determination of the price needs to be modified.

Initially, the present value model is set up for annual coupon payments. τ is defined as the period from the purchase date to the next coupon payment date expressed in years and n is defined as the number of years from the last coupon payment to maturity. This allows to write the (remaining) term to maturity as $n - 1 + \tau$, with $0 < \tau < 1$. The equation used to value the bond is now:

$$P = \frac{C}{(1+r)^{\tau}} + \frac{C}{(1+r)^{1+\tau}} + \ldots + \frac{C+M}{(1+r)^{n-1+\tau}}$$

or

$$P = C \cdot \left[\frac{(1+r)^n - 1}{r \cdot (1+r)^{n-1+\tau}} \right] + \frac{M}{(1+r)^{n-1+\tau}}$$

It needs to be kept in mind that n is an integer in the formula. For the valuation of a bond between two coupon dates, the actual term to maturity is rounded up to the next integer (= n) and τ falls between 0 and 1. A remaining term to maturity of 5.25 years, for example, means that n is equal to 6 in the equation (n is the number of years between the last coupon payment and the maturity date or the number of remaining coupon payments until maturity) and τ is set equal to 0.25.

Two methods can be used to discount the periods of less than one year: exponential or linear discounting to the purchase date (settlement date). If the standard of the ISMA (International Securities Market Association) is followed, the period is discounted exponentially.

The present value of the bond which is calculated according to the above formula represents the price of the bond plus accrued interest, which belongs to the seller of the bond. This price is called full price or dirty price. Subtracted from this price is the accrued interest to arrive at the clean price, P_{clean}.

$$P_{clean} = P - C \cdot (1 - \tau)$$

The incorporation of accrued interest is based on a linear allocation of the annual interest payments. For corporate bonds this is based on a day count convention of 30/360.

The quotation of the bonds at the exchange depends on the respective market conventions. In the US and also on the european markets, the bond prices are generally quoted without accrued interest. In the case of a purchase, the interest that has accrued during the period $1-\tau$ is charged to the buyer and must be paid in addition to the quoted price.

If the coupon payment is semi-annual – as in the case of Pharma Group – and if the next coupon payment is due in less than six months, the above equation needs to be adjusted as follows (based on market conventions):

$$P = \frac{C/2}{(1 + r/2)^{\tau}} + \frac{C/2}{(1 + r/2)^{1+\tau}} + \ldots + \frac{C/2 + M}{(1 + r/2)^{2 \cdot n - 1 + \tau}}$$

or

$$P = C/2 \cdot \left[\frac{(1 + r/2)^{2 \cdot n} - 1}{r/2 \cdot (1 + r/2)^{2 \cdot n - 1 + \tau}} \right] + \frac{M}{(1 + r/2)^{2 \cdot n - 1 + \tau}}$$

Position	Formula	Excel implementation
Coupon payments using the example of the period 0.25 (=Bond!C147)	=IF(Period under consideration=No value; No value; IF(Period under consideration= Remaining term to maturity in semi-annual periods);Nominal value + Annual coupon/ Frequency of coupon payments; Annual coupon/ Frequency of coupon payments)	=IF(B147="";"";IF(B147=Bond!$E$123;'Assumptions Bond'!$E$84+'Assumptions Bond'!$E$88/'Assumptions Bond'!$E$90;'Assumptions Bond'!$E$88/'Assumptions Bond'!$E$90))
Present value of payments using the example of the period 0.25 (=Bond!D147)	=IF(Period under consideration > Remaining term to maturity in semi-annual periods; No value; Coupon payment/(1+Capital market return/Frequency of coupon payments)^(Period considered)	=IF(B147>$E$123;"";C147/(1+'Assumptions Bond'!$E$100/'Assumptions Bond'!$E$90)^B147)

Fig. 9.89 Payment stream from the investor perspective

It must be kept in mind again that the term to maturity 2n is an integer which covers the term from the last semi-annual coupon payment to the repayment date. The sub-period τ, with $0 < \tau < 1$, is now part of a semi-annual period.

The remaining term to maturity of Pharma Group is 8.625 years (8 years and 225 days). This is equivalent to 17.25 semi-annual periods (17 semi-annual periods and 45 days). For the above equation, this implies $2n = 18$ and $\tau = 0.25$.

The bond price including accrued interest (dirty price) is €95.85. It includes accrued interest in the amount of €2.25. If the accrued interest is subtracted from the price of the bond, the clean price of €93.60 results.

Modeling of the issue price from the perspective of the investor is based on the following stream of cash flows, which comprises 17.25 semi-annual periods (see Figs. 9.89 and 9.90).

The dirty price, accrued interest and the quoted price (clean price) can be calculated with the help of the following formulas (see Figs. 9.91 and 9.92):

	A	B	C	D
143				
144		Cash flow of the bond from the purchase date		
145				
146		Periods	Coupon payments	Present value of payments
147		0.25	3	2.9743
148		1.25	3	2.8737
149		2.25	3	2.7765
150		3.25	3	2.6827
151		4.25	3	2.5919
152		5.25	3	2.5043
153		6.25	3	2.4196
154		7.25	3	2.3378
155		8.25	3	2.2587
156		9.25	3	2.1823
157		10.25	3	2.1085
158		11.25	3	2.0372
159		12.25	3	1.9683
160		13.25	3	1.9018
161		14.25	3	1.8375
162		15.25	3	1.7753
163		16.25	3	1.7153
164		17.25	103	56.9005
165				

Fig. 9.90 Payment stream from the investor perspective (Excel File Financing, Worksheet Bond)

Position	Formula	Excel implementation
Price of bond (dirty price) (=Bond!G136)	=Sum(Present value of payments)	=SUM(D147:D164)
Accrued interest (for period 1-τ) (=Bond!G138)	=Annual coupon/Frequency of coupon payments * Days between date of last coupon payment and date of purchase/Days in interest period	='Assumptions Bond'!E88/'Assumptions Bond'!E90*Bond!E129/'Assumptions Bond'!E94
Quoted price (clean price) (=Bond!G140)	= Price of bond (dirty price) – Accrued interest (for period 1-τ)	=G136-G138

Fig. 9.91 Calculating the bond price including accrued interest (dirty price), accrued interest and quoted net price (clean price)

	A	B	C	D	E	F	G
133							
134		Issue price considering the cost of issuing the bond					
135							
136		Price of bond (dirty price)					95.85
137							
138		Accrued interest (for period 1-τ)					2.25
139							
140		Quoted price (clean price)					93.60
141							

Fig. 9.92 Calculating the bond price including accrued interest (dirty price), accrued interest and quoted net price (clean price)(Excel File Financing, Worksheet Bond)

7.4 Present Value Method for Known Spot Rates

> A yield curve displays the bond yields for different terms to maturity.

In the following, we will calculate the bond price including accrued interest (dirty price) for a given yield curve.

Up to this point, all payments were discounted at the same interest rate, which implies that a flat yield curve was assumed. In reality, however, different interest rates are paid for different maturities.

If the yield curve is not flat, but, for example, upward sloping (a so-called normal yield curve), the different coupon payments of the bond must be discounted with the corresponding spot rates. If r_t is the annual interest rate (spot rate), which is paid for an investment from today ($t = 0$) until $t, t = 1, 2, \ldots, n$ the price of the bond is calculated with the help of the following present value formula:

$$P = \frac{C}{1 + r_1} + \frac{C}{(1 + r_2)^2} + \ldots + \frac{C + M}{(1 + r_n)^n}$$

When valuing bonds with semi-annual coupons, the price is determined by discounting the coupons and the maturity value at the relevant spot rate for all future semi-annual periods.

The following spot rates are assumed during the term to maturity of the bond (see Fig. 9.93):

If the coupon payments and the nominal value of the bond are discounted using the spot rates, the following values are calculated (see Fig. 9.94):

The sum of the present values of the coupon payments and the maturity value yield a bond price of 94.98 (see Fig. 9.95):

This work can be checked by calculating the return of a cash flow which includes the issue price in t_0 (see Figs. 9.96 and 9.98). This involves the use of the Excel function *XIRR*, which calculates the internal rate of return of a series of non-periodic payments. The return can also be calculated with the Excel function *YIELD*. The following formulas are utilized (see Fig. 9.96).

We have already observed that the *YIELD* function provides imprecise results due to the method of annualizing. More interesting is the function *XIRR*. It calculates a return of 7.279%. If the coupon payments are discounted with that value, a price of €94.16 is calculated, which is not equal to the target value of €94.98. Even though the function *XIRR* is the appropriate formula for calculating the internal rate of return, it does not provide the correct result. This discrepancy can be explained by the fact that Excel uses assumptions which are different form the ones we made. This is a typical black box problem, which the financial modeler will frequently encounter when working with Excel. We recommend to determine the correct internal rate of return with the goal seek function (See Fig. 9.97).

The internal rate of return can be determined as follows using Goal Seek: *Data* ➲ *Data Tools* ➲ *What-if-Analysis* ➲ *Goal Seek*:

- The target cell is the price of the bond in cell `G208`.
- The target value is the value 94.9844701778018.
- Adjustable cell is the internal rate of return in cell `G206`.

Periods	Spot Rates p.a.
0.25	6.00%
1.25	6.25%
2.25	6.45%
3.25	6.62%
4.25	6.75%
5.25	6.85%
6.25	6.90%
7.25	6.95%
8.25	6.98%
9.25	7.02%
10.25	7.05%
11.25	7.08%
12.25	7.10%
13.25	7.12%
14.25	7.13%
15.25	7.15%
16.25	7.17%
17.25	7.18%

Fig. 9.93 Spot rates for the remaining term to maturity of the bond (Excel File Financing, Worksheet Assumptions_Bond)

This leads to an internal rate of return of 7.141% which implies the desired price of €95.98.

Semi-annual periods	Coupon payments	Spot rates annual	Present value of cash flows
0.25	3	6.00%	2.977913
1.25	3	6.25%	2.886797
2.25	3	6.45%	2.793221
3.25	3	6.62%	2.698725
4.25	3	6.75%	2.605285
5.25	3	6.85%	2.513838
6.25	3	6.90%	2.426921
7.25	3	6.95%	2.341878
8.25	3	6.98%	2.260526
9.25	3	7.02%	2.180394
10.25	3	7.05%	2.103331
11.25	3	7.08%	2.028404
12.25	3	7.10%	1.956737
13.25	3	7.12%	1.887238
14.25	3	7.13%	1.821109
15.25	3	7.15%	1.755834
16.25	3	7.17%	1.692572
17.25	103	7.18%	56.053741

Fig. 9.94 Present values of the cash flows considering the spot rates (Excel File Financing, Worksheet Bond)

Price of the bond (dirty price) for given spot rates	
Price of the bond (dirty price) for given spot rates	94.98

Fig. 9.95 Price of the bond (dirty price) for given spot rates (Excel File Financing, Worksheet Bond)

The results of all calculations are once again summarized in Fig. 9.98.

Position	Formula	Excel implementation
Effective interest rate (yield to maturity) annual using XIRR (=Bond!G198)	=XIRR(Values; Dates)	=XIRR(H175:H193;G175:G193)
Yield (Yield function) annual (=Bond!G202)	=YIELD(Issue date; Repayment date; Coupon rate; Price of the bond (dirty price) for given spot rates; Nominal value; Frequency of coupon payment)	=YIELD('Assumptions Bond'!E118;'Assumptions Bond'!E120;'Assumptions Bond'!E108;G170;'Assumptions Bond'!E106;'Assumptions Bond'!E112;0)

Fig. 9.96 Calculating different types of returns

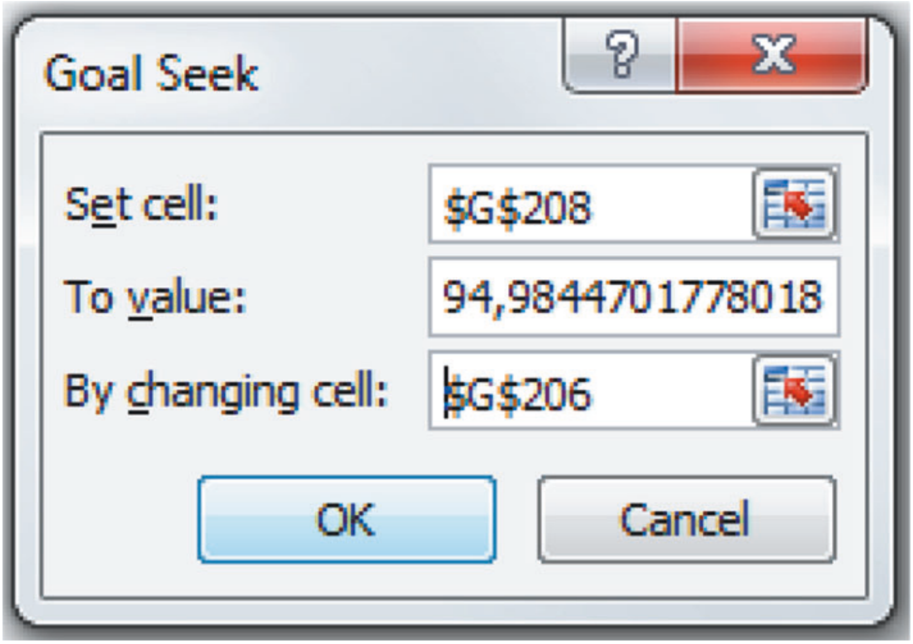


Fig. 9.97 Goal Seek

196	**Yield and price**	
198	Effective interest rate (yield to maturity) annual using XIRR	7.279%
200	Price (check)	94.16
202	Yield (Yield function) annual	6.776%
204	Price (check)	97.23
206	Yield (target value search)	7.141%
208	Price (check)	94.98

Fig. 9.98 Returns and prices for given spot rates (Excel File Financing, Worksheet Bond)

7.5 Analysis of the Present Value Method

> The price of a bond depends on its nominal value, coupon payment, yield to maturity and the (remaining) term to maturity.

From the present value approach it becomes apparent that the price of a bond is a function of the four variables nominal value, coupon payment, yield to maturity and (remaining) term to maturity:

$$P = (M, C, r, n)$$

From both the valuation equation with full periods and the valuation equation at any point in time, but excluding accrued interest, it can be seen that there is a direct relationship between the price and the coupon and between the price and the nominal value. The higher the coupon payment and the nominal value, the higher the market value.

The coupon rate c, with $c = C/M$, can be directly compared to the market interest rate:

For $c = r$: price is equal to nominal value.

For $c > r$: price is greater than nominal value.

For $c < r$: price is less than nominal value.

Since the coupon payments and the nominal value are unchanged for the bond under consideration, they cannot be the source of price changes. The term to maturity, meanwhile, will cause prices to change as long as $c \neq r$, since the remaining term to maturity is steadily reduced. The following relationships exist:

$c = r$: price is equal to nominal value; the price does not change over time.

$c > r$: price is greater than nominal value; the price goes down over time until it reaches the nominal value at maturity.

$c < r$: price is less than nominal value; the price goes up over time until it reaches the nominal value at maturity.

From the analysis of the present value approach and its determinants, the following statements can be derived concerning the bond:

- The market interest rate causes price changes in the opposite direction: if the market interest rate goes up (goes down), the price of the bond falls (increases).
- While higher coupon payments lead to a larger change in the absolute price, they dampen relative price changes. The higher the coupon rate, the smaller are relative price changes.
- The magnitude of price changes depends on the term to maturity: the longer the (remaining) term to maturity, the higher the price fluctuations.

7.6 Risk Analysis

Changes in interest rates play a major role when analyzing the risks of a bond investment.

The value of a bond investment depends strongly on the change in market interest rates. The level of market interest rates determines not only the price of the bond, but also the reinvestment opportunities for the coupon payments received by the investor.

The *interest rate risk* and its components, *price risk* and *reinvestment risk* are closely related. First, a change in market interest rates affects the price of a bond and second, a change in market interest rates implies that future coupon payments which the bondholder receives can be reinvested at different conditions, which affects the terminal value of the investor's wealth. If market interest rates go up (down), the price of the bond will decline (increase), but coupon payments can be reinvested at a higher (lower) interest rate.

The present value approach assumes that the coupon payments can be reinvested at the market interest rate, that is, the yield to maturity. This is apparent from the present value formula:

$$P = \left\{ C \left[\frac{(1+r)^n - 1}{r} \right] + M \right\} \frac{1}{(1+r)^n}$$

The term in curly braces is the future value of the coupon payments plus the nominal value, which is discounted over the term to maturity.

In the following section, the risk figures *Duration*, *Modified Duration* and *Convexity* will be utilized. These are key figures for assessing the interest rate sensitivity of a bond and define the point in time where the price and interest rate effects which are triggered by the change in market interest rates offset each other.

7.6.1 Duration

> Duration is a sensitivity measure, which identifies the average time during which the capital is tied up in the bond investment.

If a bond with annual coupon payments and an integer number of years remaining to maturity is considered, the relationship between price change and changes in interest rates is given by the first derivative of the price with respect to market interest rates. The price change of the bond is always calculated for the dirty price. If the nominal value M is considered in the cash flow structure CF_t in addition to the coupon payments, the price of a bond is:

$$P = \sum_{t=1}^{n} \frac{CF_t}{(1+r)^t}$$

For marginal changes in market interest rates it holds that

$$\frac{dP}{dr} = \sum_{t=1}^{n} -t \cdot CF_t \cdot (1+r)^{-t-1} = -\frac{1}{(1+r)} \cdot \sum_{t=1}^{n} \frac{t \cdot CF_t}{(1+r)^t}$$

If the focus is on relative price changes, it follows that

$$\frac{dP}{dr}\cdot\frac{1}{P} = -\frac{1}{(1+r)}\cdot\frac{\sum_{t=1}^{n} t\cdot CF_t\cdot(1+r)^{-t}}{\sum_{t=1}^{n} CF_t\cdot(1+r)^{-t}} = -\frac{1}{(1+r)}\cdot\frac{\sum_{t=1}^{n} t\cdot CF_t\cdot(1+r)^{-t}}{P}.$$

The term with the sigma sign divided by P is defined as duration D and it follows that:

$$\frac{dP}{dr}\cdot\frac{1}{P} = -\frac{D}{1+r}$$

The expression $\frac{D}{1+r}$ is called *modified duration*, D_{mod}, that is:

$$\frac{dP}{dr}\cdot\frac{1}{P} = -D_{mod}$$

Instead of the marginal analysis of the differential equation, the focus can also be on discrete interest rate changes. Rewriting the equation slightly shows the approximate percentage change in price for a given change in yield:

$$\frac{\Delta P}{P} = -D_{mod}\cdot\Delta r$$

In contrast to the duration, which can also be interpreted as a weighted average time-to-maturity of a bond's cash flows where the weights are the present value of each cash flow as a percentage of the price of the bond, modified duration is not measured in years, but rather in percent.

Assuming $\Delta r = 1\%$ for an increase in market interest rates and $\Delta r = -1\%$ for a decline in market interest rates, the approximate percentage change for a change in interest rates of 1% is obtained:

$$\frac{\Delta P}{P} = -D_{mod}\cdot(\pm 1\%)$$

Thus the modified duration specifies the approximate percentage change in a bond's price for a 100 basis point change in yield. In reality, interest rates frequently only change by a few basis points (one hundredth of a percentage point). If the market interest rate increases (decreases) by one basis point, the price approximately

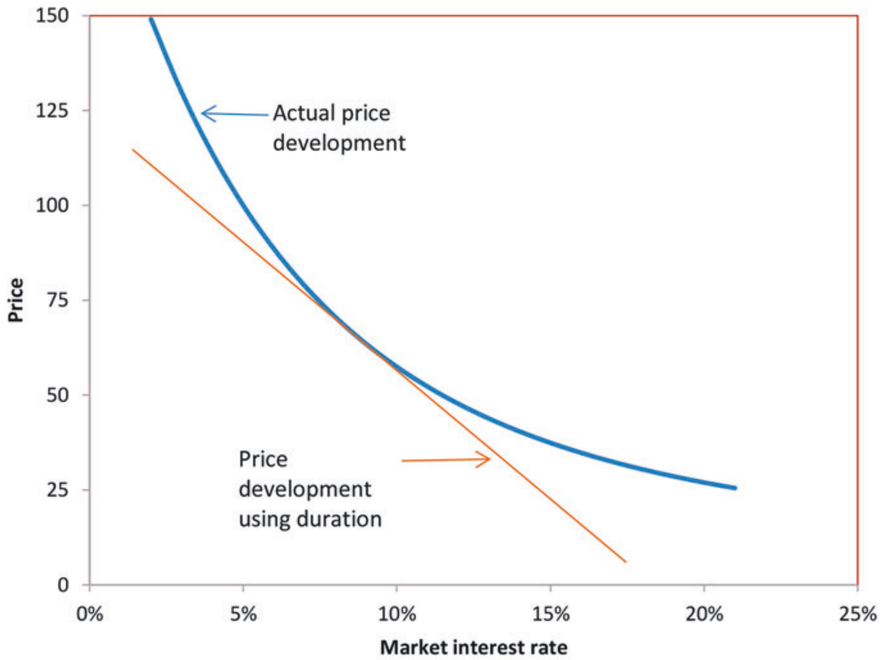


Fig. 9.99 A representation of the duration approximation

declines (increases) by D_{mod} one hundredth of a percent. In banking, this is called the price value of one basis point.

Fig. 9.99 shows the convex relationship between price and market interest rate r. The tangent line represents the first derivative.

As the figure makes clear, based on duration, price changes are underestimated for falling interest rates and overestimated for rising interest rates.

In the case of Pharma Group, the coupon payments are made semi-annual and a sub-period τ needs to be considered as well. The formula for the duration on a semi-annual basis is

$$D = \frac{\sum_{t=1}^{2n} (t-1+\tau) \cdot CF_t \cdot (1+r/2)^{-(t-1+\tau)}}{\sum_{t=1}^{2n} CF_t \cdot (1+r/2)^{-(t-1+\tau)}} = \frac{\sum_{t=1}^{2n} (t-1+\tau) \cdot CF_t \cdot (1+r/2)^{-(t-1+\tau)}}{P}$$

The number of semi-annual periods, respectively of remaining coupons is $2n = 18$. CF_t stands for the semi-annual coupon payments plus the nominal value in t = $2n$ and τ is a fraction of a semi-annual period. The term in the numerator is the price P of the bond.

The transformation of the duration in years is generally done via the relationship

$$\text{Duration in years} = \frac{\text{Duration in m periods per year}}{\text{m}}.$$

Thus the duration on a semi-annual basis needs to be divided by 2 in order to obtain the annual duration.

For the modified duration in the case of semi-annual coupon payments it holds that:

$$D_{mod} = \frac{D}{(1 + r/2)}$$

where D is the duration in years and $r/2$ the semi-annual rate of return.

The duration which results from the above formula is 6.63 years in the case of Pharma Group. The relative price change for an increase in the return of 50 basis points, starting from an interest rate level of 7% is approximately

$$\frac{\Delta P}{P} = -\frac{6.63}{1.035} \cdot 0.005 = -3.20\%$$

The precise price decline as calculated with the present value formula is

$$\frac{92.84 - 95.85}{95.85} = -3.14\%$$

Again we see that the duration overestimates the price decline in the case of increasing market interest rates.

In the case of a decline in market interest rates of 50 basis points a price increase of approximately

$$\frac{\Delta P}{P} = -\frac{6.63}{1.035} \cdot (-0.005) = 3.20\%$$

results. The precise price increase calculated with the help of the present value formula is

$$\frac{98.98 - 95.85}{95.85} = 3.27\%$$

Thus duration underestimates the price increase in the case of declining market interest rates.

It is also apparent that the estimate of the price change with the help of duration is relatively precise for small changes in market rates (up to one percent) and almost identical to the exact calculation based on the present value function.

The formula for the calculation of duration clarifies that it depends on

- the level of coupon payments,
- the term to maturity of the bond, as well as
- the yield of the bond.

Bonds with a high coupon return the capital earlier compared to bonds with a low coupon and therefore their duration is shorter. In the extreme case of no coupon payments, for example, in case of zero coupon bonds, the duration is equal to the bond's term to maturity. As the term to maturity increases, duration also goes up, but at a decreasing rate. Market interest rates, which are used to discount the future cash flows (coupon payment and repayment of principal) of a bond also influence the duration. The higher the market interest rate, the shorter the duration of the bond.

In summary, it can be stated that the duration will decrease as the coupon is increased, the term to maturity is reduced and the level of market interest rates is increased.

The duration can also be calculated for a portfolio of bonds. If we let w_i the market value of bond i divided by the market value of the portfolio, D_i Macauly duration of bond i, and k the number of bonds in the portfolio, then a portfolio's duration is

$$D_P = \sum_{i=1}^{k} w_i \cdot D_i \text{ mit } \sum_{i=1}^{k} w_i = 1$$

The modeling of duration is based on the following payment stream, which includes 17.25 semi-annual periods (see Fig. 9.100).

Duration and modified duration are calculated with the following formulas (see Figs. 9.101 and 9.102).

The formulas to calculate the price change in percent and in absolute terms in the case of an increase or decline in market interest rates using duration are as follows (see Figs. 9.103 and 9.104):

	A	B	C	D	E	F
257						
258		Semi-annual periods t	(t-1+τ)	Cash flow CFt	Present value of the cash flow	(t-1+τ) x Present value of the cash flow
259		1	0.25	3	2.974310	0.743577
260		2	1.25	3	2.873729	3.592161
261		3	2.25	3	2.776550	6.247237
262		4	3.25	3	2.682657	8.718635
263		5	4.25	3	2.591939	11.015741
264		6	5.25	3	2.504289	13.147516
265		7	6.25	3	2.419603	15.122517
266		8	7.25	3	2.337780	16.948908
267		9	8.25	3	2.258725	18.634482
268		10	9.25	3	2.182343	20.186673
269		11	10.25	3	2.108544	21.612576
270		12	11.25	3	2.037241	22.918957
271		13	12.25	3	1.968348	24.112268
272		14	13.25	3	1.901786	25.198663
273		15	14.25	3	1.837474	26.184009
274		16	15.25	3	1.775337	27.073896
275		17	16.25	3	1.715302	27.873656
276		18	17.25	103	56.900514	981.533869
277						

Fig. 9.100 Present values of the coupon payments (Excel File Financing, Worksheet Bond)

Position	Formula	Excel implementation
Duration in half years (=Bond!G241)	=Coupon payments semi-annual including one sub-period τ/Price of bond	`=SUM(F259:F276)/G239`
Duration in years (=Bond!G243)	=Duration in half years/Frequency of coupon payments	`=G241/'Assumptions Bond'!E160`
Modified duration (=Bond!G245)	=Duration in years/(1+Semi-annual capital market rate of return)	`=G243/(1+G222)`

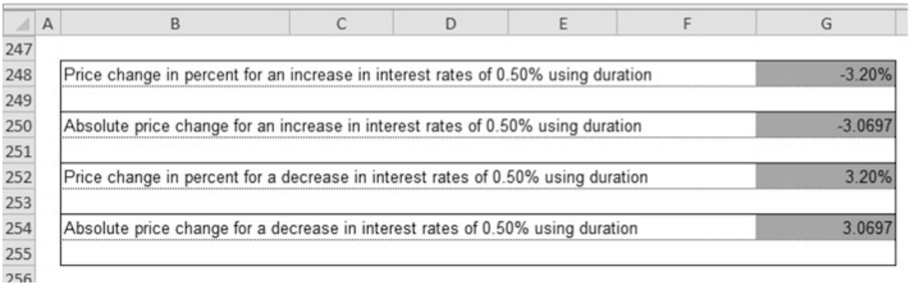
Fig. 9.101 Calculating duration and modified duration

	A	B	C	D	E	F	G
234							
235		Results					
236							
237		Price of bond (using formula)					95.85
238							
239		Price of bond (using Excel)					95.85
240							
241		Duration in half years					13.26
242							
243		Duration in years					6.63
244							
245		Modified duration					6.41
246							
247							

Fig. 9.102 Calculating duration and modified duration (Excel File Financing, Worksheet Bond)

Position	Formula	Excel implementation
Price change in percent for an increase in interest rates of 0.50% using duration (=Bond!G248)	=-Modified duration * Yield change	=-G245*'Assumptions Bond'!E172
Absolute price change for an increase in interest rates of 0.50% using duration (=Bond!G250)	=Price of bond (using formula) * Price change in percent for an increase in interest rates of 0.50% using duration	=G237*G248
Price change in percent for a decrease in interest rates of 0.50% using duration (=Bond!G252)	=-Modified duration * -Yield change	=-G245*-'Assumptions Bond'!E172
Absolute price change for a decrease in interest rates of 0.50% using duration (=Bond!G254)	= Price of bond (using formula) * Price change in percent for a decrease in interest rates of 0.50% using duration	=G237*G252

Fig. 9.103 Calculating the percentage and absolute price change for an increase and a decline in market interest rates using duration



	A	B	C	D	E	F	G
247							
248		Price change in percent for an increase in interest rates of 0.50% using duration					-3.20%
249							
250		Absolute price change for an increase in interest rates of 0.50% using duration					-3.0697
251							
252		Price change in percent for a decrease in interest rates of 0.50% using duration					3.20%
253							
254		Absolute price change for a decrease in interest rates of 0.50% using duration					3.0697
255							
256							

Fig. 9.104 Calculating the percentage and absolute price change for an increase and a decline in market interest rates using duration (Excel File Financing, Worksheet Bond)

7.6.2 Convexity

Convexity is a variable that helps to assess interest rate risk of bonds based on the notion of modified duration.

Duration is a linear approximation of the convex relationship between market interest rate and bond price. This introduces an error in the calculation, which increases with the magnitude of the change in the interest rate.

Even though most of the price changes as a result of changes in market interest rates can be explained with the help of duration, the precision can be improved, especially for large market swings, with the help of the convexity as a second order approximation (the order relates to the number of derivatives), which incorporates the curvature of the price function.

The second order Taylor-series is:

$$\frac{\Delta P}{P} = \frac{\partial P}{\partial r} \cdot \frac{1}{P} \cdot \Delta r + \frac{1}{2} \cdot \frac{\partial^2 P}{\partial r^2} \cdot \frac{1}{P} \cdot (\Delta r)^2 + \varepsilon \approx -D.\Delta r + \frac{1}{2} \cdot Convexity \cdot (\Delta r)^2$$

The first summand represents the approximate price change from the modified duration, the second summand is the expansion via convexity plus an error term ε.

The convexity for annual coupon payments and a term to maturity of full years follows from the second derivative of the price-yield function:

$$Convexity = \frac{\partial^2 P}{\partial r^2} \cdot \frac{1}{P} = \frac{\sum_{t=1}^{n} t \cdot (t+1) \cdot CF_t \cdot (1+r)^{-t-2}}{\sum_{t=1}^{n} CF_t \cdot (1+r)^{-t}}$$

The price P of the bond is in the denominator. Rewriting the equation further leads to:

$$Convexity = \frac{1}{(1+r)^{t+2}} \cdot \frac{1}{P} \cdot \sum_{t=1}^{n} t \cdot (t+1) \cdot CF_t$$

If coupon payments are made semi-annually as in the case of Pharma Group and if a sub-period τ is present, the formula for the convexity on a semi-annual basis is as follows:

$$Convexity = \frac{\partial^2 P}{\partial r^2} \cdot \frac{1}{P} = \frac{\sum_{t=1}^{2n} (t-1+\tau) \cdot (t+\tau) \cdot CF_t \cdot (1+r/2)^{-(t-1+\tau)-2}}{\sum_{t=1}^{2n} CF_t \cdot (1+r/2)^{-(t-1+\tau)}}$$

The price P of the bond is in the denominator. If the equation is rewritten further, the convexity on the basis of semi-annual payments can also be expressed as

$$Convexity = \frac{1}{(1+r/2)^{(t-1+\tau)+2}} \cdot \frac{1}{P} \cdot \sum_{t=1}^{2n} (t-1+\tau) \cdot (t+\tau) \cdot CF_t$$

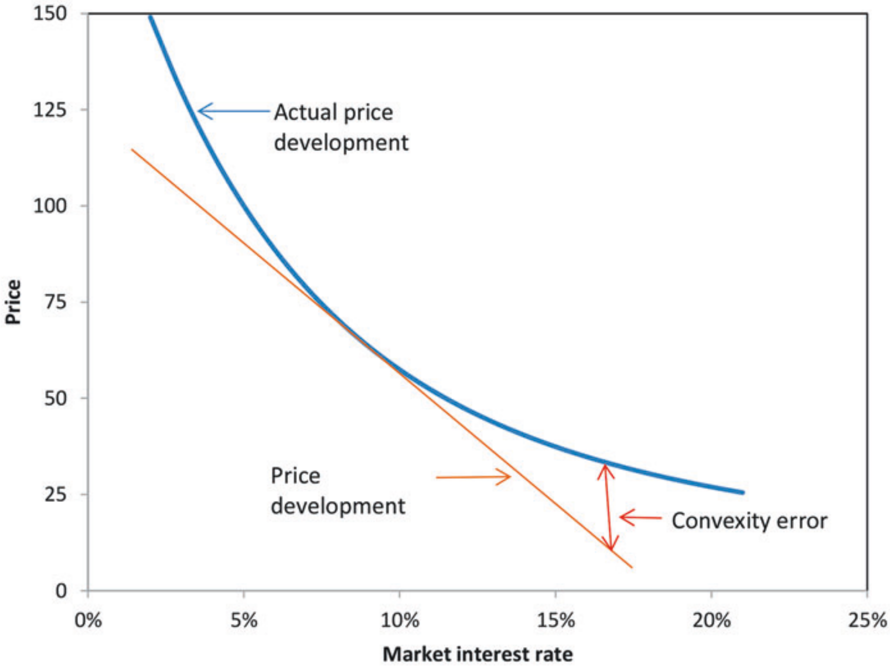


Fig. 9.105 Graphical representation of the approximation from duration and convexity

Transformation of the convexity in years is generally done through the relationship:

$$\text{Convexity in years} = \frac{\text{Convexity in m periods per year}}{m^2}$$

Thus dividing the convexity on a semi-annual basis by 2^2 leads to the convexity in years.

Figure 9.105 shows the relationship between the approximations from duration and convexity.

An interpretation of the convexity figure reveals the following results: The higher the convexity, the lower are the losses in case of an increase in interest rates and the higher are the profits in case of an interest rate reduction.

The convexity of the Pharma Group bond with a remaining term to maturity of 8.625 years is 51.79 and the modified duration is calculated as 6.41%. If market interest rates change by 50 basis points (Δr = 0.0050) to 7.5%, the percentage change of the price can be approximated with the help of duration and convexity as –3.14%.

$$\frac{\Delta P}{P} = -D_{mod} \cdot \Delta r + \frac{1}{2} \cdot Convexity \cdot \Delta r^2 = 6.41 \cdot 0.005 + \frac{1}{2} \cdot 51.79 \cdot (0.005)^2$$
$$= 0.0320 + 0.000647 = -0.0314 \text{ or } -3.14\%$$

This compares to a price change of also –3.14% using the present value formula.

$$\frac{92.84 - 95.85}{95.85} = 3.14\%$$

The two results are practically identical. However, the difference increases for larger changes in market interest rates.

For a decline in market interest rates of 50 basis points to 6.5%, the percentage change in the price as calculated with the help of duration and convexity is:

$$\frac{\Delta P}{P} = -D_{mod} \cdot \Delta r + \frac{1}{2} \cdot Convexity \cdot \Delta r^2 = -6.41 \cdot (-0.005) + \frac{1}{2} \cdot 51.79 \cdot (-0.005)^2$$
$$= 3.2675\%$$

A pleasant feature of the convexity in portfolios with identical duration is the fact that for larger convexity, an increase in market interest rates leads to smaller losses and a reduction in market interest rates to larger gains compared to a curve with lower convexity.

The convexity of a bond with identical duration increases ceteris paribus for

- lower coupon,
- declining yield and
- increased term to maturity.

Semi-annual periods t	(t-1+τ)	Cash flow CFt	1/(1+r/2)^(t-1+τ+2)	(t-1+τ)*(t+τ)	(t-1+τ)*(t+τ)*CFt / (1+r/2)^((t-1+τ)+2)
1	0.25	3	0.925517	0.312500	0.867672
2	1.25	3	0.894219	2.812500	7.544972
3	2.25	3	0.863980	7.312500	18.953554
4	3.25	3	0.834763	13.812500	34.590490
5	4.25	3	0.806534	22.312500	53.987386
6	5.25	3	0.779260	32.812500	76.708420
7	6.25	3	0.752908	45.312500	102.348479
8	7.25	3	0.727448	59.812500	130.531393
9	8.25	3	0.702848	76.312500	160.908264
10	9.25	3	0.679080	94.812500	193.155873
11	10.25	3	0.656116	115.312500	226.975174
12	11.25	3	0.633929	137.812500	262.089867
13	12.25	3	0.612491	162.312500	298.245045
14	13.25	3	0.591779	188.812500	335.205907
15	14.25	3	0.571767	217.312500	372.756546
16	15.25	3	0.552432	247.812500	410.698796
17	16.25	3	0.533751	280.312500	448.851143
18	17.25	103	0.515701	314.812500	16,721.970749

Fig. 9.106 Present value of the coupon payments (Excel File Financing, Worksheet Bond)

Position	Formula	Excel implementation
Convexity in semi-annual periods (=Bond!G306)	=Second derivative /Price of bond	=G304/G237
Convexity in years (=Bond!G308)	=Convexity in semi-annual periods/Frequency of coupon payments^2	=G306/'Assumptions Bond'!E184^2

Fig. 9.107 Calculating convexity for semi-annual periods and for full years

A problematic assumption in convexity analysis is the parallel movement of the yield curve, where the spread (difference in yields) between different bonds remains constant.

The modeling of convexity is based on the following stream of payments (see Fig. 9.106).

The convexity for semi-annual periods and for full years is calculated with the following formulas (see Figs. 9.107 and 9.108).

The formulas for calculating the price changes in percent for an increase respectively decline in market interest rates using duration and convexity are as follows (see Figs. 9.109 and 9.110):

	A	B	C	D	E	F	G
301							
302		Results					
303							
304		Second derivative					19,856.3897
305							
306		Convexity in semi-annual periods					207.1687098
307							
308		Convexity in years					51.7922
309							

Fig. 9.108 Calculating convexity for semi-annual periods and for full years (Excel File Financing, Worksheet Bond)

Position	Formula	Excel implementation
Price change in percent for an increase in interest rates of 0.50% using duration and convexity (`=Bond!G311`)	=-Modified Duration * Change in yield +0,5 * Convexity in years * Change in yield ^2	`=-G285*'Assumptions Bond'!E196+0.5*G308*'Assumptions Bond'!E196^2`
Price change in percent for a decrease in interest rates of 0.50% using duration and convexity (`=Bond!G313`)	=-Modified Duration * (-Change in yield)+0,5* Convexity in years*(-Change in yield)^2	`=-G285*(-'Assumptions Bond'!E196)+0.5*G308*(-'Assumptions Bond'!E196)^2`

Fig. 9.109 Percentage change in price for an increase and decline in market interest rates of 0.50% using duration and convexity

	A	B	C	D	E	F	G
310							
311		Price change in percent for an increase in interest rates of 0.50% using duration and					-3.1380%
312							
313		Price change in percent for a decrease in interest rates of 0.50% using duration and					3.2675%
314							

Fig. 9.110 Percentage change in price for an increase and decline in market interest rates of 0.50% using duration and convexity (Excel File Financing, Worksheet Bond)

7.6.3 Immunization and Duration

> The immunization strategy aims at stabilizing the yield of a bond portfolio.

The rate of return r derived with the present value method, the so-called *Yield to Maturity* is based on the assumption that all cash flows which become available can be reinvested at that rate until the maturity date and that the bond is held until maturity. This leads to a future value (*FV*) at the maturity date n of

$$FV = \sum_{t=1}^{n} C_t \cdot (1+r)^{n-t} + M$$

The ex-post or total return that follows from the terminal wealth and the capital invested (price of the bond) is equal to the rate of return r of the bond at the time the investment is made.

However, the actual terminal wealth (and thus the ex-post return) in a real investment situation will differ from the anticipated terminal wealth at the time of the investment decision, because of changes in market interest rates and differences in the investment period. Thus the actual terminal value or the rate of return will be above or below the rate of return (yield to maturity) that is available at the time of purchase.

For a given investment horizon h, with $h < n$ and assuming a full investment period and annual coupon payments, a terminal value at the end of the investment period of

$$FV = \sum_{t=1}^{h} C_t \cdot (1+r)^{h-t} + \sum_{t=1}^{n-h} \frac{C_{h+t}}{(1+r)^t} + \frac{M}{(1+r)^{n-h}}$$

is obtained. When calculating the terminal value, all coupon payments that happen before the end of the investment horizon h are compounded to the end of the investment horizon h, while all coupon payments that are due after the end of the investment horizon are discounted to the end of the investment horizon.

At the time of the duration, for $h = D$, the opposing price and reinvestment effects which are caused by changes in market interest rates will equalize each other, so that the terminal wealth is immunized against changes in interest rates.

Generally this can be illustrated with reference to the following considerations. Given is

$$V_0 = \frac{L}{(1+r)^h}$$

as the present value of a liability L which is due in h years and is discounted at the current market interest rate r.

This liability now needs to be immunized with the help of a bond with the following price:

$$P = \sum_{t=1}^{n} \frac{CF_t}{(1+r)^t}$$

For a change in interest rates from r to $r + \Delta r$, the value of the future liability becomes

$$V_0 + \Delta V_0 \approx V_0 + \frac{dV_0}{dr} \cdot \Delta r = V_0 + \Delta r \cdot \left[\frac{-h.L}{(1+r)^{h+1}} \right]$$

and the value of the bond changes to:

$$P + \Delta P \approx P + \frac{dP}{dr} \cdot \Delta r = P + \Delta r \cdot \sum_{t=1}^{n} \frac{-t \cdot CF_t}{(1+r)^{t+1}}$$

Setting the two equations equal leads to:

$$V_0 + \Delta r \cdot \left[\frac{-h.L}{(1+r)^{h+1}} \right] = P + \Delta r \cdot \sum_{t=1}^{n} \frac{-t \cdot CF_t}{(1+r)^{t+1}}$$

or

$$\left[\frac{-h \cdot L}{(1+r)^{h+1}} \right] = \sum_{t=1}^{n} \frac{-t \cdot CF_t}{(1+r)^{t+1}}$$

Once this equation is simplified, it follows for $P = V_0 = \dfrac{L}{(1+r)^h}$:

$$h \cdot P = \sum_{t=1}^{n} \frac{t \cdot CF_t}{(1+r)^{t+1}}$$

and

$$h = \frac{1}{P} \cdot \sum_{t=1}^{n} \frac{t \cdot CF_t}{(1+r)^{t+1}}$$

The second term of this equation is the duration D. Hence it holds that $h = D$.

This demonstrates that an investor who has a planning horizon equal to the duration of the bond under the given assumptions (flat yield curve, one-time change in market interest rates directly following the purchase time of the bond and parallel movement of the flat yield curve, fixed planning horizon, no withdrawal of funds during the planning horizon and reinvestment of all coupon payments that are received up to the planning horizon at the market interest rate) is fully immunized against the risk of changes in interest rates.

Thus the investor is in a position to actually achieve ex-post the rate of return (yield to maturity) which was anticipated at the purchase date. This rate of return, which is also called *Total Return* is calculated from the relationship

$$\text{Total return} = \left(\frac{\text{Total future income}}{P}\right)^{\frac{1}{h}} - 1,$$

where the total future income is made up from coupon payments, the interest received on the reinvested coupon payments and the market price of the bond at the end of the investment horizon. P is the purchase price of the bond including accrued interest (dirty price) and is equivalent to the capital invested.

An investor purchases a bond of Pharma Group and wants to receive the currently available yield of 7%. He chooses an investment horizon of 6.625 years (13.25 semi-annual periods) and is thus able to immunize against the risk of changes in interest rates under the given assumptions.

The following formulas are needed for the calculation of the total return p.a. and an investment horizon of 6.625 years, using the example of market interest rates of 7.50% (see Figs. 9.111 and 9.112).

Position	Formula	Excel implementation
Coupon payments (=Bond!C379)	=Annual coupon * Number of years between last coupon payment and end of investment period	=Bond!$G$342*Bond!$G$346
Compound interest on reinvested coupon payments (=Bond!D379)	= Annual coupon * ((1+Market interest rate)^ Number of years between last coupon payment and end of investment period - 1)/Market interest rate- Coupon payments	=$G$342*((1+B379)^$G$346-1)/B379-C379
Price of the bond at the end of the investment horizon (=Bond!E379)	= Annual coupon *((1+Markt interest rate)^ Number of years between end of investment period and repayment date -1)/(Market interest rate*(1+ Market interest rate)^ Number of years between end of investment period and repayment date) + Nominal value M/(1+ Market interest rate)^ Number of years between end of investment period and repayment date	=$G$342*((1+B379)^$G$348-1)/(B379*(1+B379)^$G$348)+'Assumptions Bond'!$E$202/(1+B379)^$G$348
Wealth at the end of the investment horizon (=Bond!F379)	Coupon payment + Compound interest on reinvested coupon payments + Price of the bond at the end of the investment horizon	=C379+D379+E379

Fig. 9.111 Calculating the total return p.a. for an investment horizon of 6.625 years using the example of a market interest rate of 7.50%

	A	B	C	D	E	F	G
377							
378		Market interest rate	Coupon payments	Compound interest on reinvested coupon payments	Price of the bond at the end of the investment horizon	Wealth at the end of the investment horizon	Total rate of return p.a.
379		7.50%	42	10.723931	97.306652	150.030583	6.9970%
380		7.00%	42	9.924127	98.191982	150.116108	7.0062%
381		6.50%	42	9.137220	99.089687	150.226906	7.0182%

Fig. 9.112 Calculating the total return p.a. for an investment horizon of 6.625 years using the example of a market interest rate of 7.50% (Excel File Financing, Worksheet Bond)

8 Short-Term Financing Using the Example of the Supplier Credit

> A supplier credit is created if a supplier extents a payment deadline to a counterparty which has received goods or services.

An important type of short-term debt financing is the supplier credit. In the case of the supplier credit, the payment for goods or services received by the company is due only after a certain time period (for example, after 30 days). This type of arrangement is customary only among merchants and constitutes a way of financing the turnover of the merchandise. While no interest is due on the supplier credit, it is still not free, since the immediate payment usually allows for the deduction of a cash discount. Since the price offer includes the cash discount, the interest on the supplier credit is usually already included in the purchase price. Put differently, the invoice total includes both the price for the delivered goods and the interest for utilizing the supplier credit. If the payment is made within the time period required to collect the cash discount, the supplier has the advantage that contracts are settled quicker and there is no need to send out reminders or to initiate recovery procedures. The incentive to use the cash discount becomes clear when the annual interest rate implied by the payment conditions is calculated.

8.1 Interest on the Supplier Credit

In order to calculate the implied interest rate, the terms of the supplier credit must be established. This is done in the worksheet `Assumptions_Supplier_Credit` (see Figs. 9.113 and 9.114).

Position	Explanation	Limitations/Excel implementation
Payment deadline (in days) (=Assumptions_Supplier_Credit!E14)	Input of the payment deadline (in days) specified by the supplier in its payment terms.	**Data check:** Only positive integers are allowed. **User input:** 30
Deadline for cash discount (in days) (=Assumptions_Supplier_Credit!E16)	Input of the deadline for the cash discount (in days) specified by the supplier in its payment terms. If payment is made before the deadline specified, a prespecified cash discount can be deducted from the invoice.	**Data check:** Only positive integers are allowed. **User input:** 10
Cash discount (=Assumptions_Supplier_Credit!E18)	Amount of the cash discount (in percent).	**Data check:** Only positive values are allowed. **User input:** 3%

Fig. 9.113 Assumptions needed to calculate the implied interest rate of a supplier credit

Payment terms of supplier	
Payment deadline (in days)	30
Deadline for cash discount (in days)	10
Cash discount	3%

Fig. 9.114 Assumptions needed to calculate the implied interest rate of a supplier credit (Excel File Financing, Worksheet Assumptions_Supplier_Credit)

The approximate formula for calculating the implied annual interest rate is:

$$\text{Annual interest rate} = \frac{\text{Cash discount}}{\left(\begin{array}{c}\text{Payment deadline} -\\ \text{Deadline for taking the cash discount}\end{array}\right)} \cdot 360$$

A similar formula holds for the monthly rate

$$\text{Monthly interest rate} = \frac{\text{Cash discount}}{\left(\begin{array}{c}\text{Payment deadline} -\\ \text{Deadline for taking the cash discount}\end{array}\right)} \cdot 30$$

The implementation in Excel is (see Figs. 9.115 and 9.116):

It is apparent that the interest rate on a supplier credit is normally extremely high. For that reason it is even advisable to take out a bank loan in order to collect the cash discount.

Position	Formula	Excel implementation
Monthly interest rate (=Supplier credit!H7)	=Cash discount / (Payment deadline – Deadline for cash discount) * Days per month	='Assumptions Supplier Credit'!E18/('Assumptions Supplier Credit'!E14-'Assumptions Supplier Credit'!E16)*'Assumptions Supplier Credit'!E7
Annual interest rate (=Supplier credit!H9)	=Cash discount / (Payment deadline – Deadline for cash discount) * Days per year	='Assumptions Supplier Credit'!E18/('Assumptions Supplier Credit'!E14-'Assumptions Supplier Credit'!E16)*'Assumptions Supplier Credit'!E9

Fig. 9.115 Calculating the interest rate on a supplier credit

	A	B	C	D	E	F	G	H
4								
5		Interest rate on the supplier credit						
6								
7		Monthly interest rate						4.5%
8								
9		Annual interest rate						54.0%
10								

Fig. 9.116 Calculating the interest rate on a supplier credit (Excel File Financing, Worksheet Supplier_Credit)

8.2 Granting a Supplier Credit

In the following, the conditions are analyzed which need to be in place so that the company is able to grant a supplier credit to its customers without reducing its own liquidity. Initially the payment conditions for the customers are entered together with the average storage period at the company. (Figs. 9.117 and 9.118).

Position	Explanations	Limitations/Excel implementation
Ø storage period (in days) (=Assumptions_Supplier_Credit!E24)	The average storage period at the company in days.	**Data check:** Only positive integers are allowed. **User input:** 10
Payment deadline (in days) (=Assumptions_Supplier_Credit!E26)	Input of the payment deadline in days, which the company establishes in its terms of payment.	**Data check:** Only positive integers are allowed. **User input:** 20

Fig. 9.117 Assumptions concerning the supplier credit

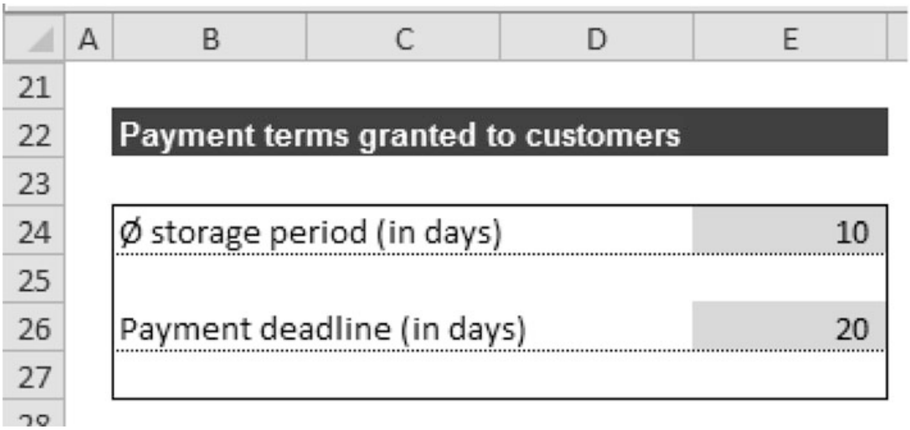


Fig. 9.118 Assumptions concerning the supplier credit (Excel File Financing, Worksheet Supplier_Credit)

Position	Formula	Excel implementation
Possibility to grant supplier credit without worsening liquidity? (`=Supplier_Credit!H15`)	=If the average storage period plus the payment deadline granted to the customer is at most as long as the payment deadline granted by the supplier, then: Yes; else: No	`=IF(('Assumptions Supplier Credit'!I24+'Assumptions Supplier Credit'!I26)<='Assumptions Supplier Credit'!I14;"YES";"NO")`

Fig. 9.119 Checking whether a supplier credit is neutral with regard to liquidity

The condition for granting the supplier credit without worsening the liquidity position is:

$$\begin{aligned} &\text{Average storage period} + \text{Payment deadline}_{\text{customer}} \\ &\quad \leq \text{Payment deadline}_{\text{supplier}} \end{aligned}$$

This can be checked with the help of an =IF( ) function in the Excel file (see Figs. 9.119 and 9.120):

This statement loses its validity as soon as the payment deadlines are not observed by the involved parties. The next section deals with such a delayed payment of the supplier credit.

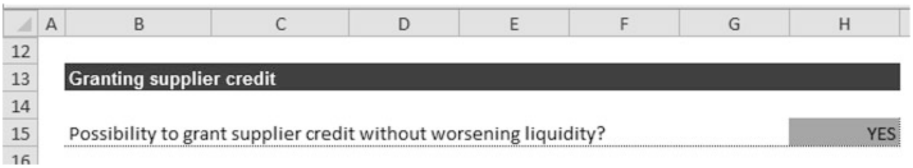


Fig. 9.120 Checking whether a supplier credit is neutral with regard to liquidity (Excel File Financing, Worksheet Supplier_Credit)

8.3 Delaying Payment on a Supplier Credit

To model the delayed payment of a supplier credit, we initially need to enter additional premises (see Figs. 9.121 and 9.122):

Position	Explanations	Limitations/Excel implementation
Credit volume (=Assumptions_Supplier_Credit!E32)	Volume of the supplier credit by the supplier, which is utilized by the company.	**Data check:** Only positive values are allowed. **User input:** 100,000
Delaying the payment (=Assumptions_Supplier_Credit!E34)	Here the user can select by how many months the payment is delayed. Available is a range from 1 to 4 months.	**Control element:** Input range: $B$43:$B$46 Cell reference: $E$42 Dropdown rows: 4 **User input:** 2 months

Fig. 9.121 Delaying payment of a supplier credit

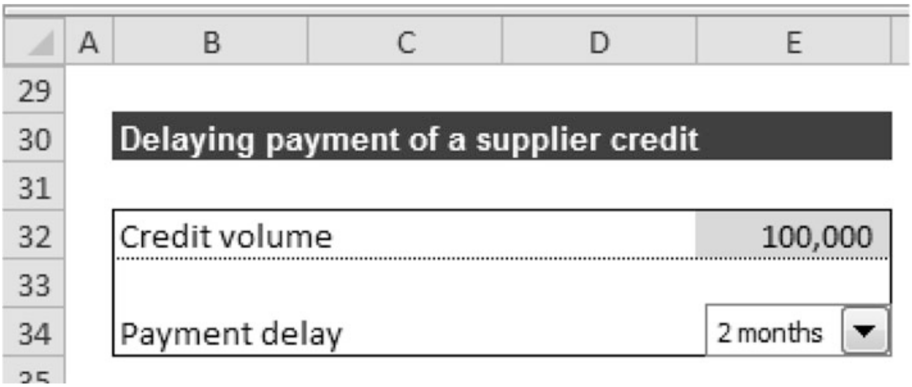


Fig. 9.122 Delaying payment of a supplier credit (Excel File Financing, Worksheet Assumptions_Supplier_Credit)

Position	Formula	Excel implementation
Monthly interest (`=Supplier_Credit!H20`)	=Cash discount / (Payment deadline + Delay of the payment (in months) * Days per month - Deadline for cash discount) * Days per month	`='Assumptions Supplier Credit'!E18/('Assumptions Supplier Credit'!E14+'Assumptions Supplier Credit'!E42*'Assumptions Supplier Credit'!$E$7-'Assumptions Supplier Credit'!E16)*'Assumptions Supplier Credit'!$E$7`
Annual interest rate (`=Supplier_Credit!H22`)	=Cash discount / (Payment deadline + Delay of the payment (in months) * Days per month - Deadline for cash discount) * Days per year	`='Assumptions Supplier Credit'!E18/('Assumptions Supplier Credit'!E14+'Assumptions Supplier Credit'!E42*'Assumptions Supplier Credit'!$E$7-'Assumptions Supplier Credit'!E16)*'Assumptions Supplier Credit'!$E$9`

Fig. 9.123 Calculating the implied interest rate if payment is delayed on a supplier credit

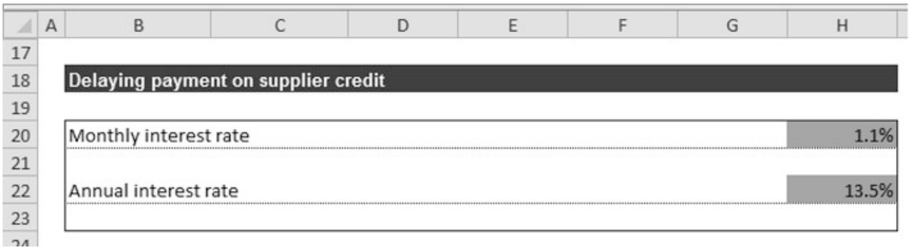


Fig. 9.124 Implied interest rate if payment is delayed on a supplier credit (Excel File Financing, Worksheet Supplier_Credit)

Given these assumptions it is now possible to determine the new interest rate implied by the supplier credit (see Figs. 9.123 and 9.124).

Thus the ability of Pharma Group to delay payment for 90 days would reduce the interest rate on the supplier credit to one fourth of the original value (13.5% instead of 54%).

If payment delays are implemented continuously, the total volume of the supplier credit utilized increases. To clarify this relationship, we present the linkages between supplier and company graphically (see Figs. 9.125 and 9.126). It is assumed that the payment deadline is set at 30 days (1 month).

Position: Credit from the purchase in...	Formula	Excel implementation
1. month		
1. month (=Supplier_Credit!C27)	=Credit volume	='Assumptions Supplier Credit'!$E$32
2. month		
1. month (=Supplier_Credit!D27)	=Credit volume	='Assumptions Supplier Credit'!$E$32
2. month (=Supplier_Credit!D28)	=Credit volume	='Assumptions Supplier Credit'!$E$32
3. month		
1. month (=Supplier_Credit!E27)	=If the payment delay is at least two months, then: Credit volume; else: Empty cell	=IF('Assumptions Supplier Credit'!$E$42>=2;'Assumptions Supplier Credit'!$E$32;"")
2. month (=Supplier_Credit!E28)	=Credit volume	='Assumptions Supplier Credit'!$E$32
3. month (=Supplier_Credit!E29)	=Credit volume	='Assumptions Supplier Credit'!$E$32
4. month		
1. month (=Supplier_Credit!F27)	=If the payment delay is at least three months, then: Credit volume; else: Empty cell	=IF('Assumptions Supplier Credit'!$E$42>=3;'Assumptions Supplier Credit'!$E$32;"")
2. month (=Supplier_Credit!F28)	=If the payment delay is at least two month, then: Credit volume; else: Empty cell	=IF('Assumptions Supplier Credit'!$E$42>=2;'Assumptions Supplier Credit'!$E$32;"")
3. month (=Supplier_Credit!F29)	=Credit volume	='Assumptions Supplier Credit'!$E$32
4. month (=Supplier_Credit!F30)	=Credit volume	='Assumptions Supplier Credit'!$E$32

Fig. 9.125 Calculating the credit relationship in the case of payment delays

5. month		
1. month (=Supplier_Credit!G27)	=If the payment delay is at least four month, then: Credit volume; else: Empty cell	=IF('Assumptions Supplier Credit'!$E$42>=4;'Assumptions Supplier Credit'!$E$32;"")
2. month (=Supplier_Credit!G28)	=If the payment delay is at least three month, then: Credit volume; else: Empty cell	=IF('Assumptions Supplier Credit'!$F$42>=3;'Assumptions Supplier Credit'!$E$32;"")
3. month (=Supplier_Credit!G29)	=If the payment delay is at least two months, then: Credit volume; else: Empty cell	=IF('Assumptions Supplier Credit'!$E$42>=2;'Assumptions Supplier Credit'!$E$32;"")
4. month (=Supplier_Credit!G30)	=Credit volume	='Assumptions Supplier Credit'!$E$32
5. month (=Supplier_Credit!G31)	=Credit volume	='Assumptions Supplier Credit'!$E$32

6. month		
2. month (=Supplier_Credit!H28)	=If the payment delay is at least four month, then: Credit volume; else: Empty cell	=IF('Assumptions Supplier Credit'!$E$42>=4;'Assumptions Supplier Credit'!$E$32;"")
3. month (=Supplier_Credit!H29)	=If the payment delay is at least three months, then: Credit volume; else: Empty cell	=IF('Assumptions Supplier Credit'!$E$42>=3;'Assumptions Supplier Credit'!$E$32;"")
4. month (=Supplier_Credit!H30)	=If the payment delay is at least two months, then: Credit volume; else: Empty cell	=IF('Assumptions Supplier Credit'!$E$42>=2;'Assumptions Supplier Credit'!$E$32;"")
5. month (=Supplier_Credit!H31)	=Credit volume	='Assumptions Supplier Credit'!$E$32
6. month (=Supplier_Credit!H32)	=Credit volume	='Assumptions Supplier Credit'!$E$32

Fig. 9.125 (Continued)

Credit from purchase in the	Credit in 1. month	2. month	3. month	4. month	5. month	6. month
1. month	100,000	100,000	100,000			
2. month		100,000	100,000	100,000		
3. month			100,000	100,000	100,000	
4. month				100,000	100,000	100,000
5. month					100,000	100,000
6. month						100,000
Credit volume	100,000	200,000	300,000	300,000	300,000	300,000

Fig. 9.126 Calculating the credit relationship in the case of payment delays (Excel File Financing, Worksheet Supplier_Credit)

9 The Cash Flow

Internal financing refers to all forms of corporate financing that do not rely on external providers of funds (such as shareholders and banks).

The last two sections will deal with the topic of internal financing. First of all, we want to calculate the cash flow, the most important variable in the area of internal financing. The importance of the cash flow becomes apparent as we consider Fig. 9.127. It holds a central role in the structure of internal financing.

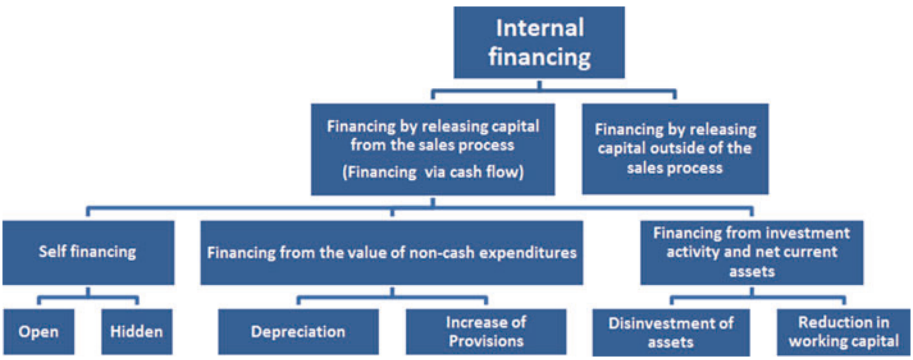


Fig. 9.127 Fields of internal financing

9.1 Basics

> The cash flow is the excess of regular operating inflows over regular operating outflows.

Any assessment of the liquidity situation of a company requires to contrast and analyze inflows and outflows. The analysis of the cash flow aims at presenting and analyzing all cash flow of a company. This helps to identify future potential liquidity shortages in a timely manner and in that way to eliminate the risk of insolvency.

In most cases, the cash flow is determined with the help of the indirect method. Cash inflows and cash outflows are derived from

- expenses and income and
- from changes in assets and liabilities.

Cash flow statement is an instrument to assess the financial strength and earnings power. It shows changes, sources and uses of the cash flows on the basis of different criteria. It allows insights into the ability of the company to

- generate financial surpluses, especially from operating activities,
- support investments,
- meet payment obligations and
- make disbursements to owners.

The cash flow of a company is typically structured as follows in the context of a cash flow statement:

Cash flow from operating business activity (operating cash flow)
+ Cash flow from investment activities (investment cash flow)
+ Cash flow from financing activities
= Change in financial funds (net cash flow)

The inflow and outflow from operating business activities follow from the processes at the company (such as sales of the goods produced, procurement of materials, wage payments). The cash flow from investment activities refers to the outflow of funds for investments minus the inflow from investments (such as new acquisitions or the sale of fixed operating assets). The cash flow from financing activity captures inflows and outflows from external financing via debt and equity including new loans, repayment of existing loans, fresh funds provided by owners and dividend payments. The sum of these three cash flows determines the total inflow or outflow in the time period under consideration and is called net cash flow. The net cash flow shows the change in available funds.

9.2 Calculating the Gross Cash Flow from Operating Business Activities

Since no planning values are available for Pharma Group, the following calculations refer to the past observations of the periods t_{-2} to t_0. The data is derived from the cash flow statement of the corresponding annual reports. In preparation, cash flow from operating business activity (operating cash flow), cash flow from investment activities and cash flow from financing activity are combined (see Fig. 9.128).

The gross cash flow measures the internal financing ability. In general, the gross cash flow from operating business activities is calculated as follows:

Annual result

+ Depreciation (- Appreciation)

+ Increase (– Decrease) of the long-term provisions (including pension provisions)

= Gross cash flow from operating business activities

The gross cash flow from operating business activities of Pharma Group is calculated as follows. We add to earnings after taxes the tax

Cash flow from cash flow statement	t_2	t_1	t_0
Cash flow from operations	5,060	4,530	5,171
Cash flow from investment activities	-3,890	-814	-2,581
Cash flow from financing	-2,213	-3,783	-2,535

Fig. 9.128 Cash flow statement for Pharma Group (Excel File Financing, Worksheet Cash_Flow)

expenditure and the financial result, subtract paid and outstanding taxes on earnings plus depreciation minus appreciations plus/minus changes in provisions for pensions minus profits or plus losses from the disposition of long-term assets minus profits from revaluation (see Fig. 9.129).

The net cash flow from operating business activities is generally calculated as follows:

Gross Cash flow from operating business activities

–Changes in working capital

= Net cash flow from operating business activities

In the case of Pharma Group, the net cash flow from operating business activities can be calculated as gross cash flow from operating business activities minus the change in working capital and other activities that do not involve cash flows (see Fig. 9.130).

Gross cash flow from operations	t_2	t_1	t_0
Earnings after taxes	2,472	2,453	3,186
Taxes	891	723	1,021
Financial result	786	752	727
Taxes on earnings paid or owed	-1,067	-1,560	-1,644
Deprecation on property, plant and equipment and intangible assets	2,769	2,988	2,896
Changes in pension provisions	-504	-581	-249
Profits (–) Losses (+) from the disposal of noncurrent assets	-175	-219	-105
Gross cash flow from operations	**5,172**	**4,556**	**5,832**

Fig. 9.129 Gross cash flow from operating business activities of Pharma Group (Excel File Financing, Worksheet Cash_Flow)

Net cash flow from operations	t_2	t_1	t_0
Gross cash flow from operations	5,172	4,556	5,832
Increase/decrease inventories	-241	-680	-608
Increase/decrease accounts receivable	-389	-455	-751
Increase/decrease accounts payable	245	550	389
Changes in other net assets/Other actiivties that do not involve cash flows	273	559	309
Net cash flow from operations	**5,060**	**4,530**	**5,171**

Fig. 9.130 Net cash flow from operating business activities of Pharma Group (Excel File Financing, Worksheet Cash_Flow)

9.3 Calculating the Operating Free Cash Flow

The calculation of the operating free cash flow requires the deduction of investments in long-term assets from operating business activities. Investments in long-term assets serve to generate operating earnings over the long term. They are also called CAPEX (Capital Expenditures).

In the case of Pharma Group, the calculation of the operating free cash flows requires the deduction of expenses for tangible assets and immaterial assets from the net cash flow (see Fig. 9.131).

	A	B	C	D	E
37					
38		**Operating free cash flow**	t_2	t_1	t_0
39					
40		Net cash flow from operations	5,060	4,530	5,171
41		Investment in property, plant and equipment and intangible assets	-1,615	-1,929	-2,157
42					
43		**Operating free cash flow**	**3,445**	**2,601**	**3,014**

Fig. 9.131 Operating free cash flow of Pharma Group (Excel File Financing, Worksheet Cash_Flow)

9.4 Calculating the Net Cash Flow

Calculating the net cash flow requires summing up the three types of cash flow, namely cash flow from operating business activity, cash flow from investment activities and cash flow from financing activities. Also considered are the effects of exchange rate fluctuations as well as a change in available financial assets which follows from a change in the group of consolidated companies (see Figs. 9.132 and 9.133).

Position	t_2 Formula	Excel implementation
Cash flow from operations (=Cash_Flow!C48)	=Cash flow from operations	=C7
Cash flow from investment activities (=Cash_Flow!C49)	=Cash flow from investment activities	=C9
Cash flow from financing activities (=Cash_Flow!C50)	=Cash flow from financing activities	=C11
Changes resulting from modifications to the group of consolidated companies (=Cash Flow!C51 and C52)	=Changes in the group of consolidated companies	='Cash Flow Statement'!C40
Changes from exchange rate fluctuations (=Cash Flow!C51 and C52)	=Changes from exchange rate fluctuations	='Cash Flow Statement'!C41
Net cash flow (=Cash_Flow!C54)	=Cash flow from operations + Cash flow from investment activities + Cash flow from financing activities + Changes in the group of consolidated companies + Changes from exchange rate fluctuations	=SUM(C48:C52)

Fig. 9.132 Calculating the net cash flow of Pharma Group

	A	B	C	D	E
45					
46		**Cash flows from cash flow statement**	t_2	t_1	t_0
47					
48		Cash flow from operations	5,060	4,530	5,171
49		Cash flow from investment activities	-3,890	-814	-2,581
50		Cash flow from financing	-2,213	-3,783	-2,535
51		Changes resulting from modifications to the group of consolidated companies	0	0	0
52		Changes from exchange rate changes	-27	-6	-91
53					
54		**Net cash flow**	-1,070	-73	-36

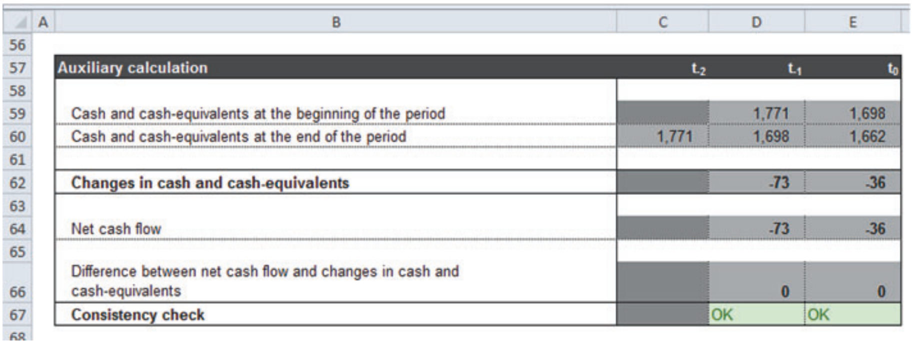
Fig. 9.133 Net Cash flow of Pharma Group (Excel File Financing, Worksheet Cash_Flow)

9.5 Control Calculations

The control calculations compare the previously determined net cash flows with the changes in cash and cash equivalents (see Figs. 9.134 and 9.135). These changes in cash and cash equivalents are calculated as the difference between cash and cash equivalents at the end of the period and cash and cash equivalents at the beginning of the period. The difference between net cash flows and the change in cash and cash equivalents must be equal to zero.

Position	t_1 Formula	Excel implementation
Cash and cash equivalents at the beginning of the period (=Cash_Flow!D59)	=Cash and cash equivalents at the beginning of the period	`=Assets!C18`
Cash and cash equivalents at the end of the period (=Cash_Flow!D60)	=Cash and cash equivalents at the end of the period	`=Assets!D18`
Change in cash and cash equivalents (=Cash_Flow!D62)	=Cash and cash equivalents at the end of the period - Cash and cash equivalents at the beginning of the period	`=D60-D59`
Net cash flow (=Cash_Flow!D64)	=Net cash flow	`='Cash Flow Statement'!D43`
Difference between net cash flow and changes in cash and cash equivalents (=Cash_Flow!D66)	=Difference between net cash flow and changes in cash and cash equivalents	`=D64-D62`
Consistency check (=Cash_Flow!D67)	=If the rounded difference between net cash flow and changes in cash and cash-equivalents is 0; then "OK"; else "DEVIATION"	`=IF(ROUND(D66;2)=0;"OK";"DEVIATION")`

Fig. 9.134 Setting up the control calculations



	A	B	C	D	E
56					
57		**Auxiliary calculation**	t_2	t_1	t_0
58					
59		Cash and cash-equivalents at the beginning of the period		1,771	1,698
60		Cash and cash-equivalents at the end of the period	1,771	1,698	1,662
61					
62		**Changes in cash and cash-equivalents**		-73	-36
63					
64		Net cash flow		-73	-36
65					
66		Difference between net cash flow and changes in cash and cash-equivalents		0	0
67		**Consistency check**		OK	OK

Fig. 9.135 Control calculations (Excel File Financing, Worksheet Cash_Flow)

10 Financing via Shortening of the Capital Commitment Period

> The capital commitment period comprises the time period during which financial funds are tied up in the production process of a company.

In this section, we want to analyze possibilities for internal financing that are unrelated to the production process. We will use the example of a shortening of the capital commitment period.

An important task of working capital management is to find ways of reducing the capital commitment period in assets. The financial funds which are released in that way can be used for other activities. In that sense, the reduction of asset holdings can be seen as a source of financing. We will analyze the two most important items, namely accounts receivable and inventories.

10.1 Premises when Shortening the Capital Commitment Period

We again need a number of assumptions for the calculations. They can be entered in the worksheet `Assumptions_Capital_Commitment` (see Figs. 9.136 and 9.137).

Position	Explanation	Limitations/Excel implementation
Accounts receivable (`=Assumptions_Capital_Commitment!E7`)	The value of accounts receivable is taken from the balance sheet.	**Formula:** `=Assets!E16`
Reduction Ø payment deadline (in days) (`=Assumptions_Capital_Commitment!E9`)	The user can provide an input for the desired reduction in the payment deadline.	**Data check:** Only positive integers are allowed. **User input:** 5
Inventory reduction (`=Assumptions_Capital_Commitment!E11`)	The input provides a percentage value for the desired inventory reduction via efficiency gains.	**Data check:** Only values between 0 and 100% are allowed. **User input:** 20%

Fig. 9.136 Assumptions concerning the reduction of the capital commitment period

	A	B	C	D	E
4					
5		**Asset Reduction**			
6					
7		Receivables			7,569
8					
9		Reduction Ø payment deadline (in days)			5
10					
11		Inventory reduction			20%
12					

Fig. 9.137 Assumptions concerning the reduction of the capital commitment period (Excel File Financing, Worksheet Assumptions_Capital_Commitment)

10.2 Reducing Receivables

The worksheet `Capital commitment period` is used for all calculations concerning capital. The decisive financing effect when reducing accounts receivable comes from the payment deadline granted. If it can be shortened, the financing volume for the accounts receivable is reduced, since the turnover goes up. The Excel model initially calculates the turnover and the average payment deadline from the average volume of receivables. Starting from the assumed shortening of the payment deadline, the new values are calculated (see Figs. 9.138 and 9.139).

This allows a clarification of the effects of shortening the payment deadline. The Figs. 9.140 und 9.141 show changes of the average volume of receivables and the turnover before and after the reduction of the payment deadline:

We see that average receivables can be reduced significantly if the payment deadline is shortened by a few days.

Position	Formula	Excel implementation
Trade accounts receivable $_{old}$ (=Capital_Commitment_Period!E7)	= Trade accounts receivable	=Assets!E16
Turnover $_{Receivables,old}$ (=Capital_Commitment_Period!E9)	=Total sales / Trade accounts receivable $_{old}$	='Income Statement'!E7/E7
Payment due $_{old}$ (in days) (=Capital_Commitment_Period!E11)	=Number of days per year / Turnover $_{Receivables,old}$	='Assumptions General'!E8/E9
Reduction Ø payment period (in days) (=Capital_Commitment_Period!E13)	=Reduction of Ø payment deadline	='Assumptions Capital Commitment'!E9
Payment due $_{new}$ (in days) (=Capital_Commitment_Period!E15)	=Payment due $_{old}$ - Reduction Ø of payment period	=E11-E13
Trade accounts receivable $_{new}$ (=Capital_Commitment_Period!E17)	=Total sales * Payment due $_{new}$ / Number of days per year	='Income Statement'!E7*E15/'Assumptions General'!E8
Turnover $_{Receivables,new}$ (=Capital_Commitment_Period!E19)	=Sales / Trade accounts receivable $_{new}$	='Income Statement'!E7/E17

Fig. 9.138 Reducing receivables

	A	B	C	D	E
4					
5		**Receivables reduction**			
6					
7		Trade accounts receivable $_{old}$			7,569
8					
9		Turnover $_{Receivables,old}$			5.3
10					
11		Payment due $_{old}$ (in days)			67.9
12					
13		Reduction in Ø payment period (in days)			5.0
14					
15		Payment due $_{new}$ (in days)			62.9
16					
17		Trade accounts receivable $_{new}$			7,011
18					
19		Turnover $_{Receivables,new}$			5.7
20					

Fig. 9.139 Reducing receivables (Excel File Financing, Worksheet Capital_Commitment_Period)

Position	Absolute	Excel implementation	Relative	Excel implementation
Change in trade accounts receivable outstanding (=Capital_Commitment_Period!E25:F25)	=Trade accounts receivable $_{new}$ – Trade accounts receivable $_{old}$	=E17-E7	= Trade accounts receivable $_{new}$ / Trade accounts receivable $_{old}$ - 1	=E17-E7-1
Turnover $_{Receivables}$ (=Capital_Commitment_Period!E27:F27)	=Turnover $_{Receivables,new}$ - Turnover $_{Receivables,old}$	=E19-E9	=Turnover $_{Receivables,new}$ / Turnover $_{Receivables,old}$ -1	=E19/E9-1

Fig. 9.140 Effect of a reduction of payment deadlines

	A	B	C	D	E	F
22						
23		Effect of shortening the payment period			absolute	relative
24						
25		Change in trade accounts receivable			-558	-7.4%
26						
27		Turnover $_{Receivables}$			0.4	8.0%
28						
29						

Fig. 9.141 Effect of a reduction of payment deadlines (Excel File Financing, Worksheet Capital_Commitment_Period)

10.3 Inventory Reductions

The inventory reduction can be analyzed in a similar way as the reduction of receivables. Now we are not concerned about a reduction of the payment deadline, but instead reduce the level of inventories by the percentage listed in the assumptions. The relevant figure is the inventory range. It gives the number of days for which the available inventories support the production process (see Figs. 9.142 and 9.143).

Again the absolute and relative effects of a change in inventories is analyzed with a focus on the variables turnover and inventory range (see Figs. 9.144 and 9.145):

Position	Formula	Excel implementation
Turnover $_{\text{Inventory.old}}$ (=Capital_Commitment_Period!E34)	=Total sales / Inventory	='Income Statement'!E7/Assets!E15
Inventory range $_{\text{old}}$ (in days) (=Capital_Commitment_Period!E36)	=Number of days per year / Turnover $_{\text{Inventory.old}}$	='Assumptions General'!E8/E34
Inventory $_{\text{new}}$ (=Capital_Commitment_Period!E38)	=Inventory * (1 – Inventory reduction)	=Assets!E15*(1-'Assumptions Capital Commitment '!E11)
Turnover $_{\text{Inventory,new}}$ (=Capital_Commitment_Period!E40)	=Total sales / Inventory $_{\text{new}}$	='Income Statement'!E7/E38
Inventory range $_{\text{new}}$ (in days) (=Capital_Commitment_Period!E42)	= Number of days per year / Turnover $_{\text{Inventory.new}}$	='Assumptions General'!E8/E40

Fig. 9.142 Reduction of inventory

	A	B	C	D	E
31					
32		**Inventory reduction**			
33					
34		Turnover $_{\text{Inventory,old}}$			5.6
35					
36		Inventory range $_{\text{old}}$ (in days)			63.9
37					
38		Inventory $_{\text{new}}$			5,703
39					
40		Turnover $_{\text{Inventory,new}}$			7.0
41					
42		**Inventory range $_{\text{new}}$ (in days)**			**51.1**

Fig. 9.143 Reduction of inventory (Excel File Financing, Worksheet Capital_Commitment_Period)

The inventory range is reduced by the same percentage as the inventory. To put these measures in perspective, the effects on the return on total capital will be clarified (see Figs. 9.146 and 9.147).

Position	Absolute	Excel implementation	Relative	Excel implementation
Turnover $_{Inventory}$ (=Capital_Commitment_Period!E48:F48)	=Turnover $_{Inventory,new}$ - Turnover $_{Inventory.old}$	=E40-E34	=Turnover $_{Inventory,new}$ / Turnover $_{Inventory.old}$ - 1	=E40/E34-1
Inventory range (in days) (=Capital_Commitment_Period!E50:F50)	=Inventory range $_{new}$ - Inventory range $_{old}$	=E42-E36	=Inventory range $_{new}$ / Inventory range $_{old}$ – 1	=E42/E36-1

Fig. 9.144 Effect of an inventory reduction

	A	B	C	D	E	F
45						
46		Effects of reducing inventory			absolute	relative
47						
48		Turnover $_{Inventory}$			1.4	25.0%
49						
50		Inventory range (in days)			-12.8	-20.0%
51						

Fig. 9.145 Effect of an inventory reduction (Excel File Financing, Worksheet Capital_Commitment_Period)

Position	Formula	Excel implementation
Return on total capital $_{old}$ (=Capital_Commitment_Period!E56)	=EBIT / Total assets	='Income Statement'!E19/Assets!E22
Return on total capital $_{new}$ (=Capital_Commitment_Period!E58)	=EBIT / (Total assets + Change in trade accounts receivable + (Inventory $_{new}$ - Inventory))	='Income Statement'!E19/(Assets!E22+E25+(E38-Assets!E15))

Fig. 9.146 Effect of an inventory reduction

Fig. 9.147 Return on total capital for a reduction of the capital commitment period (Excel File Financing, Worksheet Capital_Commitment_Period)

11 Summary

In this chapter on financing, the financial modeler has obtained an overview of methods and approaches in financial analysis:

Fundamental rules of financing:

- Fundamental financing rules provide a first insight into the financial structure of the company.
- Among the fundamental financing rules are the golden rule for balance sheets, the relationship between equity and debt and the leverage effect.

Analysis of key figures:

- An important method to assess companies is the calculation of key figures.
- They compress the data contained in annual reports and thus allow a quick overview of the financial situation.
- The most important key figures analyze the
  - profitability,
  - financial structure,
  - asset structure,
  - capital structure,
  - earnings structure and
  - cash flow.

Ordinary capital increase:

- A capital increase is the increase of the equity of a listed company via issuance of new shares.
- Existing shareholders have the opportunity to maintain their ownership percentage in the company via subscription rights. If they acquire additional subscription rights, they can also increase their ownership share.

Long-term loan:

- Among the types of external financing, the loan is a form of debt financing.
- There are three ways to repay the loan:
  - Annuities (Annuity loan)
  - Installments (Amortizable loan)
  - Full repayment at maturity (bullet loan)

Bond:

- Bonds, just like long-term loans, are a form of external financing.
- In contrast to the loan, the volume of a bond is usually so high that a single provider of capital is unable – or unwilling – to provide the entire amount.
- For that reason, the loan amount is broken up into smaller nominal values and issued to several bond holders.
- The risk management of bonds relies on key figures such as duration und convexity.

Short-term financing using the example of the supplier credit:

- An important type of short-term debt financing is the supplier credit.
- The supplier credit gives the company the opportunity to make payments for goods or raw materials received only after a certain period (for example, after 30 days).
- While no interest payments are due for the supplier credit, it is still not free, since immediate payment allows the deduction of a cash discount.

The cash flow:

- Cash flow is the most important position in the structure of internal financing.
- Cash flow statement is an instrument for the assessment of the financial and earnings strength. It shows changes, sources and uses of cash flows based on several structural criteria. It allows an assessment of the position of the company concerning the,
  - Ability to obtain financial surpluses, especially from operating activities,
  - Ability to fund investment activities,
  - Ability to meet payment obligations and
  - Ability to disburse funds to the owners.

Financing via shorter capital commitment period:

- Shortening the capital commitment period is an additional possibility of internal financing.
- The aim of working capital management is to reduce the amount of capital tied up in assets.
- The financial funds released in that way can be used for different activities.
- In that sense, the reduction of certain asset holdings can be seen as a financing effect.
- The most important holdings that can be used to shorten the capital commitment period are accounts receivable and inventories.

Notes

1. The calculations for periods 6. . . 10 are principally the same as for the years 2. . . 5. The additional IF functions assure that only those cells contain values for which the credit is still outstanding in the period. If this is not the case, the cells remain empty.

Literature and Suggestions for Further Reading

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10

Corporate Finance Part I

1 Executive Summary

In this section the financial modeler will learn how to derive a valuation range for a company – here Pharma Group. The summary and presentation of the results of the various valuation methods relies on the so-called football field graph. As Fig. 10.1 reveals, the result of the company valuation – the valuation range of the listed company Pharma Group – is based on the following five valuation methods:

- DCF method (Corporate Finance Part I)
- Market capitalization (Corporate Finance Part II)
- Book value (Corporate Finance Part II)
- Trading multiples (Corporate Finance Part II)
- Transaction multiples (Corporate Finance Part II)

The **football field graph** provides an overview of the valuation results (Excel File Corporate Finance, Worksheet Executive_Summary)

The results of the three discounted cash flow approaches WACC approach, APV approach and equity approach (the first and last approach were implemented with a period-specific calculation) are exactly identical. The result is a market value of the equity of Pharma Group of €85.5 billion. However, the financial modeler never reports results up to the last cent. Due to the volatility of the value drivers, he conducts a sensitivity analysis of the final results and provides a range to his clients. Here the value range is between €83.6 billion and €87.0

J. Häcker and D. Ernst, *Financial Modeling*,
Global Financial Markets, DOI 10.1057/978-1-137-42658-1_10

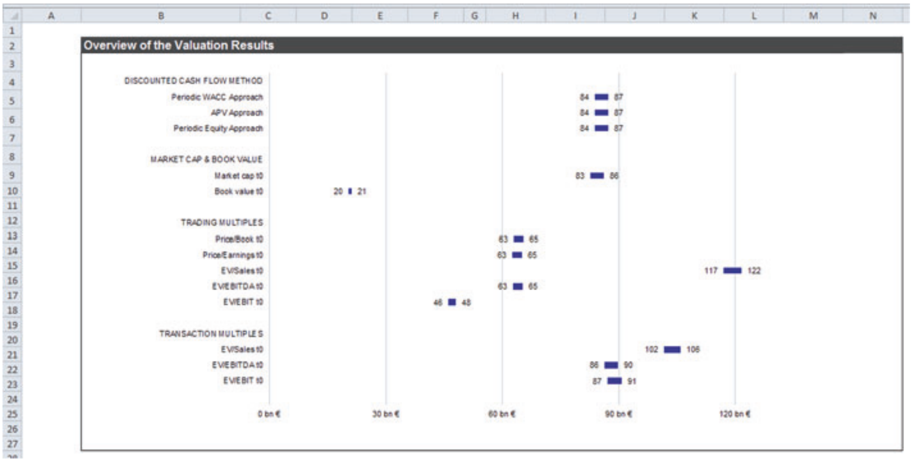


Fig. 10.1 The football field graph

billion. Compared to the other methods used here, the DCF approach is the key method in company valuation.

The **market capitalization** is equal to €84.4 billion at time t_0. If the investor is interested in purchasing 100% of Pharma Group, the market capitalization gives the minimum purchase price which the buyer must pay in order to conduct such a transaction.

The **book value** of Pharma Group is equal to €20.7 billion at time t_0 and can generally be considered as the absolute low boundary of the valuation. In general no seller is willing to dispose of his company below the book value.

The peer group of Pharma Group comprises a total of seven publicly listed companies. The results are based on the multiples price/book, price/earnings, EV/EBITDA and EV/EBIT and are significantly below the market capitalization. The reason for this is the low profitability of Pharma Group compared to the other seven companies in the peer group. Since the median of the peer group multiples is multiplied with the low earnings figures of Pharma Group, a relatively low result is obtained for Pharma Group. Relative to the peer group, a lower corporate value would result.

Contrasting results are obtained with the EV/sales multiple. The range of results from €117 billion to €122 billion would lead to a higher corporate value compared to the peer group. This is explained by the strong sales performance of Pharma Group compared to the seven other companies. The median EV/sales multiple of the peer group is 3.3. Since this multiple is multiplied by the above average sales of Pharma Group, an above average corporate value is obtained. While the EV/sales multiple is least affected by differences in tax systems and accounting standards, the result should be ignored in this context. The use of sales as a point of reference cannot be recommended, since no information about costs or profitability is provided.

This example also demonstrates the importance of selecting the correct peer group. For that reason, the financial modeler should also possess excellent knowledge about the industry, the business model and macroeconomic interrelations in addition to strong skills in corporate valuation.

The results for the two **transaction multiples** EV/EBITDA and EV/EBIT are between €86.0 billion and €90.5 billion. Just like the trading multiples, the high result from the EV/sales multiple must be excluded from the valuation. The results obtained with the transaction multiples are higher than the results from the trading multiples. This is explained by the fact that takeover premiums are usually paid for acquisitions of companies.

If a potential buyer of Pharma Group has given a mandate to the financial modeler to conduct a company valuation, the financial modeler will provide him with a valuation range and a walk-away-price. Once all the data has been carefully condensed in a bottom up process, the art is to turn this into a final result. It is ultimately true that valuation is much more an art than a science. In this current case, the financial modeler will most likely provide the client with the valuation range of €84 billion to €90 billion. The market capitalization and the lower end of the valuation range from the DCF method support the value of €84 billion. The upper end is supported by the results based on EV/EBITDA and EV/EBIT from the method of transaction multiples. Inside this range is the result of the DCF method which was subject to a sensitivity analysis. The two EV/sales multiples are to be excluded as discussed above. Only the result from the trading multiples suggests a value below the valuation range. In applied work, the financial modeler will now turn to a detailed analysis of the entire business model of Pharma Group and a comparison with the peer group. This may result in an adjustment of the valuation range.

Ultimately, the client is not interested in a value, but rather in a price. A potential buyer would like to know how far he can go in a bidding process. The walk-away-price helps him to optimally design his behavior (price in the letter of intent, in the binding offer and in the purchase contract) and negotiating tactics. In the case of Pharma Group, the walk-away-price is € 100 billion, which implies a takeover premium of close to 20% based on the current market capitalization.

2 Introduction, Structure, Learning Outcomes and Case Study

Structure

The chapter Corporate Finance Part I serves as an introduction to corporate finance and company valuation and answers the following questions:

- What is meant by corporate finance?
- Which methods of company valuation exist?
- Which fundamentals of corporate planning play an important role in applied work?
- How is corporate planning implemented in a concrete situation?
- How are the relevant cash flows derived?
- What are the basics of capital market theory?
- How is the cost of capital derived?
- How is company valuation implemented with the help of the various DCF approaches?
- How are sensitivity analysis and scenario analysis conducted?
- Which model adjustments are needed so that all DCF approaches yield identical company values?

Learning Outcomes

The financial modeler

- Is able to reproduce and critically discuss the basic ideas of corporate planning and company valuation;
- Obtains the tools necessary to implement corporate planning and company valuation in Excel;
- Is as a result able to solve actual problems that arise in corporate planning and company valuation;
- Is able to develop his own planning model from financial statements of the past three to five years;

- Can derive the relevant cash flows for valuation from the planning model;
- Can use the WACC, period-specific WACC, APV and equity approach to independently conduct a company valuation and critically assess the results;
- Can independently conduct a sensitivity analysis as well as a scenario analysis;
- Is able to adjust and expand the model in a way that all DCF valuation methods lead to the same result;

Case Study

> The term corporate finance refers to a sub-field of finance. Corporate finance deals with questions of optimal capital structure, the dividend policy of the company as well as the valuation of investment decisions and the determination of the company value.

In the world of banking, corporate finance is a part of investment banking, which offers financing and advisory services such as mergers & acquisitions, IPOs, private equity, venture capital, mezzanine, acquisition financing, project financing or asset backed financing.

> There are numerous occasions for company valuations.

Company valuation constitutes a fundamental component of corporate finance, since it is applied in all aspects of corporate finance advisory and financing activities. Companies are assessed from a qualitative as well as a quantitative perspective in order to reach decisions about a complete or partial purchase and sale. In addition, numerous occasions necessitate company valuations in applied work. These include:

Valuations as a consequence of legal regulations, such as

- Compensation of shareholders in the context of a squeeze-out
- Implementation of profit transfer and control agreements

Valuations that arise form entrepreneurial activities such as

- Investment controlling
- Goodwill impairment test or purchase price allocation in corporate acquisitions as required by IAS/IFRS
- Determination of the lending limit when assessing creditworthiness
- Corporate management in the context of value based management
- Analysis of a company during restructuring (reorganization, recapitalization, liquidation and so forth)

Valuations arising from contractual obligations such as

- Joining or exit of partners
- Allocations on the basis of inheritance law or matrimonial property rights (divorce)
- Legal or arbitrational proceedings which involve the value of a corporation
- Determination of existing wealth for tax reasons (conversions, bestowals and so forth)

Valuations resulting from entrepreneurial activity such as

- Complete or partial purchase or sale of companies
- Mergers and spin-offs of companies – involving the transfer of ownership of shares
- Management Buy Out (MBO)/Management Buy In (MBI)
- IPO of a company
- Establishing a joint venture
- Capital increase

The financial model for the case study can be found in the Download Section in the Excel-Sheet `Corporate Finance Part I`. Use the contents of the download section together with the text:

- The individual learning steps are broken down into small units and found on separate worksheets.
- All calculations are done directly in Excel. This assures traceability of the calculations.

- All assumptions which serve as input data used for calculations in the financial model are found in the worksheet `Assumptions`.
- All input data is marked in the color light orange. These are values which are assumed by the valuation expert and can be set individually.
- All calculations and output data use the color light gray. These are values which result from calculations.
- Mixed formulas that contain both numerical values and cell references are highlighted using green font.
- For better traceability Income Statement, Assets Equity and Liabilities, Auxiliary Calculations and Cash Flow Calculations are done on separate sheets.
- The part on company valuation starts with a calculation of the cash flow.
- This and the following sheets refer to the discounted cash flow (DCF) approaches as well as to the multiple approaches.
- In the first step, the cash flows necessary for the DCF valuation are derived.
- In the following, the different discount rates are calculated.
- In the next step, the valuations of the company based on the methods WACC, APV and equity approach are calculated.
- As a refinement of the WACC approach, company valuation based on a period-specific WAAC is presented.
- For these approaches a sensitivity analysis and a scenario analysis are conducted.
- In the next step it is described how adjustments can be used to assure that all DCF valuation approaches produce identical results.
- Finally, the corporate valuation is conducted using book value, market capitalization, as well as trading and transaction multiples.

Figure 10.2 shows the menu and the documentation of the Excel file `Corporate Finance Part I`.

The applied example of the Pharma Group illustrates all steps in the chapter Corporate Finance

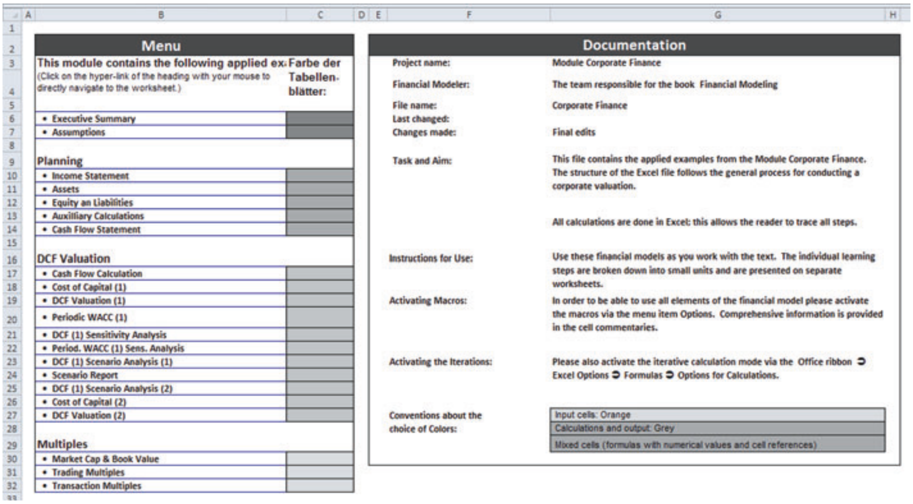


Fig. 10.2 Menu and Documentation (Excel File Corporate Finance, Worksheet Menu and Documentation)

Pharma Group

The corporate planning and valuation which is conducted on the following pages is based on the example of Pharma Group, a global leader in the fields of pharmaceuticals, agriculture and high-end materials. The financial reporting of Pharma Group is based on IFRS and uses the cost of sales method. The owners want to assess the value of the company. Consequently, a company valuation is conducted in a first step by an M&A department of a bank. This initially involves planning for a five year period, which serves as the basis for the DCF valuation. The corporate planning is an important component of the potential prospectus. The highest possible degree of precision of corporate planning is therefore of major importance to arrive at an accurate valuation.

Pharma Group has the following income statement as well as balance sheet assets and liabilities (see Figs. 10.3 to 10.5).

I million	Actual t_{-2}	Actual t_{-1}	Actual t_0
Total sales	**36,528**	**39,741**	**40,157**
- COGS	17,975	19,070	19,347
Gross profit on sales	**18,553**	**20,671**	**20,810**
- Selling expenses	8,958	9,981	10,080
- Research and development expenses	2,932	3,013	3,190
- General administration expenses	1,713	1,866	1,883
+ Other operating income	859	1,087	897
- Other operating expenses	1,660	2,970	1,620
Operating result (EBIT)	**4,149**	**3,928**	**4,934**
+ Result from associates accounted for using the equity method	-45	-18	-16
+ Financial income	586	503	389
- Financial expenses	1,327	1,237	1,100
Earnings before taxes (EBT)	**3,363**	**3,176**	**4,207**
- Income taxes	891	723	1,021
Earnings after taxes	**2,472**	**2,453**	**3,186**
- of which attributable to non-controlling interest	2	50	-3
Net income	**2,470**	**2,403**	**3,189**
Dividend	1,364	1,571	1,737
Shares entitled to the dividend			
Weighted average number of issued ordinary shares (m)	827	827	827
Number of ordinary shares in issue (m)	827	827	827
Ordinary shares in issue			
Dividend (in I)	1.65	1.90	2.10

Fig. 10.3 Income Statement of the Pharma Group (Excel File Corporate Finance, Worksheet Assumptions)

Assets

€ million	Actual t_2	Actual t_1	Actual t_0
Goodwill	9,148	9,293	9,862
Other intangible assets	10,284	9,464	8,914
Property, plant and equipment	9,887	9,898	10,015
Investments accounted for using the equity method	265	225	203
Other noncurrent assets	1,773	1,849	1,699
Deferred taxes	1,312	1,579	1,596
Noncurrent assets	32,669	32,308	32,289
Inventories	6,370	6,991	7,129
Trade accounts receivable	7,060	7,433	7,569
Other assets	4,876	2,888	2,668
Cash and cash equivalents	1,771	1,698	1,662
Current assets	20,077	19,010	19,028
Total assets	52,746	51,318	51,317

Fig. 10.4 Balance sheet assets of Pharma Group (Excel File Corporate Finance, Worksheet Assumptions)

Equity and Liabilities

€ million	Actual t_2	Actual t_1	Actual t_0
Subscribed capital of Pharma Group	2,117	2,117	2,117
Capital reserves of Pharma Group	6,167	6,167	6,167
Other reserves	8,442	7,764	9,245
Net income	2,470	2,403	3,189
Equity attributable to non-controlling interest	59	100	86
Equity	19,255	18,551	20,804
Provisions for pensions and other post-employment benefits	7,787	9,246	7,368
Other provisions	1,726	2,111	1,977
Financial liabilities	7,995	6,962	5,590
Other liabilities	474	409	362
Deferred taxes	2,116	935	1,193
Noncurrent liabilities	20,098	19,663	16,490
Other provisions	4,217	4,844	4,727
Financial liabilities	3,683	2,568	3,441
Trade accounts payable	3,785	4,305	4,473
Income tax liabilities	76	72	101
Other liabilities	1,632	1,315	1,281
Current liabilities	13,393	13,104	14,023
	-	-	-
Total equity and liabilities	52,746	51,318	51,317

Fig. 10.5 Balance sheet liabilities of Pharma Group (Excel File Corporate Finance, Worksheet Assumptions)

3 Overview of the Methods of Company Valuation

> In applied work a broad range of different company valuation methods is found.

The range of company valuation methods used in applied work has been expanded in the past years. While methods with a historical focus on the basis of existing annual reports were used in the past, the focus today is clearly on forward looking approaches, which aim to assess the future success of corporations. Additionally, share prices or prices from prior M&A transactions are used to arrive at prices of companies.

The most frequently and globally used methods of valuation are presented in Fig. 10.6:

The internationally accepted methods of company valuation can be segmented into three groups:

- **Book value of equity and market capitalization:** The **book value of equity** as derived from the balance sheet is a reflection of corporate development, accounting policy and dividend policy in the past. For that reason it cannot be used as an indicator for the future earnings power of the company. The book value of the equity can still be interpreted as the value of a company for the specific case of a breakup. It represents the lower bound of a potential valuation range for the company. For the valuation of publicly listed companies, the current **market capitalization** can be taken as the value of the company. Under the assumption that the efficiency hypothesis of Fama is valid (current prices reflect all available information about the company), the market capitalization is the simplest and quickest possibility to value a publicly listed company. The market capitalization is calculated by multiplying the current share price with the number of shares issued.

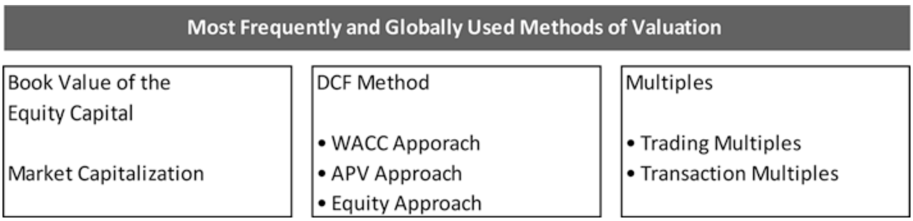


Fig. 10.6 Overview of globally used methods of company valuation

- **Multiple approaches:** The valuation involving **trading multiples** is a market-oriented approach. It uses the valuation of publicly listed companies as a reference to determine the value of companies. The share prices of comparable companies which form the basis of the valuation already reflect information about the corporate environment and therefore reflect the current market valuation. The valuation of companies with the help of multiples derived from listed companies is frequently used in applied work, since the use of this method is relatively simple and quickly provides a first indication of value. Valuations of companies with the help of **transaction multiples** are based on comparable M&A transactions and follow the principle already familiar from trading multiples. Under the assumption that comparable companies should have similar values, the company value can be calculated using multiples based on historical M&A transactions. In daily business the use of transaction multiples is widespread, especially for upcoming acquisitions and disposals of companies. Reasons for the use of this method are first, the simplicity of the calculations and second, the orientation on prices that were actually paid in the past.
- **Discounted Cash Flow (DCF) approaches:** In the DCF approach, the company value is equal to the present value of future cash flows from the corporate activities plus the value of the non-operating assets, which must be determined separately. Since the cash flows are derived from corporate planning that has been checked for plausibility, the DCF methods explicitly take into consideration company-specific features.

Depending on the definition of the cash flows that are relevant for the valuation and the applicable discount rates, several DCF approaches can be distinguished:

- The **Weighted Average Cost of Capital approach (WACC approach)** is determined by discounting all future cash flows available to all providers of capital – both debt and equity providers – at a rate that adequately reflects the mix of debt and equity. To arrive at the market value of equity, the market value of the interest-bearing debt needs to be subtracted.
- In the **Adjusted Present Value approach (APV approach)** the market value of the entity value is determined in a first step under the assumption of complete equity financing. In a second step, the

effect of debt financing on the company value is taken into consideration in the form of a so-called tax shield. It reflects the tax savings which result from the deduction of interest payments on debt from earnings. In order to arrive at the equity value, the market value of interest-bearing debt is again subtracted.

- In the **equity approach** only cash flows available to the providers of equity are discounted. Discounting is done therefore at the cost of equity of the company. This method directly leads to the market value of equity.

As long as identical assumptions are made about future financing activities, all three approaches will yield the same result.

4 Company Valuation Using Discounted Cash Flow Models

Discounted Cash Flow (DCF) approaches are based on the principle that the value of the corporation which needs to be determined is derived from the future earnings power.

The DCF method has strong foundations in investment theory. The value of a corporation – as in the case of investment valuation – is determined on the basis of the cash flows expected in the future which are discounted to the relevant time of valuation. The company value is given by the net present value of all future cash flows from operations plus the value of the assets not required for operations, which must be determined separately.

The DCF method calculates the value of a company by discounting the cash flows which can be expected in the future to the valuation date.

Normally the detailed planning of the cash flows only covers a few years. For the time period following this planning horizon, the terminal value is assessed. The terminal value is calculated as a perpetuity which is based on the sustainable cash flow. The company value is equal to the present value of the cash flows from detailed planning plus the present value of the terminal value.

Depending on the definition of the cash flows which are relevant for valuation and the discount rates used, the following DCF approaches can be distinguished:

- Weighted Average Cost of Capital approach (WACC approach)
- Adjusted Present Value (APV) approach
- Equity approach

The WACC approach and the APV approach are also called entity approach, since they initially calculate the entity value. In a second step, the interest-bearing liabilities are subtracted to arrive at the net company value (= market value of equity). The equity approach directly calculates the market value of equity. All three approaches yield the same result as long as identical assumptions are made about the future financial structure.

4.1 Basics of Corporate Planning

> Any company valuation that rests on a solid quantitative foundation must incorporate detailed and integrated planning figures for the income statement and the balance sheet.

Not surprisingly, the insight about "garbage in - garbage out" is fully valid in this context as well. The quality and results of any company valuation depend crucially on the quality of the planning figures used in the valuation. The basis for every company valuation is thus thorough planning, which adequately reflects the future earnings power of the company.

Any company valuation requires concrete numerical inputs. This involves transforming the partly qualitative results of the analysis of the macroeconomic environment, the market and competitive environment and the company analysis into planning figures based on quantitative premises. Starting point is the analysis of the present and the recent past, which is used by the financial modeler as the basis for forecasts about the future development of the key value drivers.

Digression

A simple forward projection of the past must be avoided

Planning which is purely based on an uncritical and static extrapolation of past values is unlikely to yield satisfactory results. The main reason is the continuous change in framework conditions of the corporate environment (business cycle, industry, competitors and so forth). This obliges companies to anticipate change in their decision making and to react adequately, a fact that must also be reflected in planning. Rarely will the reasons for the historic development of the company continue to hold for the planning period due to learning, technical progress, substitution effects for materials and other efficiency gains. The financial modeler should implement corrections with regard to the value drivers or at a minimum talk to the persons responsible for planning, if changes in the corporate environment can be expected and/or if the corporate policy changes.

The identification of major drivers of success (sustainable earnings power) which is conducted in the context of the analysis of the annual reports constitutes the bridge between past performance and planning. It is decisive for the quality of planning that the planners are able to adequately anticipate future developments. The following list summarizes a selection of central aspects that need to be considered in this regard.

Practical Tip

Anticipating the future: main aspects

- Which industry features had the strongest influence in the past on the value drivers? What is their likely future development?
- Which company-specific abilities and strengths had the greatest influence on the value drivers in the past? Is the company able to maintain or expand these value drivers or to establish new ones?
- Are risks adequately captured in the planning process?

- Can the industry features and the competitive strength of the company be expected to remain constant? If not, what changes are likely in the future?
- What needs to change in the corporate environment or inside the company in order to trigger a clear increase or decline of the level of the value drivers?
- Is the planned earnings outlook realistic in light of the business development observed in the past?

In this section, the planning of the Income Statement and the balance sheet of Pharma Group is presented. The planning model follows an integrated approach which coordinates the individual components of planning and considers the various interdependencies between the assumptions made in the planning process. The financial modeler can use it to conduct his own planning or to check existing plans for plausibility in order to prevent typical mistakes during the planning process.

The model is a basic version, which can be adjusted to consider the specifics of the corporate situation. It is suitable

- for top-down planning,
- to verify planning presented by third parties and
- for IFRS financial statements.

Despite the simplicity of the setup, which was chosen on purpose to allow easy application, a complex set of interactions between the various planning elements is created (see the example of a planning scheme in Fig. 10.7).

Starting from the income statement and the balance sheet of the past years t_{-2} to t_0, the past annual reports of the Pharma Group are analyzed with a focus on key figures. The key figures are used in the worksheet `Assumptions` to determine the input data, which serve as the basis for the calculation of the planned values for income statement and balance sheet.

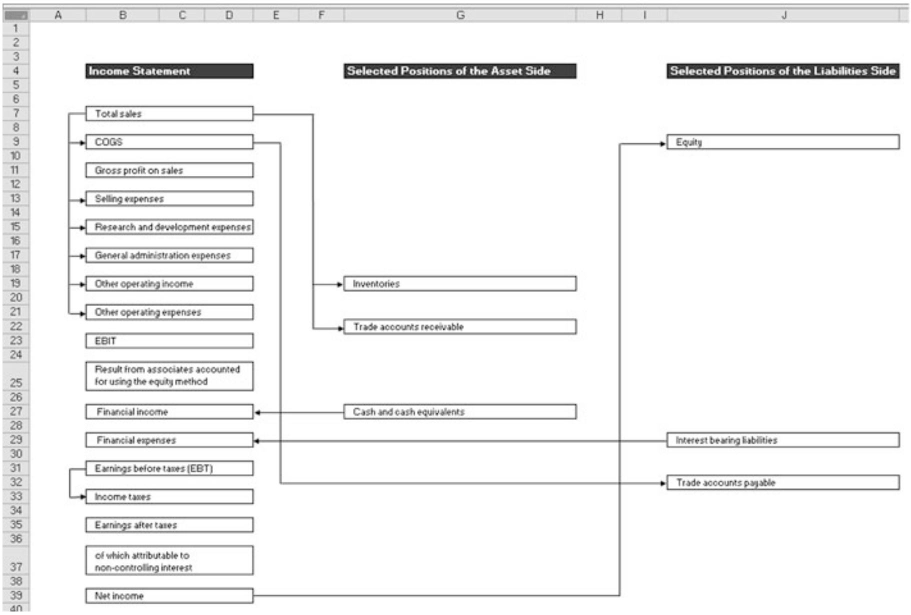


Fig. 10.7 Planning scheme of the corporate finance training model

4.1.1 Planning Period

> The reliability of all planning processes is always affected negatively by the unpredictability of environmental influences.

The probability of actually meeting the planning figures is likely to be higher for a shorter time period than for a very long interval (for example in excess of ten years).

> Practical Tip

The choice of an appropriate planning period
In order to do justice to the ever present uncertainty about the future, any corporate planning process should be broken down into two or three stages (three-stage-model):

1. Detailed planning period,
2. Transitional or adjustment stage and
3. Infinite planning horizon.

> Financial modelers regularly limit the planning period to two stages, the detailed planning period and the infinite planning horizon.

A three-stage-model with transitional or adjustment stage is only used in cases where the companies are characterized by extremely high growth rates (for example innovations at the beginning of the life cycle).

- **Phase 1 - Detailed planning period:** This phase requires thorough and comprehensive planning. The time period for meaningful detailed planning regularly comprises three to six years. At a minimum it should be long enough to allow the establishment of individual and reliable planning figures for each year of planning. The length of the detailed planning period can vary and be somewhat shorter or longer depending on circumstances:
  - Shorter (1 to 5 years): for companies that operate in mature markets.
  - Longer (5 to 15 years): for companies that will sell new products with strong sales and revenue in the future and at the same time have strong patent protection, specific knowledge that is hard to imitate, unique attributes or monopoly positions (for example utilities).

  If the company is active in an industry with strong cyclical fluctuations, the detailed planning period should cover one entire business cycle. Otherwise the inappropriate choice of the first detailed planning period can lead to mistakes in the following determination of the transition stage and the terminal value. This happens in all cases where boom or recession periods are used as the basis for extrapolation into the future.
- **Phase 2 - Infinite planning horizon:** This phase covers the remaining lifespan of the company. The corporate development should reflect sustainable, long-term earnings. In company valuation, this is regularly reflected in the so-called terminal value.

4.1.2 Planning Premises or Structure of Planning in the Model

In the following, it will be demonstrated how the financial modeler can structure a corporate planning model with the help of key figures and assumptions for income statement, balance sheet assets and balance sheet liabilities.

Income Statement

The various financial figures of the income statement are planned using assumptions based on an analysis of past values of the income statement.

The following steps are recommended:

Step 1: Analyzing past values of the income statement using key figures

Step 2: Calculating and determining the planning assumptions

Step 3: Calculating the planning values

Step 1: Analyzing past values of the income statement using key figures

Figure 10.8 demonstrates with the help of an example how the actual values from the income statement in year t_0 can be analyzed in the worksheet `Assumptions` using key figures. The additional cells for the years t_{-1} and t_{-2} which also contains formulas (gray cells in the Financial Model), can simply be treated accordingly.

Figure 10.9 shows the values of the key figures for the years t_{-2} until t_0.

Step 2: Calculating and determining the planning assumptions

In the next step, key figures for the future are derived from past values.

Practical Tip

Possible ways of calculating the key planning figures

In applied work there are two possibilities for calculating key figures for planning purposes.

1. If a trend is observable in the time series of past data, it is suggested to use the last value as a starting point.
2. If no trend is observable, an average of past values can be formed.

Position	Calculations for t_0	Comments
Total sales of segments: growth in % (=Assumptions!E 115)	=Total sales t_0 / Total sales t_{-1} - 1: =E14/D14-1	The growth of total sales shows the past ability of the company to grow. This figure can be compared to the industry average.
Ratios for * COGS * Selling expenses * R&D expenses * General administration expenses * Other operating income * Other operating expenses (=Assumptions!E 117 to E127)	=Expenses or income / Net sales: =E16/E14 =E20/E14 =E21/E14 =E22/E14 =E23/E14 =E24/E14	Past values of the various positions are related to total sales.
Average interest rate on interest-bearing liabilities (=Assumptions!E 133)	=Interest expenses/(Pension provisions + Noncurrent financial liabilities + Current financial liabilities): =E30/(E89+E92+E99)	Interest expenses are related to interest-bearing liabilities (in this case pension provisions as well as noncurrent and current financial liabilities).
Income tax rate (=Assumptions!E 135)	Income taxes/EBT: =E34/E32	The tax rate is calculated by determining the ratio of corporate taxes to earnings before taxes.
Income attributable to non-controlling interest (in % of EAT) (=Assumptions!E 137)	= Income attributable to non-controlling interest / EAT: =E38/E36	The amount that is due to minority owners is related to EAT.

Fig. 10.8 Explanations for the analysis of key figures for the income statement

When setting the planning figures, consistency with the economic framework conditions and the specifics of the industry and the company must be assured. In applied work it is a big advantage if these key figures can be discussed and compared with the support of a controller from the company.

Figure 10.10 shows which assumptions and key figures are used in planning.

Practical Tip

€ million	Actual t_2	Actual t_1	Actual t_0
Total sales of segments: growth in %		8.8%	1.0%
COGS margin of sales	49.2%	48.0%	48.2%
Selling expenses margin of sales	24.5%	25.1%	25.1%
Research and development expenses margin of sales	8.0%	7.6%	7.9%
General administration expenses margin of sales	4.7%	4.7%	4.7%
Other operating income margin of sales	2.4%	2.7%	2.2%
Other operating expenses margin of sales	4.5%	7.5%	4.0%
Result from associates accounted for using the equity method: growth in percent compared with t0			
Interest rate (deposit)			
Average interest rate on interest bearing liabilities	6.8%	6.6%	6.7%
Tax rate	26.5%	22.8%	24.3%
Quote minorities	0.1%	2.0%	-0.1%
Dividend payout ratio	55.2%	65.4%	54.5%
Number of ordinary shares in issue (m)	827	827	827

Fig. 10.9 Analysis of past values of the income statement (Excel File Corporate Finance, Worksheet Assumptions)

Consistency in the Excel File

When calculating the planning assumptions, the following rules concerning the consistency in Excel file should be followed:

- If the value of the last actual year is used as a planning assumption, a cell reference between planning value t_1 and actual value t_0 should be established. Simply copying the value for t_0 cannot be recommended, since Excel uses the correct number of decimal places and a discrepancy between planning value t_1 and actual value t_0 could arise. After this, the planning value can be used for the following planning periods via copying.

Position	Assumptions	Comments	Formulas for t_1
Sales growth (Assumptions!F115 to K115)	t_1 = 6,0 %; t_2 = 6,0 %; t_3 = 6,0 %; t_4 = 6,0 %; t_5 = 2,0 %; TV = 2,0 % The growth assumptions were carefully assessed.	Sales planning is most challenging. The development of sales is the most important value driver of company valuation. It is regularly the main planning stage, which is used as point of reference for subordinated planning values. Starting point of the sales planning is a forecast of developments in the relevant sales market. As a next step it is best to study the existing stock of orders and the potential for future sales of the company.	User input
Ratios for * COGS * Selling expenses * R&D expenses * General administration expenses * Other operating income * Other operating expenses (Assumptions!F117 to K127)	The ratios are determined from the average of the years t_{-2} to t_0. The values are given in figure 10.11.	If a trend is present, it is also possible to use the figures of the last actual year instead of the averages. The choice of method used to calculate these values will have an effect on the company valuation.	=AVERAGE(C117:E117) =AVERAGE(C119:E119) =AVERAGE(C121:E121) =AVERAGE(C123:E123) =AVERAGE(C125:E125) =AVERAGE(C127:E127)
Change in the result from associates (Assumptions!F129 to K129)	t_1 = -100 %; t_2 to TV = 0 % The assumptions were not derived from past data, but instead started with the result from associates in year t_0 with an assumed development in the following years as specified above.	Detailed planning is difficult in this case. The result from associates is thus considered to be an item that must be analyzed separately from the corporate planning model. If fluctuations were small in the past, an arithmetic mean can be assumed as sufficient approximation for future periods.	User input
Interest rate (deposit) (Assumptions!F131 to K131)	The interest rate on cash & cash equivalents as well as excess liquidity was set at 3% for all planning years.	The interest rate should be in line with the market interest rate.	User input

Fig. 10.10 Assumptions and key figures for the income statement planning

- If the average of the historical data is used as the planning assumption, it must be calculated using the Excel function *Average*. For the following planning values this cell cannot be copied, since this would mean that the calculation is used and different values would be generated over the planning horizon. For that reason the cells

Average interest rate on interest bearing liabilities (Assumptions!F133 to K133)	The market interest rate was used for the interest rate on noncurrent and current financial liabilities as well as pension provisions. It is calculated from the risk-free rate of interest plus the risk premium (debt) and is equal to 3.8%.	The relevant interest rates for noncurrent and current financial liabilities, pension provisions as well as for the financing gap are not the interest rates from existing loan agreements, but rather the current market interest rates. This value must be identical to the cost of debt used in the company valuation.	=E228+E238 (=Risk-free rate of interest + Risk premium)
Tax rate (Assumptions!F135 to K135)	The tax rate of the group is equal to the tax rate in the year t_0.	In the case of internationally active companies it is hard to establish a weighted tax rate which reflects the taxable income in various countries. Therefore a realistic tax rate for the group is used for planning purposes.	=E135
Income attributable to non-controlling interest (in % of EAT) (Assumptions!F137 to K137)	The share of income attributable to non-controlling interest was calculated as the average for the years t_{-2} to t_0 and is equal to 0.7%.	The income attributable to non-controlling interest is modeled for future periods as ratio of income attributable to non-controlling interest to EAT for the last audited annual reports.	=AVERAGE(C137:E137)
Dividend payout ratio (Assumptions!F139 to K139)	The dividend payout ratio was set at 54.5 %.		User input
Number of ordinary shares in issue (m) (Assumptions!F141 to K141)	The number of shares entitled to the dividend was taken from t_0 and is equal to 826.9 for all years of the planning period.		=E141

Fig. 10.10 (Continued)

must be fixed with F4 when calculating the mean. After this, the planning value can be copied for use in the following planning periods.

Figure 10.11 shows the assumptions and key figures for the income statement planning.

Practical Tip

€ million	Actual t_{-2}	Actual t_{-1}	Actual t_0	Plan t_1	Plan t_2	Plan t_3	Plan t_4	Plan t_5	Plan TV
Total sales of segments: growth in %		8.8%	1.0%	6.0%	6.0%	6.0%	6.0%	2.0%	2.0%
COGS margin of sales	49.2%	48.0%	48.2%	48.5%	48.5%	48.5%	48.5%	48.5%	48.5%
Selling expenses margin of sales	24.5%	25.1%	25.1%	24.9%	24.9%	24.9%	24.9%	24.9%	24.9%
Research and development expenses margin of sales	8.0%	7.6%	7.9%	7.9%	7.9%	7.9%	7.9%	7.9%	7.9%
General administration expenses margin of sales	4.7%	4.7%	4.7%	4.7%	4.7%	4.7%	4.7%	4.7%	4.7%
Other operating income margin of sales	2.4%	2.7%	2.2%	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%
Other operating expenses margin of sales	4.5%	7.5%	4.0%	5.4%	5.4%	5.4%	5.4%	5.4%	5.4%
Result from associates accounted for using the equity method: growth in percent compared with t_0				-100.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Interest rate (deposit)				3.0%	3.0%	3.0%	3.0%	3.0%	3.0%
Average interest rate on interest bearing liabilities	6.8%	6.6%	6.7%	3.8%	3.8%	3.8%	3.8%	3.8%	3.8%
Tax rate	26.5%	22.8%	24.3%	24.3%	24.3%	24.3%	24.3%	24.3%	24.3%
Income attributable to non-controlling interest (in % of EAT)	0.1%	2.0%	-0.1%	0.7%	0.7%	0.7%	0.7%	0.7%	0.7%
Dividend payout ratio	55.2%	65.4%	54.5%	54.5%	54.5%	54.5%	54.5%	54.5%	54.5%
Number of ordinary shares in issue (m)	827	827	827	827	827	827	827	827	827

Income Statement

Fig. 10.11 Assumptions and key figures for the income statement planning (Excel File Corporate Finance, Worksheet Assumptions)

Overview of the linkages using buttons

Figure 10.11 shows a button as an example. With this button it is possible to move in Excel from the worksheet `Assumptions` directly to the worksheet `Income Statement`. This is a convenient way to get a quick overview of the linkages between the various assumptions and calculations. To make the work user-friendly, buttons were also inserted for all further assumptions and calculations.

Step 3: Calculating the planning values

The planning of the income statement follows these calculations in Excel (see Fig. 10.12):

With the help of the planning formulas and assumptions stated above, it is now possible to establish the pro forma income statement of the Pharma Group (see Fig. 10.13).

Balance Sheet Assets

For the planning of the balance sheet assets the approach which was already applied to the income statement is again used.

Step 1: Analyzing past values of the balance sheet assets using key figures

Step 2: Calculating and determining the planning assumptions

Step 3: Calculating the planning values

Position	Formulas	Excel implementation for t_1
Total sales (Income_Statement!F7)	=Total sales t_0 * (1 + Growth in total sales t_1)	=E7*(1+Assumptions!F115)
COGS (Income_Statement!F9)	=Total sales * Percentage COGS	=F7*Assumptions!F117
Gross profit on sales (Income Statement!F11)	=Total sales – COGS	=F7-F9
Selling expenses (Income_Statement!F13)	= Total sales * Percentage selling expenses	=F7*Assumptions!F119
R&D expenses (Income_Statement!F14)	= Total sales * Percentage R&D expenses	=F7*Assumptions!F121
General administration expenses (Income_Statement!F15)	= Total sales * Percentage general administration expenses	=F7*Assumptions!F123
Other operating income (Income_Statement!F16)	= Total sales * Percentage other operating income	=F7*Assumptions!F125
Other operating expenses (Income_Statement!F17)	= Total sales * Percentage other operating expenses	=F7*Assumptions!F127
EBIT (Income_Statement!F19)	= Gross profit on sales – COGS – R&D expenses – General administration expenses + Other operating income - Other operating expenses	=F11-F13-F14-F15+F16-F17
Result from associates accounted for using the equity method (Income_Statement!F21)	= Result from associates t_0 * (1 + growth of result from associates in percent compared with t_0)	=E21*(1+Assumptions!F129)
Financial income (Income_Statement!F22)	= (Cash & cash equivalents t_0 + Cash & cash equivalents t_1)/2 * Interest rate (deposit) + (Excess liquidity t_0 + Excess liquidity t_1)/2 * Interest rate (deposit)	=(Assets!E19+Assets!F19)/2*Assumptions!F131+(Assets!E21+Assets!F21)/2*Assumptions!F131

Fig. 10.12 Formulas for the calculation of the income statement planning values

Step 1: Analyzing past values of the balance sheet assets using key figures

Figure 10.14 explains with reference to the actual values in the year t_0 how the positions on the asset side of the balance sheet can be analyzed using the data in the worksheet `Assumptions`.

Financial expenses (Income_Statement !F23)	= (Pension provisions t_0 + Pension provisions t_1) / 2 * Interest rate on interest-bearing liabilities + (Non-current financial liabilities t_0 + Non-current financial liabilities t_1) / 2 * Interest rate on interest-bearing liabilities + (Current financial liabilities t_0 + Current financial liabilities t_1) / 2 * Interest rate on interest-bearing liabilities	=('Equity and Liabilities'!E15+'Equity and Liabilities'!E17+'Equity and Liabilities'!E25)/2*Assumptions !F133+('Equity and Liabilities'!F15+'Equity and Liabilities'!F17+'Equity and Liabilities'!F25)/2*Assumptions !F133
Earnings before taxes (EBT) (Income_Statement !F25)	=EBIT+ Result from associates + Financial income – Financial expenses	=F19+F21+F22-F23
Income taxes (Income_Statement !F27)	= EBT * Tax rate	=F25*Assumptions!F135
Earnings after taxes (Income_Statement !F29)	=EBT – Income taxes	=F25-F27
Income attributable to non-controlling interest (Income_Statement !F31)	=Earnings after taxes * Income attributable to non-controlling interest (in % of EAT)	=F29*Assumptions!F137
Net income (Income_Statement !F33)	=Earnings after taxes – Income attributable to non-controlling interest	=F29-F31
Dividend (during period) (Income_Statement !F35)	=Net income * Dividend payout ratio	=F33*F52

Fig. 10.12 (Continued)

Figure 10.15 shows the values of the key figures discussed above for the years t_{-2} to t_0.

Step 2: Calculating and determining the planning assumptions
In the next step, the key figures from the past are used to derive key figures for the future.

Income Statement

€ million	Actual t_2	Actual t_1	Actual t_0	Plan t_1	Plan t_2	Plan t_3	Plan t_4	Plan t_5	Plan TV
Total sales	36,528	39,741	40,157	42,566	45,120	47,828	50,697	51,711	52,745
- COGS	17,975	19,070	19,347	20,627	21,864	23,176	24,567	25,058	25,559
Gross profit on sales	18,553	20,671	20,810	21,940	23,256	24,651	26,131	26,653	27,186
- Selling expenses	8,958	9,981	10,080	10,605	11,241	11,915	12,630	12,883	13,141
- Research and development expenses	2,932	3,013	3,190	3,342	3,542	3,755	3,980	4,060	4,141
- General administration expenses	1,713	1,866	1,883	1,997	2,117	2,244	2,378	2,426	2,474
+ Other operating income	859	1,087	897	1,039	1,101	1,167	1,237	1,262	1,287
- Other operating expenses	1,660	2,970	1,620	2,278	2,414	2,559	2,713	2,767	2,822
Operating result (EBIT)	4,149	3,928	4,934	4,757	5,043	5,345	5,666	5,779	5,895
+ Result from associates accounted for using the equity method	-45	-18	-16	0	0	0	0	0	0
+ Financial income	586	503	389	68	108	153	203	261	323
- Financial expenses	1,327	1,237	1,100	632	652	676	706	730	744
Earnings before taxes (EBT)	3,363	3,176	4,207	4,194	4,499	4,822	5,163	5,311	5,474
- Income taxes	891	723	1,021	1,018	1,092	1,170	1,253	1,289	1,328
Earnings after taxes	2,472	2,453	3,186	3,176	3,407	3,652	3,910	4,022	4,145
- of which attributable to non-controlling interest	2	50	-3	21	23	25	26	27	28
Net income	2,470	2,403	3,189	3,155	3,384	3,627	3,884	3,995	4,118
Dividend	1,364	1,571	1,737	1,718	1,843	1,975	2,115	2,175	2,242

Fig. 10.13 Pro forma income statement of Pharma Group (Excel File Corporate Finance, Worksheet Income Statement)

Figure 10.16 shows the assumptions and key figures used for planning. Figure 10.17 shows the assumptions and key figures for the planning of balance sheet assets.

Step 3: Calculating the planning values

The planning of balance sheet assets is implemented in Excel with the help of the following calculations (see Fig. 10.18):

With the help of the planning formulas above and the assumptions it is now possible to put together the planned balance sheet assets of the Pharma Group (see Fig. 10.19).

Assumptions concerning non-operating assets

Non-operating assets are not part of the core business of the company and generate no revenues or only below average revenues. They are thus not needed to assure the sustainable success of the company. For that reason they are not included in the determination of sustainable earnings. An adequate use must be found for non-operating assets – their sale is an obvious possibility. The balance sheet items which are

Position	Calculations for t_0	Explanation
Goodwill (=Assumptions! E150)	=Value from balance sheet assets: =E57	No explicit calculations. Figure is taken from the balance sheet.
Other intangible assets (=Assumptions! E151)	=Value from balance sheet assets: =E58	No explicit calculations. Figure is taken from the balance sheet.
Property, plant and equipment (=Assumptions! E152)	=Value from balance sheet assets: =E59	No explicit calculations. Figure is taken from the balance sheet.
Investments account-ed for using the equi-ty method (=Assumptions! E153)	=Value from balance sheet assets: =E60	No explicit calculations. Figure is taken from the balance sheet.
Other noncurrent assets (=Assumptions! E154)	=Value from balance sheet assets: =E61	No explicit calculations. Figure is taken from the balance sheet.
Deferred taxes (=Assumptions! E155)	=Value from balance sheet assets: =E62	No explicit calculations. Figure is taken from the balance sheet.
Number of days per year (=Assumptions! E157)	User input: =365	
Period of storage: inventories (in days) (=Assumptions! E158)	=Inventory / COGS * Number of days per year: =E66/E16*E157	The inventory turnover days shows how many days on average the inventory remains within the company until used up. It is a very important measure, since an optimized inventory level can reduce the capital that is tied up.
Days sales outstand-ing (=Assumptions! E159)	=Trade accounts receivable / Total sales * Number of days per year: =E67/E14*E157	The analysis of the days sales outstanding provides information about the structure of receivables of a company. The days sales outstanding has a direct impact on the li-quidity situation, since the time period be-tween production and payment by the buyer needs to be financed.
Other (current) assets (in % of sales) (=Assumptions! E160)	= Other (current) assets / Total sales: =E68/E14	Other (current) assets are related to sales.

Fig. 10.14 Explaining the analysis of key figures for the balance sheet assets

linked to non-operating assets need to be corrected (such as interest income from securities not needed for operations and all debt related to non-operating assets). Assets not required for operations of Pharma Group in t_0 are equal to 0.

Assumptions: Assets

€ million	Actual t_2	Actual t_1	Actual t_0
Goodwill	9.148	9.293	9.862
Other intangible assets	10.284	9.464	8.914
Property, plant and equipment	9.887	9.898	10.015
Investments accounted for using the equity method	265	225	203
Other noncurrent assets	1.773	1.849	1.699
Deferred taxes	1.312	1.579	1.596
Number of days per year	365	365	365
Period of storage: inventories	129	134	134
Days sales outstanding	71	68	69
Other assets to total sales in %	13,3%	7,3%	6,6%

Fig. 10.15 Analysis of key figures for the past values of balance sheet assets (Excel File Corporate Finance, Worksheet Assumptions)

> The term "non-operating assets" captures all assets that are not needed in daily operations. This can include: land and buildings, securities, participations, cash & cash equivalents, loans and claims on affiliated companies.

Balance Sheet Liabilities

Planning of the balance sheet liabilities follows the same procedure already familiar from determining the asset side of the balance sheet.

Step 1: Analyzing past values of the balance sheet liabilities using key figures

Step 2: Calculating and determining the planning assumptions

Step 3: Calculating the planning values

Step 1: Analyzing past values of the balance sheet liabilities using key figures

Figure 10.20 explains with reference to the actual values in the year t_0 how the positions on the liability side of the balance sheet can be analyzed using the data in the worksheet `Assumptions`.

Figure 10.21 shows the values of the above discussed key figures for the years t_{-2} to t_0.

Position	Assumptions	Explanations	Formulas for t_1
Goodwill (=Assumptions! F150 to K150)	No corporate acquisitions are planned. Value from t_0 is used for all planning years.	If investments in corporate acquisitions are planned, the goodwill needs to be included in the planning.	Value from the previous year: =E150
Other intangible assets (=Assumptions! F151 to K151)	No investments are planned in intangible assets. Value from t_0 is used for all planning years.	If investments are planned in other intangible assets, they need to be included in the planning. The same is true for amortization of intangible assets.	Value from the previous year: =E151
Property, plant and equipment (=Assumptions! F152 to K152)	No investments are planned in property, plant and equipment. Value from t_0 is used for all planning years.	If investments are planned in property, plant and equipment, they need to be included in planning. The same is true for depreciation of property, plant and equipment.	Value from the previous year: =E152
Investments accounted for using the equity method (=Assumptions! F153 to K153)	Position is assumed to be constant in planning. Value from t_0 is used for all planning years.	Investments accounted for using the equity method cannot be planned by external valuation experts, since its change in market value is not subject to constant or periodically recurring components.	Value from the previous year: =E153
Other noncurrent assets (=Assumptions! F154 to K154)	Position is assumed to be constant in planning. Value from t_0 is used for all planning years.	The position of other noncurrent assets cannot be planned by external valuation experts, since its change in market value is not subject to constant or periodically recurring components.	Value from the previous year: =E154
Deferred taxes (=Assumptions! F155 to K155)	Value from t_0 is used for all planning years.	Due to the lack of a solid informational base, no changes in deferred taxes are considered in the context of this treatment.	Value from the previous year: =E155
Number of days per year (=Assumptions! F157 to K157)	=365		=E157
Inventory turnover days (in days) (=Assumptions! F158 to K158)	The inventory turnover days was calculated as an average for the years t_{-2} to t_0. It is equal to 133 days.	If measures are planned to optimize inventory management during the planning period, this needs to be taken into consideration when setting the inventory turnover days.	Average for the years t_{-2} to t_0: =AVERAGE(C158:E158)
Days sales outstanding (in days) (=Assumptions! F159 to K159)	The days sales outstanding was calculated as an average for the years t_{-2} to t_0. It is equal to 69 days.	If measures are planned to optimize credit control during the planning period, this needs to be taken into consideration when setting the days sales outstanding.	Average for the years t_{-2} to t_0: =AVERAGE (C159:E159)
Other (current) assets (in % of sales) (=Assumptions! F160 to K160)	Due to the trend in past data, the ratio from t_0 was used here. It is equal to 6.6%.	If no trend is apparent, instead of the last actual value it is also possible to use the average value of the past observations.	Value from the previous year: =E160

Fig. 10.16 Assumptions and key figures for the planning of balance sheet assets

	A	B	C	D	E	F	G	H	I	J	K
144											
145		**Assumptions: Assets**									
146											
147			Actual	Actual	Actual	Plan	Plan	Plan	Plan	Plan	Plan
148		€ million	t_2	t_1	t_0	t_1	t_2	t_3	t_4	t_5	TV
149											
150		Goodwill	9,148	9,293	9,862	9,862	9,862	9,862	9,862	9,862	9,862
151		Other intangible assets	10,284	9,464	8,914	8,914	8,914	8,914	8,914	8,914	8,914
152		Property, plant and equipment	9,887	9,898	10,015	10,015	10,015	10,015	10,015	10,015	10,015
153		Investments accounted for using the equity method	265	225	203	203	203	203	203	203	203
154		Other noncurrent assets	1,773	1,849	1,699	1,699	1,699	1,699	1,699	1,699	1,699
155		Deferred taxes	1,312	1,579	1,596	1,596	1,596	1,596	1,596	1,596	1,596
156											
157		Number of days per year	365	365	365	365	365	365	365	365	365
158		Period of storage: inventories	129	134	134	133	133	133	133	133	133
159		Days sales outstanding	71	68	69	69	69	69	69	69	69
160		Other assets to total sales in %	13.3%	7.3%	6.6%	6.6%	6.6%	6.6%	6.6%	6.6%	6.6%

Fig. 10.17 Assumptions and key figures for the planning of balance sheet assets (Excel File Corporate Finance, Worksheet Assumptions)

Position	Formulas	Excel implementation for t_1
Goodwill (=Assets!F7)	=Goodwill from the worksheet Assumptions	=Assumptions!F150
Other intangible assets (=Assets!F8)	=Other intangible assets from the worksheet Assumptions	=Assumptions!F151
Property, plant and equipment (=Assets!F9)	=Property, plant and equipment from the worksheet Assumptions	=Assumptions!F152
Investments accounted for using the equity method (=Assets!F10)	=Investments accounted for using the equity method from the worksheet Assumptions	=Assumptions!F153
Other noncurrent assets (=Assets!F11)	=Other noncurrent assets from the worksheet Assumptions	=Assumptions!F154
Deferred taxes (=Assets!F12)	=Deferred taxes from the worksheet Assumptions	=Assumptions!F155
Noncurrent assets (=Assets!F14)	=Goodwill + Other intangible assets + Property, plant and equipment + Investments accounted for using the equity method + Other noncurrent assets + Deferred taxes	=SUM(F7:F12)
Inventories (=Assets!F16)	=COGS * Period of storage (inventories) / Number of days per year	='Income Statement'!F9*Assumptions!F158/Assumptions!F157
Trade accounts receivable (=Assets!F17)	=Total sales * Days sales outstanding / Number of days per year	='Income Statement'!F7*Assumptions!F159/Assumptions!F157
Other (current) assets (=Assets!F18)	=Total sales * Ratio of other (current) assets	='Income Statement'!F7*Assumptions!F160
Cash & cash equivalents (=Assets!F19)	=Average value for the years t_2 to t_0	=AVERAGE(C19:E19)
Excess liquidity (=Assets!F21)	=Excess liquidity from the worksheet Balance Sheet Liabilities (for comprehensive information see section "Equating the two sides of the balance sheet: the overflow valve")	='Equity and Liabilities'!F44
Current assets (=Assets!F23)	=Inventories + Trade accounts receivable + Other (noncurrent assets) + Cash & cash equivalents + Excess liquidity	=SUM(F16:F21)
Total assets (=Assets!F25)	= Noncurrent assets + Current assets	=F14+F23

Fig. 10.18 Formulas for the calculation of planned balance sheet assets

Assets

€ million	Actual t_2	Actual t_1	Actual t_0	Plan t_1	Plan t_2	Plan t_3	Plan t_4	Plan t_5	Plan TV
Goodwill	9,148	9,293	9,862	9,862	9,862	9,862	9,862	9,862	9,862
Other intangible assets	10,284	9,464	8,914	8,914	8,914	8,914	8,914	8,914	8,914
Property, plant and equipment	9,887	9,898	10,015	10,015	10,015	10,015	10,015	10,015	10,015
Investments accounted for using the equity method	265	225	203	203	203	203	203	203	203
Other noncurrent assets	1,773	1,849	1,699	1,699	1,699	1,699	1,699	1,699	1,699
Deferred taxes	1,312	1,579	1,596	1,596	1,596	1,596	1,596	1,596	1,596
Noncurrent assets	32,669	32,308	32,289	32,289	32,289	32,289	32,289	32,289	32,289
Inventories	6,370	6,991	7,129	7,491	7,940	8,416	8,921	9,100	9,282
Trade accounts receivable	7,060	7,433	7,569	8,071	8,555	9,068	9,612	9,804	10,000
Other assets	4,876	2,888	2,668	2,828	2,998	3,178	3,368	3,436	3,504
Cash and cash equivalents	1,771	1,698	1,662	1,710	1,710	1,710	1,710	1,710	1,710
Excess Liquidity				1,194	2,584	4,174	5,972	8,013	10,115
Current assets	20,077	19,010	19,028	21,294	23,787	26,546	29,584	32,064	34,612
Total assets	52,746	51,318	51,317	53,583	56,076	58,835	61,873	64,353	66,901

Fig. 10.19 Planned balance sheet assets of Pharma Group (Excel File Corporate Finance, Worksheet Assets)

Position	Calculations for t_0	Explanation
Subscribed capital (=Assumptions!E169)	=Value from "Equity and Liabilities": =E82	Changes in the subscribed capital indicate a significant change in the capital structure. A capital increase is frequently needed for the acquisition of another company.
Capital reserves (=Assumptions!E170)	=Value from "Equity and Liabilities": =E83	Capital reserves provide self-financing and strengthen the equity base of the company. Their concrete uses include for example covering losses and financing investments.
Equity attributable to non-controlling interest (=Assumptions!E171)	=Value from "Equity and Liabilities": =E86	This required balance sheet item provides information about the shares not held by the parent company.
Other noncurrent liabilities (=Assumptions!E175)	=Value from "Equity and Liabilities": =E93	No explicit calculations. Figure is taken from the balance sheet.
Deferred taxes (=Assumptions!E176)	=Value from "Equity and Liabilities": =E94	No explicit calculations. Figure is taken from the balance sheet.
Number of days per year (=Assumptions!E179)	=365	
Days payables outstanding (in days) (=Assumptions!E180)	=Trade accounts payable / COGS * Number of days per year: =E100/E16*E179	An analysis of the days payables outstanding provides information about the payment practices of a company. Just as days sales outstanding, days payables outstanding directly affects the liquidity situation, since trade accounts payable are a form of interest-free financing for the company.
Income tax liabilities (=Assumptions!E181)	=Value from "Equity and Liabilities": =E101	No explicit calculations. Figure is taken from the balance sheet.
Other current liabilities (as % of sales) (=Assumptions!E182)	=Other liabilities/Total sales: =E102/E14	Other current liabilities are considered relative to total sales.

Fig. 10.20 Explaining the analysis of key figures for balance sheet liabilities

	B	C	D	E
163				
164	**Assumptions: Equity and Liabilities**			
165				
166		Actual	Actual	Actual
167	€ million	t_2	t_1	t_0
168				
169	Subscribed capital of Pharma Group	2,117	2,117	2,117
170	Capital reserves of Pharma Group	6,167	6,167	6,167
171	Equity attributable to non-controlling interest	59	100	86
172	Provisions for pensions and other post-employment benefits: build-up rate in %			
173	Other noncurrent provisions: growth in %			
174	Noncurrent financial liabilities: build-up rate in %			
175	Other noncurrent liabilities	474	409	362
176	Noncurrent deferred taxes	2,116	935	1,193
177	Other current provisions: growth in %			
178	Current financial liabilities: build-up rate in %			
179	Number of days per year	365	365	365
180	Days payables outstanding	76.9	82.4	84.4
181	Income tax liabilities	76	72	101
182	Other current reserves to total sales in %	4.5%	3.3%	3.2%

Fig. 10.21 Analysis of key figures for the past values of balance sheet liabilities (Excel File Corporate Finance, Worksheet Assumptions)

Step 2: Calculating and determining the planning assumptions

In the next step, the key figures from the past are used to derive key figures for the future.

Figure 10.22 shows the assumptions and key figures used for planning.

Figure 10.23 shows the assumptions and key figures for the planning of balance sheet liabilities.

Step 3: Calculating the planning values

The planning of balance sheet liabilities is established in Excel with the help of the following calculations (see Fig. 10.24):

With the help of the planning formulas above and the assumptions, it is now possible to compile the planned balance sheet liabilities of the Pharma Group (see Fig. 10.25).

> The way the result from the income statement is transferred to the equity capital is decisive when planning the liability side.

It is done via the item "net income." The other reserves for the year under consideration are calculated as other reserves from the previous

Position	Assumptions	Explanations	Formulas for t_1
Subscribed capital (=Assumptions!F169 to K169)	No changes planned for the subscribed capital.	If changes are planned for the subscribed capital, they need to be incorporated into the projections.	=E169
Capital reserves (=Assumptions!F170 to K170)	No changes planned for capital reserves.	The planning of capital reserves can also be based on the average of past data.	=E170
Equity attributable to non-controlling interest (=Assumptions!F171 to K171)	The equity attributable to non-controlling interest is assumed to be constant and the value from t_0 is used.	If a future change in the equity attributable to non-controlling interest is known, it must be taken into consideration for planning.	=E171
Provisions for pensions and other post-employment benefits, build-up rate in % (=Assumptions!F172 to K172)	Provisions for pensions and other post-employment benefits increase in the years t_1 to t_4 by 10% annually. In t_5 as well as in the terminal value, the increase is set at 2%.		User input: 10% or 2%
Other noncurrent provisions, increase in % (=Assumptions!F173 to K173)	The other noncurrent provisions in the years t_1 to t_4 are constant, based on the value in t_0. In t_5 as well as in the terminal value they go up by 2%.	The growth of noncurrent provisions depends on the relevance of these provisions for the company.	User input: 0% or 2%
Noncurrent financial liabilities, build-up rate in % (=Assumptions!F174 to K174)	The growth rate of the noncurrent financial liabilities from t_1 to t_4 is - 8.7%. For both the year t_5 and the terminal value, the financial liabilities are increased by 2%.		User input: -8.7% or 2%
Other noncurrent liabilities (=Assumptions!F175 to K175)	Value from t_0 is used for all planning years.	Due to the lack of a solid informational base we will not consider changes in other noncurrent liabilities in the context of this treatment.	=E175

Fig. 10.22 Assumptions and key figures for the planning of balance sheet liabilities

year plus net income minus dividends for the current year. The net income is the net income from the income statement of the current year. In the end the equity capital will go up in an amount equal to the net income which is (retained earnings). This is equal to the net income in the year under review minus the dividends for the year under review.

Deferred taxes (=Assumptions!F 176 to K176)	Value from t_0 is used for all planning years.	Due to the lack of a solid informational base we will not consider changes in deferred taxes in the context of this treatment.	=E176
Other current provisions, growth in % (=Assumptions!F 177 to K177)	Other current provisions for t_1 to t_4 are constant, based on the value in t_0. In t_5 as well as in the terminal value, they increase by 2%.	The growth of current provisions depends on the relevance of various provisions for the company. If, for example, warranty provisions are important, the growth of provisions can be in line with the overall output.	User input: 0 % or 2%
Current financial liabilities, increase in % (=Assumptions!F 178 to K178)	The reduction of current financial liabilities from t_1 to t_4 is equal to 6%. For the year t_5 and for the terminal value meanwhile, financial liabilities are increased by 2%.		User input: -6% or 2%
Number of days per year (=Assumptions!F 179 to K179)	=365		User input: 365
Days payables outstanding (in days) (=Assumptions!F 180 to K180)	Due to the apparent growth trend, the value for t_0 was used (84.4 days).	If measures are planned to optimize payables management during the planning period, this needs to be taken into consideration when setting the days payables outstanding.	=E180
Tax liabilities (=Assumptions!F 181 to K181)	Value from t_0 is used for all planning years.	Due to the lack of a solid informational base we will not consider changes in tax liabilities in the context of this treatment.	Value from the previous year: =E181
Other short term liabilities (as % of sales) (=Assumptions!F 182 to K182)	For other short term liabilities as % of sales the value from t_0 was used. It is equal to 3.2 %.	Instead of the value from t_0 it is also possible to use an average.	=E182

Fig. 10.22 (Continued)

	A	B	C	D	E	F	G	H	I	J	K
165											
166			Actual	Actual	Actual	Plan	Plan	Plan	Plan	Plan	Plan
167		€ million	t_2	t_1	t_0	t_1	t_2	t_3	t_4	t_5	TV
168											
169		Subscribed capital of Pharma Group	2,117	2,117	2,117	2,117	2,117	2,117	2,117	2,117	2,117
170		Capital reserves of Pharma Group	6,167	6,167	6,167	6,167	6,167	6,167	6,167	6,167	6,167
171		Equity attributable to non-controlling interest	59	100	86	86	86	86	86	86	86
172		Provisions for pensions and other post-employment benefits: build-up rate in %				10.0%	10.0%	10.0%	10.0%	2.0%	2.0%
173		Other noncurrent provisions: growth in %				0.0%	0.0%	0.0%	0.0%	2.0%	2.0%
174		Noncurrent financial liabilities: build-up rate in %				-8.7%	-8.7%	-8.7%	-8.7%	2.0%	2.0%
175		Other noncurrent liabilities	474	409	362	362	362	362	362	362	362
176		Noncurrent deferred taxes	2,116	935	1,193	1,193	1,193	1,193	1,193	1,193	1,193
177		Other current provisions: growth in %				0.0%	0.0%	0.0%	0.0%	2.0%	2.0%
178		Current financial liabilities: build-up rate in %				6.0%	6.0%	6.0%	6.0%	2.0%	2.0%
179		Number of days per year	365	365	365	365	365	365	365	365	365
180		Days payables outstanding	76.9	82.4	84.4	84.4	84.4	84.4	84.4	84.4	84.4
181		Income tax liabilities	76	72	101	101	101	101	101	101	101
182		Other current liabilities to total sales in %	4.5%	3.3%	3.2%	3.2%	3.2%	3.2%	3.2%	3.2%	3.2%

Fig. 10.23 Assumptions and key figures for the planning of balance sheet liabilities (Excel File Corporate Finance, Worksheet Assumptions)

Position	Formulas for t_1	Excel implementation for t_1
Subscribed capital (=Equity_and_Liabilities!F7)	Subscribed capital from the sheet Assumptions	=Assumptions!F169
Capital reserves (=Equity_and_Liabilities!F8)	Capital reserves from the sheet Assumptions	=Assumptions!F170
Other reserves (=Equity_and_Liabilities!F9)	= Other reserves t_0 + Net income t_0 – Dividend	=E9+E10-Income-Statement!F35
Net income (=Equity_and_Liabilities!F10)	Net income from the sheet "Income Statement"	='Income Statement'!F33
Equity attributable to non-controlling interest (=Equity_and_Liabilities!F11)	Equity attributable to non-controlling interest from the sheet Assumptions	=Assumptions!F171
Equity (=Equity_and_Liabilities!F13)	=Subscribed capital + Capital reserves + Other reserves + Net income + Equity attributable to non-controlling interest	=SUM(F7:F11)
Provisions for pensions and other post-employment benefits (=Equity_and_Liabilities!F15)	=Provisions for pensions and other post-employment benefits t_0 * (1 + Provisions for pensions and other post-employment benefits (build-up rate in %))	=E15*(1+Assumptions!F172)
Other noncurrent provisions (=Equity_and_Liabilities!F16)	= Other provisions t_0 * (1 + Other provisions, increase in %)	=E16*(1+Assumptions!F173)
Noncurrent financial liabilities (=Equity_and_Liabilities!F17)	Financial liabilities t_0 * (1 + Build-up rate noncurrent financial liabilities)	=E17*(1+Assumptions!F174)

Fig. 10.24 Formulas for the calculation of planned balance sheet liabilities

Balancing the Two Sides: The Overflow Valve

When modeling a company valuation, the financial modeler will occasionally encounter a situation where the sum of balance sheet assets is not equal to the sum of balance sheet liabilities. Even the careful

Other noncurrent liabilities (=Equity_and_Liabilities!F18)	Other noncurrent liabilities from the sheet Assumptions	=Assumptions!F175
Deferred taxes (=Equity_and_Liabilities!F19)	Deferred taxes from the sheet Assumptions	=Assumptions!F176
Noncurrent liabilities (=Equity_and_Liabilities!F21)	=Provisions for pensions and other post-employment benefits + Other noncurrent provisions + Financial liabilities + Other liabilities + Deferred taxes	=SUM(F15:F19)
Financing gap (=Equity_and_Liabilities!F23)	Cell reference to the auxiliary calculation Overflow Valve (additional information in the following Section).	=F46
Other current provisions (=Equity_and_Liabilities!F24)	Other current provisions t_0 * (1 + Growth rate other provisions)	=E24*(1+Assumptions!F177)
Current financial liabilities (=Equity_and_Liabilities!F25)	=Current financial liabilities t_0 * (1+ Build-up rate in current financial liabilities)	=E25*(1+Assumptions!F178)
Trade accounts payable (=Equity_and_Liabilities!F26)	= COGS * Days payables outstanding / Number of days per year	='Income Statement'!F9*Assumptions!F180/Assumptions!F179
Tax liabilities (=Equity_and_Liabilities!F27)	Tax liabilities from the sheet Assumptions	=Assumptions!F181
Other liabilities (=Equity_and_Liabilities!F28)	= Total sales * Other liabilities as % of sales	='Income Statement'!F7*Assumptions!F182
Current liabilities (=Equity_and_Liabilities!F30)	= Financing gap + Other provisions + Current financial liabilities + Trade accounts payable + Tax liabilities + Other liabilities	=SUM(F23:F28)
Total equity and liabilities (=Equity_and_Liabilities!F32)	= Equity + Current liabilities + Noncurrent liabilities	=F13+F21+F30

Fig. 10.24 (Continued)

construction of the financial model does not generally rule out the possibility of such a deviation.

It is relatively easy to find the cause of the deviation for the historical values, since assets and liabilities have to be identical by definition. If there are differences,

Equity and Liabilities

€ million	Actual t_{-2}	Actual t_{-1}	Actual t_0	Plan t_1	Plan t_2	Plan t_3	Plan t_4	Plan t_5	Plan TV
Subscribed capital of Pharma Group	2,117	2,117	2,117	2,117	2,117	2,117	2,117	2,117	2,117
Capital reserves of Pharma Group	6,167	6,167	6,167	6,167	6,167	6,167	6,167	6,167	6,167
Other reserves	8,442	7,764	9,245	10,716	12,028	13,437	14,949	16,658	18,410
Net income	2,470	2,403	3,189	3,155	3,384	3,627	3,884	3,995	4,118
Equity attributable to non-controlling interest	59	100	86	86	86	86	86	86	86
Equity	**19,255**	**18,551**	**20,804**	**22,241**	**23,782**	**25,434**	**27,203**	**29,022**	**30,898**
Provisions for pensions and other post-employment benefits	7,787	9,246	7,368	8,105	8,915	9,807	10,787	11,003	11,223
Other provisions	1,726	2,111	1,977	1,977	1,977	1,977	1,977	2,017	2,057
Financial liabilities	7,995	6,962	5,590	5,103	4,658	4,252	3,881	3,959	4,038
Other liabilities	474	409	362	362	362	362	362	362	362
Deferred taxes	2,116	935	1,193	1,193	1,193	1,193	1,193	1,193	1,193
Noncurrent liabilities	**20,098**	**19,663**	**16,490**	**16,740**	**17,105**	**17,591**	**18,201**	**18,534**	**18,873**
Financing gap				0	0	0	0	0	0
Other provisions	4,217	4,844	4,727	4,727	4,727	4,727	4,727	4,822	4,918
Financial liabilities	3,683	2,568	3,441	3,647	3,866	4,098	4,344	4,431	4,520
Trade accounts payable	3,785	4,305	4,473	4,769	5,055	5,358	5,680	5,793	5,909
Income tax liabilities	76	72	101	101	101	101	101	101	101
Other liabilities	1,632	1,315	1,281	1,358	1,439	1,526	1,617	1,650	1,683
Current liabilities	**13,393**	**13,104**	**14,023**	**14,602**	**15,189**	**15,810**	**16,469**	**16,797**	**17,130**
	-	-	-						
Total equity and liabilities	**52,746**	**51,318**	**51,317**	**53,583**	**56,076**	**58,835**	**61,873**	**64,353**	**66,901**

Fig. 10.25 Planned balance sheet liabilities of Pharma Group (Excel File Corporate Finance, Worksheet Equity and Liabilities)

- this is the responsibility of the person who created the balance sheet,
- this indicates that mistakes have been made when entering the data and/or
- the financial model does not function properly.

The case is different for balance sheet items planned by the financial modeler. Differences between the two sides of the planned balance sheet arise systematically, since assets and liabilities are planned step by step in sub-groups that are not linked directly. The development of property, plant and equipment is based on separate investment calculations, while current assets are determined by assumptions concerning inventory turnover days and days sales outstanding, which in turn depend on assumptions from the income statement. Planning of the equity is determined primarily by the net income. The financial plan of a company and especially the forecasts about interest expenses and income in the income statement form the basis for the planning of financial liabilities.

These examples clarify that the various positions of the balance sheet are largely planned independently, but at the same time are closely interrelated and linked to the income statement.

The financial model for the balance sheet planning is equipped with an equilibrating mechanism in the form of a so-called overflow valve. It is a variable which assures that the sum of planned assets is equal to the sum of planned liabilities. At the same time, possible implications for the income statement are determined.

The overflow valve takes on a positive value for only one of the two sides of the balance sheet. To improve the exposition, both variables are added to the planned annual reports in addition to the legally required standard items.

- The case of **excess liquidity** arises if the overflow valve is needed to adjust the assets (assets < liabilities).
- The case of a **financing gap** is present on the liability side (assets > liabilities).

The overflow valve triggers a circularity problem, which is solved with the help of a mathematical iterative function of Excel (detailed explanations are found in the Practical Tip on solving the circularity problem with Excel)

Figure 10.26 provides an overview of the solution as well as the implications of excess liquidity and financing gap for the balance sheet and the income statement.

In addition to its original purpose of balancing assets and liabilities, the overflow valve can also be used to optimize planning. The implementation is shown in Fig. 10.27.

A significant difference between the planned balance sheet items liquidity and excess liquidity may suggest that the financial planner should consider the following possibilities:

- Reduce the amount of overall liquidity in order to reduce the need for debt financing and interest expenses or to distribute funds to the owners.
- The financing potential can be used to plan additional investments, for example in new equipment or for a market expansion.

A financing gap does not necessarily imply an increase of debt. It is also possible to carry out a capital increase

Figure 10.28 shows the auxiliary calculations for the overflow valve.

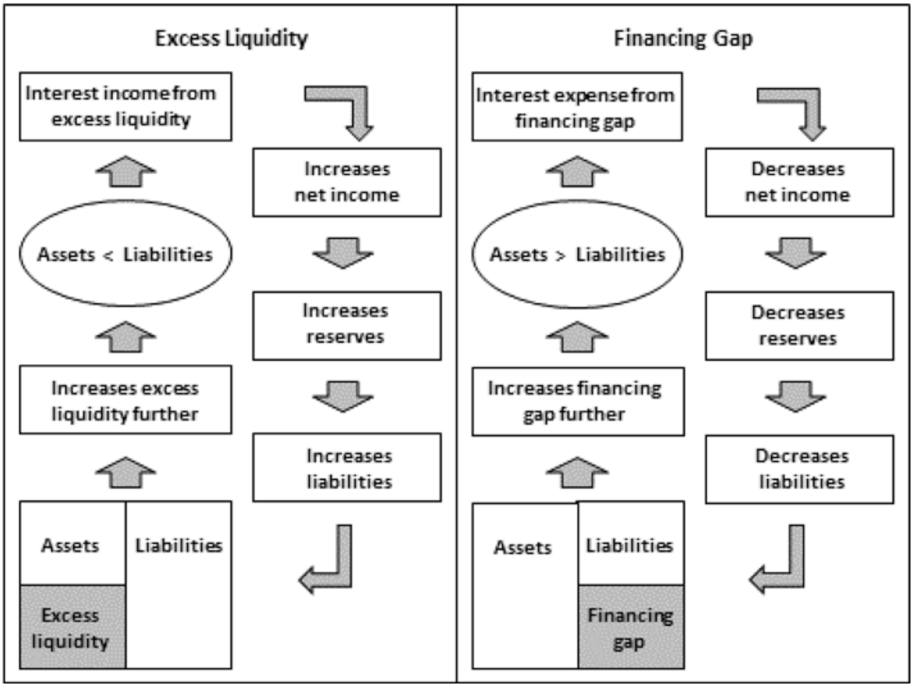


Fig. 10.26 Effect of the overflow valve on balance sheet and income statement

Auxiliary Calculations

> In order to simplify the coming cash flow calculations, we recommend that those values which are constructed from several items on the income statement and the balance sheet are calculated separately in auxiliary calculations.

These values can be used directly at a later stage.

The following positions are determined in the auxiliary calculations:

- Investment in total assets (excluding deferred taxes) = CAPEX
- Depreciation and amortization
- Net Working Capital
- Interest-bearing liabilities
- Other provisions
- Deferred taxes and tax liabilities

Position	Explanations	Excel implementation for t_1
Total assets without excess liquidity (=Equity_and_Liabilities!F40)	= Noncurrent assets + Current assets – Excess liquidity	=Assets!F14+Assets!F23-Assets!F21
Equity and liabilities without financing gap (=Equity_and_Liabilities!F41)	= Equity + Noncurrent liabilities + Current liabilities – Financing gap	=F13+F21+F30-F23
Difference (=Equity_and_Liabilities!F42)	The function *ISERROR* is used on the difference between the two positions above. It prevents an infinite loop of the financial model which could arise due to the circularity problem in case of a mistake.	=IF(ISERROR(F41-F40);0;F41-F40)
Excess liquidity (=Equity and Liabilities!F44)	If the difference is positive, in other words liabilities>assets, the value of the difference represents the excess liquidity. If the difference is negative, this value is 0.	=MAX(F42;0)
Financing gap (=Equity and Liabilities!F46)	If the difference is negative, in other words liabilities<assets, the value of the difference represents the financing gap. If the difference is positive, this value is 0.	=-MIN(F42;0)
Difference between total assets and equity and liabilities (=Equity and Liabilities!F48)	Control.	=Assets!F25-F32
Total assets = equity and liabilities? (=Equity and Liabilities!F49)	In case there is a mistake in the auxiliary calculation for the overflow valve, the user is informed that there is a difference between assets and liabilities. Otherwise the output is "OK."	=IF(ROUND(F48;2)=0;"OK";"DEVIATION")

Fig. 10.27 The architecture of the overflow valve (see Tjia, 2009, pp. 74-81)

Investment in total assets (excluding deferred taxes) = CAPEX
The necessity to incorporate the cash outflows from investments in goodwill, other intangible assets, property, plant and equipment and other financial assets follows from the future investment policy of the company. If growth is assumed in the valuation, a consistent implementation also requires the consideration of the needed investments for replacement and expansion.

Auxiliary Calculation: Overflow Valve

€ million	Plan t_1	Plan t_2	Plan t_3	Plan t_4	Plan t_5	Plan TV
Total assets without excess liquidity	52,389	53,492	54,662	55,901	56,339	56,786
Equity and liabilities without financing gap	53,583	56,076	58,835	61,873	64,353	66,901
Difference	1,194	2,584	4,174	5,972	8,013	10,115
Excess liquidity	**1,194**	**2,584**	**4,174**	**5,972**	**8,013**	**10,115**
Financing gap	0	0	0	0	0	0
Difference between total assets and equity and liabilities	0	0	0	0	0	0
Total assets = equity and liabilities?	OK	OK	OK	OK	OK	OK

Fig. 10.28 Auxiliary calculations for the Overflow Valve (Excel File Corporate Finance, Worksheet Equity and Liabilities)

Auxiliary Calculation: Investment in Total Assets (without Deferrred Taxes)

€ million	Actual t_{-2}	Actual t_{-1}	Actual t_0	Plan t_1	Plan t_2	Plan t_3	Plan t_4	Plan t_5	Plan TV
Goodwill			9,862	9,862	9,862	9,862	9,862	9,862	9,862
+ Other intangible assets			8,914	8,914	8,914	8,914	8,914	8,914	8,914
+ Property, plant and equipment			10,015	10,015	10,015	10,015	10,015	10,015	10,015
+ Investments accounted for using the equity method			203	203	203	203	203	203	203
+ Other noncurrent assets			1,699	1,699	1,699	1,699	1,699	1,699	1,699
+ Goodwill amortization			0	0	0	0	0	0	0
+ Amortization of other intangible assets			0	0	0	0	0	0	0
+ Deprecation on property, plant and equipment			2,896	2,896	2,896	2,896	2,896	2,896	2,896
+ Amortization of Investments accounted for using the equity method			0	0	0	0	0	0	0
+ Amortization of other noncurrent assets			0	0	0	0	0	0	0
Capital expenditures				**2,896**	**2,896**	**2,896**	**2,896**	**2,896**	**2,896**
Check				OK	OK	OK	OK	OK	OK

Fig. 10.29 Calculating capital expenditures (Excel File Corporate Finance, Worksheet Auxiliary Calculations)

Investments in total assets which serve the purpose to generate operating income over the long term are also called CAPEX (Capital Expenditures).

When calculating CAPEX, the changes compared to the previous period in goodwill, other intangible assets, property, plant and equipment and other financial assets are added. This number is added to the depreciation and amortization for the period under consideration. Since total assets were assumed to be constant during the planning period, CAPEX is equal to depreciation and amortization. Thus all investments serve to maintain the operating base of the company.

The calculation is presented in Fig. 10.29. The individual items are taken from the balance sheet assets and the assumptions.

Auxiliary Calculation: Depreciation and Amortization

€ million	Actual t_2	Actual t_1	Actual t_0	Plan t_1	Plan t_2	Plan t_3	Plan t_4	Plan t_5	Plan TV
+ Amortization of goodwill				0	0	0	0	0	0
+ Amortization of other intangible assets				0	0	0	0	0	0
+ Deprecation on property, plant and equipment				2,896	2,896	2,896	2,896	2,896	2,896
+ Amortization of other financial assets				0	0	0	0	0	0
Depreciation and amortization				**2,896**	**2,896**	**2,896**	**2,896**	**2,896**	**2,896**
Check				OK	OK	OK	OK	OK	OK

Fig. 10.30 Calculating depreciation and amortization (Excel File Corporate Finance, Worksheet Auxiliary Calculations)

Depreciation and Amortization

> Depreciation and amortization which cannot be taken from the income statement is calculated via depreciation and amortization rates.

The depreciation and amortization rates are set in the worksheet `Assumptions`.

The calculation of depreciation and amortization is presented in Fig. 10.30.

Net working capital

> Net working capital is equal to the surplus of operating current assets over current liabilities that are not interest-bearing. Key determinants for net working capital are the short-term nature for the company and the fact that no interest is paid.

Change in net working capital during a period indicates the amount of capital invested (increase) or disinvested (decrease) in the assets that make up the net working capital.

With the help of the net working capital, the financial modeler can determine whether current assets are sufficient to cover short-term liabilities that are due.

The calculation of net working capital is shown in Fig. 10.31. The individual items are taken from the balance sheet assets and balance sheet equity & liabilities.

Auxiliary Calculation: Net Working Capital

€ million	Actual t_2	Actual t_1	Actual t_0	Plan t_1	Plan t_2	Plan t_3	Plan t_4	Plan t_5	Plan TV
Inventories	6,370	6,991	7,129	7,491	7,940	8,416	8,921	9,100	9,282
+ Trade accounts receivable	7,060	7,433	7,569	8,071	8,555	9,068	9,612	9,804	10,000
+ Other assets (current)	4,876	2,888	2,668	2,828	2,998	3,178	3,368	3,436	3,504
- Trade accounts payable	3,785	4,305	4,473	4,769	5,055	5,358	5,680	5,793	5,909
- Other liabilities (current)	1,632	1,315	1,281	1,358	1,439	1,526	1,617	1,650	1,683
Net working capital	**12,889**	**11,692**	**11,612**	**12,263**	**12,998**	**13,778**	**14,605**	**14,897**	**15,195**
Check				OK	OK	OK	OK	OK	OK

Fig. 10.31 Calculating net working capital (Excel File Corporate Finance, Worksheet Auxiliary Calculations)

Auxiliary Calculation: Interest-bearing Liabilities

€ million	Actual t_2	Actual t_1	Actual t_0	Plan t_1	Plan t_2	Plan t_3	Plan t_4	Plan t_5	Plan TV
Provisions for pensions and other post-employment benefits	7,787	9,246	7,368	8,105	8,915	9,807	10,787	11,003	11,223
Noncurrent financial liabilities	7,995	6,962	5,590	5,103	4,658	4,252	3,881	3,959	4,038
Current financial liabilities	3,683	2,568	3,441	3,647	3,866	4,098	4,344	4,431	4,520
Interest-bearing Liabilities	**19,465**	**18,776**	**16,399**	**16,855**	**17,440**	**18,157**	**19,013**	**19,393**	**19,781**
Check				OK	OK	OK	OK	OK	OK

Fig. 10.32 Calculating interest-bearing liabilities (Excel File Corporate Finance, Worksheet Auxiliary Calculations)

Interest-bearing liabilities

> The interest-bearing liabilities comprise all positions on the liability side on which interest must be paid.

At Pharma Group this includes provisions for pensions and other post-employment benefits as well as noncurrent and current financial liabilities.

The calculation of interest-bearing liabilities is presented in Fig. 10.32. The individual items are taken from the balance sheet liabilities.

Cash Flow Statement

Before we can start with company valuation in the next step, it is possible to check the consistency of the planning for income statement

	B	C	D	E	F	G	H	I	J	K
4		Actual	Actual	Actual	Plan	Plan	Plan	Plan	Plan	Plan
5	I million	t_{-2}	t_{-1}	t_0	t_1	t_2	t_3	t_4	t_5	TV
7	EBIT				4,757	5,043	5,345	5,666	5,779	5,895
8	+ Amortization of goodwill				0	0	0	0	0	0
9	+ Amortization of other intangible assets				0	0	0	0	0	0
10	+ Deprecation on property, plant and equipment				2,896	2,896	2,896	2,896	2,896	2,896
11	+ Amortization of Investments accounted for using the equity method				0	0	0	0	0	0
12	+ Amortization of other financial assets				0	0	0	0	0	0
13	+ Change in other noncurrent provisions				0	0	0	0	40	40
14	+ Change in other current provisions				0	0	0	0	35	36
15	- Change in inventories				362	449	476	505	178	182
16	- Change in trade accounts receivable				502	484	513	544	192	196
17	- Change in other assets (current)				160	170	180	191	67	69
18	+ Change in trade accounts payable				296	286	303	321	114	116
19	+ Change in other liabilities (current)				77	81	86	92	32	33
20	- Income taxes				1,018	1,092	1,170	1,253	1,289	1,328
22	**Operating cash flow**				**5,985**	**6,111**	**6,291**	**6,482**	**7,229**	**7,301**
24	- Investment in goodwill				0	0	0	0	0	0
25	- Investment in other intangible assets				0	0	0	0	0	0
26	- Investment in property, plant and equipment				2,896	2,896	2,896	2,896	2,896	2,896
27	- Investment in Investments accounted for using the equity method				0	0	0	0	0	0
28	- Investment in other noncurrent assets				0	0	0	0	0	0
29	+ Change in other liabilities (noncurrent)				0	0	0	0	0	0
30	+ Change in deferred taxes (asset side), deferred taxes (liabilities side), and income tax liabilities				0	0	0	0	0	0
32	**Investing cash flow**				**-2,896**	**-2,896**	**-2,896**	**-2,896**	**-2,896**	**-2,896**
34	- Dividend				1,718	1,843	1,975	2,115	2,175	2,242
35	- Income after taxes attributable to non-controlling interest				21	23	25	26	27	28
36	+ Change in provisions for pensions and other post-employment benefits				737	810	892	981	216	220
37	+ Change in noncurrent financial liabilities				-487	-445	-406	-371	78	79
38	+ Change in current financial liabilities				206	219	232	246	87	89
39	+ Result from associates accounted for using the equity method				0	0	0	0	0	0
40	+ Financial income				68	108	153	203	261	323
41	- Financial expenses				632	652	676	706	730	744
43	**Financing cash flow**				**-1,847**	**-1,825**	**-1,806**	**-1,788**	**-2,291**	**-2,303**
45	**Net cash flow**				**1,242**	**1,390**	**1,589**	**1,798**	**2,042**	**2,102**
47	Liquidity 01.01				1,662	2,904	4,294	5,884	7,682	9,724
48	Liquidity 31.12			1662	2,904	4,294	5,884	7,682	9,724	11,826
50	**Change**				**1,242**	**1,390**	**1,589**	**1,798**	**2,042**	**2,102**
52	Check				OK	OK	OK	OK	OK	OK

Fig. 10.33 Planning of the cash flow statement for the Pharma Group (Excel File Corporate Finance, Worksheet Cash Flow Statement)

and balance sheet one more time with the help of the cash flow statement. This worksheet serves as a control and completes the analysis (see Fig. 10.33).

> The net cash flow must be equal to the change in the sum of cash & cash equivalents and excess liquidity from one period to the next.

In the context of the model review, additional controls will be undertaken. They are summarized in Fig. 10.34.

	A	B	C	D	E	F	G	H	I	J	K
57											
58		I million	t_{-2}	t_{-1}	t_0	t_1	t_2	t_3	t_4	t_5	TV
59											
60		Change in noncurrents assets				0	0	0	0	0	0
61		+ Depreciation/Amortization - CAPEX				0	0	0	0	0	0
62											
63		Check				OK	OK	OK	OK	OK	OK
64											
65		Inventories				362	449	476	505	178	182
66		+ Trade accounts receivable				502	484	513	544	192	196
67		+ Other assets (current)				160	170	180	191	67	69
68		- Trade accounts payable				296	286	303	321	114	116
69		- Other liabilities (current)				77	81	86	92	32	33
70		= Net Working Capital				651	736	780	827	292	298
71		Net Working Capital				651	736	780	827	292	298
72											
73		Check				OK	OK	OK	OK	OK	OK
74											
75		Change in other noncurrent provisions				0	0	0	0	40	40
76		Change in other noncurrent provisions				0	0	0	0	40	40
77		Change in other current provisions				0	0	0	0	95	96
78		Change in other current provisions				0	0	0	0	95	96
79											
80		Check				OK	OK	OK	OK	OK	OK
81											
82		Change in equity				1,437	1,541	1,652	1,769	1,819	1,875
83											
84		Earnings after taxes				3,176	3,407	3,652	3,910	4,022	4,145
85		- Dividend				1,718	1,843	1,975	2,115	2,175	2,242
86		- Income after taxes attributable to non-controlling interest				21	23	25	26	27	28
87		= Retained earnings				1,437	1,541	1,652	1,769	1,819	1,875
88											
89		Check				OK	OK	OK	OK	OK	OK
90											
91		Change in noncurrent and current financial liabilities				-281	-226	-174	-125	165	168
92		Change in noncurrent and current financial liabilities				-281	-226	-174	-125	165	168
93											
94		Check				OK	OK	OK	OK	OK	OK
95											
96											
97		Change in provisions for pensions and other post-employment benefits				737	810	892	981	216	220
98		Change in provisions for pensions and other post-employment benefits				737	810	892	981	216	220
99											
100		Check				OK	OK	OK	OK	OK	OK

Fig. 10.34 Controls to check for the plausibility of the planning for the Pharma (Excel File Corporate Finance, Worksheet Cash Flow Statement)

4.2 WACC Approach

4.2.1 The Idea behind the WACC Approach

The name “WACC approach” refers to the Weighted Average Cost of Capital – a combination of cost of equity and cost of debt.

> The WACC approach is the most frequently used method – especially in an international context – of valuation.

It is also called text book formula.

The WACC approach works with the cash flows which are available to satisfy the claims of all providers of capital – both debt and equity. Providers of debt are those investors that supply the company with (normally) interest-bearing funds. These are thus cash flows before interest and amortization payments have been made. The tax effects of debt financing are not taken into consideration in the determination of the cash flows. The cash flows which are relevant for the WACC approach are called operating Free Cash Flows (oFCF).

The operating free cash flows are discounted using an interest rate that combines both the return expectations of the providers of equity and of debt. The weights represent the shares of equity and debt in total capital. The weighting is based on market values and not book values. This discount rate is called WACC (Weighted Average Cost of Capital). Integrated in the WACC is the tax shield, which represents the tax benefit that debt provides.

> The WACC approach is a method that focuses on the total value of a company. This is accomplished by discounting the operating free cash flows available to the providers of debt and equity. The discount rate represents the weighted cost of capital, which considers both the cost of equity as well as of debt.

All DCF approaches only take into consideration operating cash flows, meaning cash flows generated by the core business of the company. All non-operating assets are valued separately and added to the present value of the free cash flows. The sum of the present value of the operating free cash flows, the cash & cash equivalents and the separately determined market value of the non-operating assets is equal to the market value of total capital. This number is also called entity value. It is the market value of equity plus the market value of (interest-bearing) debt. In order to arrive at the equity value, the interest-bearing financial liabilities need to be subtracted. Fig. 10.35 clarifies this approach.

A valuation using the WACC approach requires the following steps:

1. First the operating free cash flows are determined.
2. The operating free cash flows are discounted using the weighted average cost of capital (WACC). The result is called enterprise value.

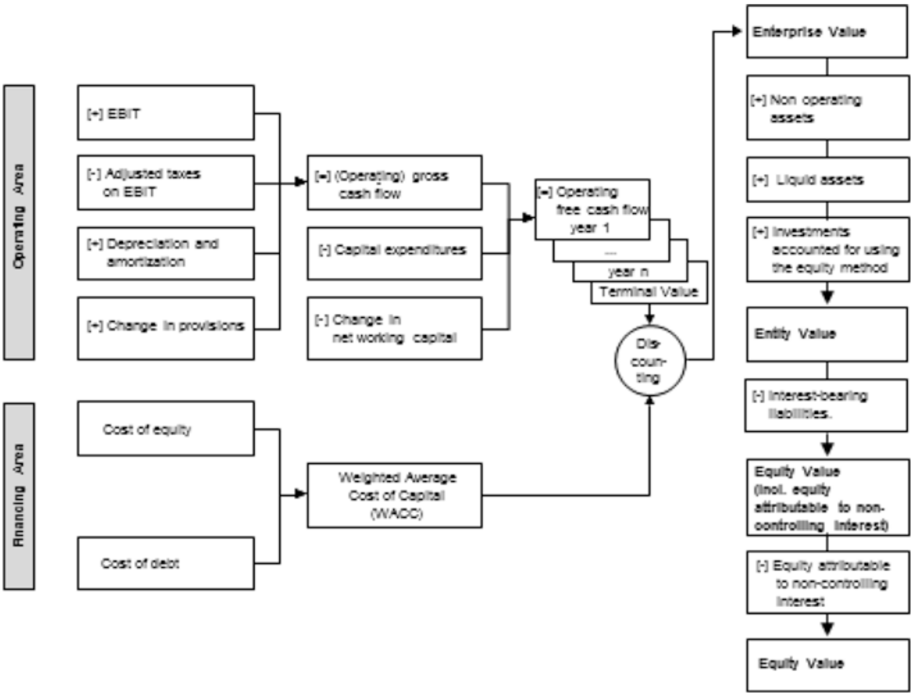


Fig. 10.35 Discounted cash flow method using the WACC approach

3. If non-operating assets, cash & cash equivalents and investments accounted for using the equity method are added to the enterprise value, the entity value results.
4. In order to arrive at the equity value including equity attributable to non-controlling interest, the financial modeler subtracts the interest-bearing liabilities from the entity value.
5. The equity value (market value of the equity) of the shareholders follows once the equity attributable to non-controlling interest is subtracted.

The relevant cash flows in the WACC approach are independent of the financing structure of the company. The influence of the capital structure on the value of the corporation is captured in the discount rate.

4.2.2 Calculating the Operating Free Cash Flows

Operating free cash flows are cash flows which come from the core business of the company (therefore: operating) and which are freely available to both the providers of (interest-bearing) debt and the provider of equity (therefore: free).

The WACC approach calculates the cash flow available to the providers of (interest-bearing) debt as well as equity. The calculation of this operating free cash flow follows a general scheme that needs to be adjusted to the specific corporate situation of the individual valuation object:

	Earnings before interest and taxes (EBIT)
-	Adjusted taxes on EBIT
=	Net operating profit less adjusted taxes (NOPLAT)
+	Depreciation and amortization
+	Change in provisions
=	(Operating) gross cash flow
-	CAPEX
-	Change in net working capital
=	Operating free cash flow (OFCF)

With the help of that scheme, the earnings figure EBIT is transformed into a cash flow figure called operating free cash flow. Earnings and expense figures that do not correspond to cash flows are eliminated. Cash flows that do not constitute earnings and expense figures are added.

EBIT

Starting point for the calculation of the operating free cash flow is Earnings Before Interest and Taxes (EBIT). Deducted are the so-called adjusted taxes on EBIT.

Adjusted taxes

Adjusted taxes are the (fictitious) income taxes of the company, which would be due if it had no debt and no non-operating earnings and expenses. They are calculated by applying the corporate tax rate to EBIT.

A "mistake" is made for companies that actually have debt on their balance sheet when using adjusted taxes, since the tax savings which follow from the tax-deduction caused by interest payment, the so-called tax shield, are not considered. The fact that this tax shield is not considered ultimately means that adjusted taxes are too high and hence the free cash flow does not reflect the true earnings power. This mistake is corrected in the WACC approach by incorporating the tax advantage of debt financing into the weighted average cost of capital (WACC).

NOPLAT

The resulting net operating profit less adjusted taxes (NOPLAT) reflects the operating result achievable in the absence of debt financing. Extraordinary expenses and revenues are not included.

Operating gross cash flow

In order to arrive at the (operating) gross cash flow, the expense figures which do not correspond to cash flows (for example depreciation and amortization or increases in provisions) are added to NOPLAT and the earnings figures which do not correspond to cash flows (for example reductions in provisions) are subtracted.

> The (operating) gross cash flow is the amount which is available for investments or distributions to all providers of capital without the need to raise additional capital.

In order to maintain the operating free cash flow, the operating gross cash flow must be adjusted to capture investments and disinvestments in noncurrent assets and the change in net working capital.

Operating free cash flow

A look at the operating free cash flow clarifies the separation between operations (expressed by operating free cash flow) and financing (captured by the discount rate).

> The operating free cash flow reflects the operations of the company and illustrates the cash flow which the company can generate regardless of the type of financing chosen.

The operating free cash flow is equal to the cash flow which the company can generate before financing measures are considered.

The operating free cash flow is thus neutral with regard to financing; it is not influenced by the capital structure of the company. The operating free cash flow does not contain any cash flows which are

Position	Formulas	Excel implementation for t_1
Earnings before interest and taxes (EBIT) (=Cash_Flow_Calculation!F16)	=EBIT t_1 from the sheet Income Statement	='Income Statement'!F19
Adjusted taxes on EBIT (=Cash_Flow_Calculation!F17)	=EBIT t_1 * Tax rate t_1	=F16*Assumptions!F135
NOPLAT (=Cash_Flow_Calculation!F19)	=EBIT t_1 – Adjusted taxes on EBIT t_1	=F16-F17
Depreciation and amortization (=Cash_Flow_Calculation!F21)	=Depreciation and amortization t_1 from the sheet Auxiliary Calculations	='Auxilliary Calculations'!F33
Change in other provisions (=Cash_Flow_Calculation!F22)	=Other provisions t_1 – Other provisions t_0	='Auxilliary Calculations'!F76-'Auxilliary Calculations'!E76
Gross cash flow (=Cash_Flow_Calculation!F24)	=NOPLAT t_1 + Depreciation and amortization t_1 + Change in other provisions t_1	=F19+SUM(F21:F22)
Capital expenditures (=Cash_Flow_Calculation!F26)	=Investment from the sheet Auxiliary Calculations	='Auxilliary Calculations'!F18
Change in net working capital (=Cash_Flow_Calculation!F27)	=Change in net working capital from the sheet Auxiliary Calculations	='Auxilliary Calculations'!F49-'Auxilliary Calculations'!E49
Change in noncurrent other liabilities (=Cash_Flow_Calculation!F28)[i]	=Noncurrent other liabilities t_1- Noncurrent other liabilities t_0	='Equity and Liabilities'!F18-'Equity and Liabilities'!E18
Change in deferred taxes (asset side), deferred taxes (liabilities side)[ii], and income tax liabilities[iii] (=Cash_Flow_Calculation!F29)	= Change in deferred taxes (asset side), deferred taxes (liabilities side), and income tax liabilities t_1 - Change in deferred taxes (asset side), deferred taxes (liabilities side), and income tax liabilities t_0	='Auxilliary Calculations'!F90-'Auxilliary Calculations'!E90
Operating free cash flow (OFCF) (=Cash_Flow_Calculation!F31)	=(Operating) gross cash flow t_1 – Capital expenditures t_1 - Change in net working capital t_1 + Change in noncurrent other liabilities t_1 - Change in deferred taxes (asset side), deferred taxes (liabilities side), and income tax liabilities t_1	=F24-F26-F27+F28+F29

Fig. 10.36 Calculating the operating free cash flow

linked to financing, such as interest expenses, change in financial liabilities or dividends. And corporate taxes are also determined without considering any tax deductions for interest payments on the company debt.

Figure 10.36 shows how the operating free cash flow is calculated with reference to the year t_1.

Operating Free Cash Flow

€ million	Plan t_1	Plan t_2	Plan t_3	Plan t_4	Plan t_5	Plan TV
Operating result (EBIT)	4,757	5,043	5,345	5,666	5,779	5,895
- Adjusted taxes	1,155	1,224	1,297	1,375	1,403	1,431
Net Operating Profit Less Adjusted Taxes (NOPLAT)	**3,603**	**3,819**	**4,048**	**4,291**	**4,377**	**4,464**
+ Depreciation and amortization	2,896	2,896	2,896	2,896	2,896	2,896
+ Change in other provisions	0	0	0	0	134	137
Gross cash flow	**6,499**	**6,715**	**6,944**	**7,187**	**7,407**	**7,497**
- Capital expenditures	2,896	2,896	2,896	2,896	2,896	2,896
- Change in net working capital	651	736	780	827	292	298
+ Change in other liabilities (noncurrent)	0	0	0	0	0	0
- Change in deferred taxes (asset side), deferred taxes (liabilities side), and income tax liabilities	0	0	0	0	0	0
Operating free cash flow (oFCF)	**2,952**	**3,083**	**3,268**	**3,464**	**4,219**	**4,303**

Fig. 10.37 Calculating the operating free cash flow of the Pharma Group (Excel File Corporate Finance, Worksheet Cash Flow Calculation)

This allows the calculation of the operating free cash flows for the years t_1 to t_5, as well as the perpetuity (see Fig. 10.37).

4.2.3 Calculating the Cost of Capital

> While the operating free cash flow available to all providers of capital follows from the operations of the company, the financing activities of the company are captured with the help of the discount rate.

Consequently the discount rate needs to combine both the cost of equity and the cost of debt. These costs of capital of the various sources of financing are weighted in line with their relative share in the total invested capital of the company. The weighting is not based on book values, but instead on market values. Only the market values are a true economic measure of the claims of the various providers of capital. The discount rate determined in this fashion is called WACC (Weighted Average Cost of Capital).

The weighted average cost of capital is determined with the help of the following formula:

$$WACC = r_e \cdot \frac{e}{e+d} + r_d \cdot (1-t) \cdot \frac{d}{e+d}$$

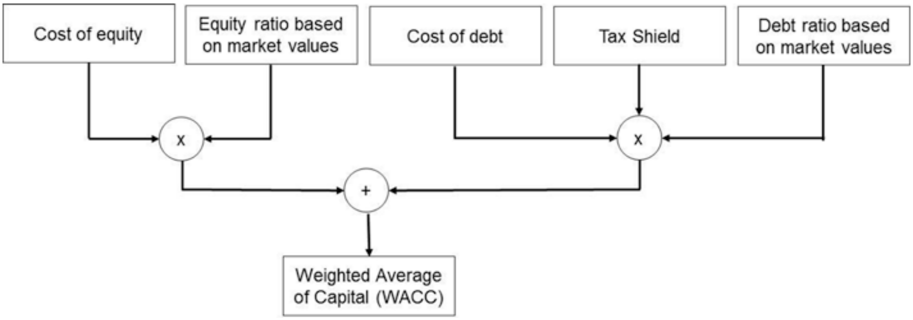


Fig. 10.38 Determination of the WACC

with

r_e = Return on equity
= Cost of equity
$r_d \cdot (1 - t)$ = Cost of debt after taxes
r_d = Cost of debt before taxes
t = Corporate tax rate
e = Market value of equity
d = Market value of the interest-bearing debt
$e + d$ = Market value of the total capital

Figure 10.38 once again clarifies these linkages.

> The WACC is a weighted average of the costs for all sources of funds. To simplify matters, only two types of financing – equity and interest-bearing debt – are distinguished in the formula.

The formula can easily be expanded to include other sources of capital with different return expectations. Possible is for example the separate consideration of mezzanine capital or preferred shares or even the breakdown of debt in different components such as leasing, loans, bonds, convertible bonds and so forth. For each source of financing included, an appropriate weighting factor on the basis of the percentage of the market value must be determined.

Fig. 10.39 shows the input data for the calculation of the cost of capital.

Cost of Capital	
Cost of equity	
Riskfree rate of return	1.8%
Market risk premium	5.00%
Beta (levered) Pharma Group	0.95
Cost of debt	
Risik premium (spread)	2.0%
Tax rate	24.3%

Fig. 10.39 Assumptions for the cost of capital (Excel File Corporate Finance, Worksheet Assumptions)

Determining the Cost of Equity

When determining the cost of equity, two cases can be distinguished:

- Case 1: Specific return expectations are given
- Case 2: The cost of equity is derived with reference to theoretical capital market models

Case 1: Specific return expectations are given

> The determination of the cost of equity is simple if the cost of equity is already given when conducting the valuation.

In applied work, this is the case if the provider of equity, for whom the valuation is conducted, has concrete return expectations for the valuation object. Private equity companies, for example, will specify return expectations, which in turn must be passed along to their investors in the form of a concrete return objective. The return objective of private equity companies for medium sized companies is frequently 15% per annum after taxes as a minimum threshold.

Case 2: The cost of equity is derived with reference to theoretical capital market models

> If no specific values are stated, the cost of equity is derived from a risk-free rate of interest plus a risk premium.

$$r_e = r_f + RP$$

with

r_f = risk-free rate of return
RP = risk premium

Determining the interest rate of a risk-free investment

> The risk-free rate of return is the return of an investment that has no default risk and is uncorrelated with returns of other capital investments.

There are two ways to determine the risk-free rate of return:

- Interest rate on a government bond with a triple-A rating
- Derivation from the term structure of interest rates

Interest rate on a government bond with a triple-A rating:
In practice, no risk-free investment exists. Therefore it is assumed that long-term fixed-coupon bonds of governments have no default risk. The interest rate on these Triple-A (AAA) bonds are thus indicative of the risk-free investment opportunity.

Derivation from the term structure of interest rates:
As an alternative to the determination of the risk-free rate of return from a bond with a triple-A (AAA) rating, the calculation on the basis of published data about the term structure of interest rates is recommended. According to this approach, for each future payment date, a discount rate with matching term to maturity needs to be determined from the current term structure of interest rates. The risk-free rate of interest is derived from the relevant interest rate on a zero coupon bond. To have an objective base, it is recommended to rely on the Svensson-method when calculating the term structure of interest

rates. Estimates of the parameters required for the determination of the term structure of interest rates can be obtained for the Euro from the time series database of the ECB and for the US-Dollar from the time series database of the Fed. For a given structure of financial surpluses, the uniform risk-free rate of return can be derived with the help of financial mathematics.

Practical Tip

Suggestions for choosing the risk-free rate of interest
If the prevailing interest rate on the day of the valuation is used, there is a risk that transitory and unusually high or low interest rates form the basis of the valuation. For that reason, historic averages of long-term public bonds are normally used.

When picking the risk-free rate of return, the following aspects need to be considered:

- The currency in which the government debt is issued should be identical to the returns or cash flows of the company that is valued; otherwise currency risk may complicate a comparison with other companies.
- The relevant risk-free rate of return should have the same maturity as the planned investment. Since risk-free rates of return usually have a fixed maturity (such as 5, 10, or 30 years), the maturity which is closest to the holding period of the planned investment should be selected. For the perpetuity which is frequently used for the determination of the terminal value of the company valuation, a different risk-free rate of return should be used than for the detailed planning period.
- The average yield of public bonds with a maturity between 5 and 30 years is published daily in the financial press.
- In applied valuation work, the 10-year government bond is used most frequently, since the trading volume and thus the significance is greatest.

Determination of the risk premium with the help of the CAPM

> For the determination of the risk premium, usually theoretical capital market models such as the Capital Asset Pricing Model (CAPM) are utilized. The CAPM is the international standard for the determination of the cost of equity.

Assumptions of the CAPM

> If the CAPM is used by the financial modeler to derive the risk premium for the valuation, he should realize that it is based on rather restrictive assumptions, which do not hold in that form in reality:

- Existence of a perfect capital market. There are no information costs and transaction costs when purchasing or selling securities. There are also no taxes or other limitations such as market regulation.
- Individual investors cannot influence market prices.
- The number of investment objects is constant; all assets are liquid and infinitely divisible.
- All investors have homogeneous expectations concerning security returns, variances and covariances.
- Risk-free assets exist and unlimited borrowing and lending at the risk-free rate of return is possible.

Calculating the cost of equity

The two components for determining the risk premium according to the CAPM are:

1. component: **market risk premium**

   The market risk premium for investments in equity, which is given by the return difference between an equity investment and the risk-free rate of interest.

2. component: **beta factor**

   The specific risk premium for the valuation object is called beta factor in the CAPM. Since companies normally – such as Pharma Group – show financial liabilities, the beta factor is also called levered beta.

Market risk premium and beta factor combined determine the risk premium, respectively the business risk. The formula for thebusiness risk is:

$$RP = MRP \cdot \beta^l$$

with

MRP = Market risk premium
β^l = Beta levered (l stands for levered).

Formulas for the Cost of Equity

$$\begin{aligned} r_e &= r_f + RP \\ &= r_f + MRP \cdot \beta^l \end{aligned}$$

with

r_f = Risk-free return
MRP = Market risk premium
β^l = Company-specific beta factor of a company that uses leverage (l stands for levered).

Market risk premium: In perfect capital markets – a basic assumption of the CAPM – investors have the opportunity to hold a perfectly diversified market portfolio. The unsystematic risk of the individual holdings is eliminated via diversification. In contrast to the risk-free asset, the market portfolio is subject to systematic risk. For that reason investors demand a so-called market risk premium for an investment in the market portfolio. The market risk premium is the market price of (systematic) risk.

Digression

Types of risk

- Two types of risk can be distinguished:
- systematic risk and
- unsystematic risk.

Systematic risk comprises all factors that are part of the general macroeconomic and political environment. Examples are

- Exchange rate fluctuations/changes in exchange rate parities,
- Interest rate changes,
- Changes in inflation,
- Fluctuations in commodity prices, business cycle fluctuations,
- Tax reform,
- Changes in incidental wage costs,
- Trade agreements among nations,
- Environmental regulations, wars, bad harvests or natural disasters.

These factors cannot be influenced by the company and are considered to be general (market) risks. Systematic risk cannot be eliminated by the investor with the help of diversification.

Unsystematic risk captures all risk factors that are directly linked to the individual firm. They only influence the financial situation of a specific company. This includes for example

- Market positioning,
- Competitive position of the goods offered,
- Existence of barriers to entry, number and size of competitors,
- Market introduction of substitutes,
- Degree of dependency from clients or suppliers,
- Management quality,
- Unplanned departure of a managing director or
- Negative press reports (for example because of questionable accounting practices).

These company-specific factors are responsible for the fact that the returns of different companies do not all develop in the same direction. While the values of some companies will go up, those of others will decline. An investor who does not put all his capital in one company, but instead adequately diversifies his holdings, can reduce, or in an ideal case eliminate his unsystematic risk.

> The market risk premium is calculated as the difference between the expected return of the market portfolio and the risk-free rate of return:

$$MRP = E(r_m) - r_f$$

with
$E(r_m)$ = Expected value of the return of the market portfolio
r_f = risk-free rate of return

This leads to the following equation for the cost of equity:

$$\begin{aligned} r_E &= r_f + RP \\ &= r_f + MRP \cdot \beta^l \\ &= r_f + \left(E(r_m) - r_f\right) \cdot \beta^l \end{aligned}$$

The market risk premium is one component of the discount rate. The discount rate is used to discount FUTURE cash flows. Therefore, the market risk premium that is predicted for the future must be utilized. This variable is called expected market risk premium. In most applications this forecasted value is based on historical values. Empirically the (historical) market risk premium can be determined by comparing the long-term geometric mean of the equity return with the geometric mean return of long-term government bonds. The equity return can be determined with the help of indexes. For Germany, for example, the DAX could be used. The CDAX (Composite DAX) is closest to the idea of the CAPM of a completely diversified market portfolio.

> An internationally recognized source for the determination of the market risk premium is the following homepage of ASWATH DAMODARAN of the Stern School of Business of New York University.

http://pages.stern.nyu.edu/~adamodar/New_Home_Page/datafile/ctryprem.html

It shows for almost all countries the current market risk premium.

A screenshot of Damodaran's homepage is found in Fig. 10.40.

Beta factor

Not the general market risk premium, but the specific risk premium of an individual company is relevant for calculating the cost of equity. It is determined by multiplying the market risk premium with the beta factor of the company that is valued.

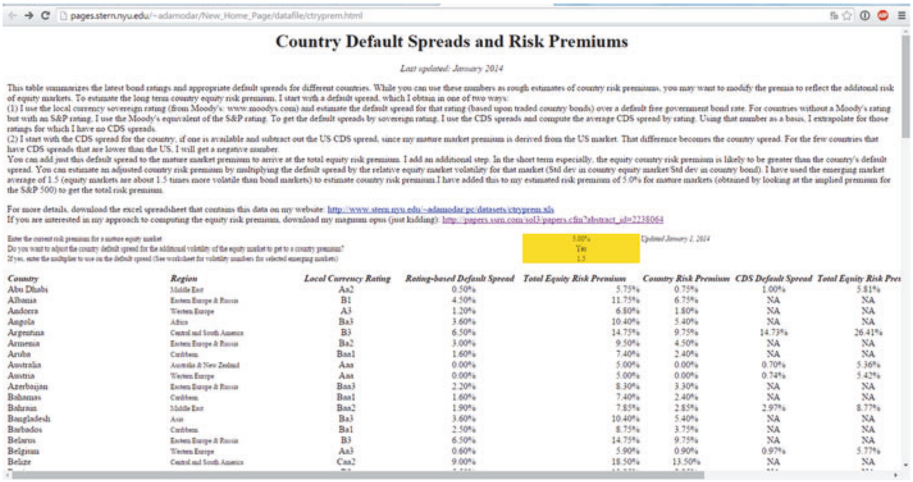


Fig. 10.40 Damodaran's homepage for the determination of the equity risk premium (see http://pages.stern.nyu.edu/~adamodar/New_Home_Page/datafile/ctryprem.html)

> The beta factor measures the systematic risk of a specific security. As a relative risk measure it describes the degree to which the return of an individual security moves in line with the changes of the return of the market portfolio.

The beta factor can also be interpreted as a volatility measure, since it relates the range of variation of the prices of an investment object to the range of variation of the broad market valuation. Mathematically the beta factor is given as the quotient of the covariance of the return of investment j with the return of the market portfolio $Cov\left(r_j, r_m\right)$ ăand the variance of the return of the market portfolio $Var\left(r_m\right)$:

> Formula for the Beta Factor

$$\beta = \frac{Cov\left(r_j, r_m\right)}{Var\left(r_m\right)}$$

> Practical Tip

What do the values of the beta factor indicate?

- A beta factor of 1.0 means that the return of a single investment develops approximately in line with the return of the market portfolio. If, for example, the market return goes up (goes down) by 5%, the individual return also goes up (goes down) by 5%.
- If the beta factor is greater than 1.0, the reaction of the security to changes in the market return tends to be disproportionately large. The individual returns show larger fluctuations than the market return. If, for example, the market return goes up (goes down) by 10%, a beta factor of 1.5 indicates that the return of the individual security goes up (goes down) during the same time period by 15%.
- If the beta factor is less than 1.0, the reaction of the security to changes in the market return tends to be disproportionately small.
- A risk-free asset does not have any return fluctuations and thus it has a beta factor of 0.
- The higher the beta factor, the higher is the range of fluctuations and thus the risk of the investor and the required risk premium.

Case 1: The subject of the valuation is publicly listed
For publicly listed companies such as the Pharma Group, the financial modeler arrives at the levered beta as follows:

1. Determination of the levered beta from a database such as Bloomberg, Thompson Reuters, Data Stream etc. The levered beta of Pharma Group is 0.95.
2. Taking out the debt from the levered beta with the help of the following formula[4]:

$$\beta^u = \beta^l / \left(1 + (1 - t) \cdot \frac{d}{e}\right)$$

with

β^u = Beta (unlevered)

β^l = Beta (levered)

t = Corporate tax rate

d = Interest-bearing liabilities

e = Market capitalization

The market capitalization is used for e. The result is the unlevered beta of the company which is the subject of the valuation. For Pharma Group an unlevered beta of 0.83 is obtained.

3. Relevering the unlevered beta with the following formula:

$$\beta^l = \beta^u \cdot \left(1 + (1 - t) \cdot \frac{d}{e}\right)$$

In this step, the result of the company valuation, the equity value (calculated as enterprise value minus interest-bearing liabilities) is used for e (dual circularity problem). This is the only way to assure that later all three DCF approaches (WACC-approach, equity approach and APV-approach) arrive at identical valuations for the company. For Pharma Group the financial modeler arrives at a relevered beta of 0.95 after rounding.

In the following, the calculation of the unlevered beta is shown (see Fig. 10.41):

Case 2: The subject of the valuation is not publicly listed
For companies that are not publicly listed, the beta factor of the valuation object is derived from the beta factors of a comparable group of publicly listed companies of similar size and from a similar industry. In this case, the financial modeler proceeds as follows:

1. For the publicly listed peer group, the levered betas are taken from a database such as Bloomberg, Thompson Reuters, Data Stream, etc.

Position	Formula	Excel implementation
Beta (unlevered) (=Cost_of_Capital_(1)!E15)	= Beta (levered) / (1 + (1 – Tax rate) * Interest-bearing liabilities / Market capitalization)	=Assumptions!E233/(1+(1-Assumptions!E240)*'Auxilliary Calculations'!E63/(Assumptions!E259*Assumptions!E260))

Fig. 10.41 Calculation of beta (unlevered)

2. These levered betas are delevered. This results in unlevered betas for the companies from the peer group:

$$\beta^u = \beta^l / \left(1 + (1 - t) \cdot \frac{d}{e}\right)$$

3. These are now aggregated using the median. As a result, the financial modeler obtains the unlevered beta of the valuation subject which is not publicly listed.
4. In order to obtain the levered beta of the valuation subject, the unlevered beta is relevered using the results from the DCF method (tax rate, interest-bearing liabilities as well as equity value).

$$\beta^l = \beta^u \cdot \left(1 + (1 - t) \cdot \frac{d}{e}\right)$$

The calculation of the market value of equity suffers from a circularity problem which can be described as follows: the financial modeler needs the market value of the equity as an input to calculate the levered beta (equity = enterprise value – interest-bearing liabilities). But the goal of the company valuation is the determination of the market value of equity – by discounting the cash flows that are relevant for the valuation using the WACC.

Figure 10.42 presents the circularity problem graphically.

Practical Tip

Solving the circularity problem with the help of Excel

A circular reference is a reference to a cell which contains the formula itself. This can also be considered as a form of self-reference. Excel cannot solve this problem and provides an error message (Fig. 10.43).

In Excel the circularity problem is solved with the help of mathematical iteration. It is activated as follows: ➲ *File* ➲ *Options* ➲ *Formulas* ➲ *Enable iterative Calculation* (Fig. 10.44).

The link between WACC and company valuation is established by connecting the following cells in the worksheets

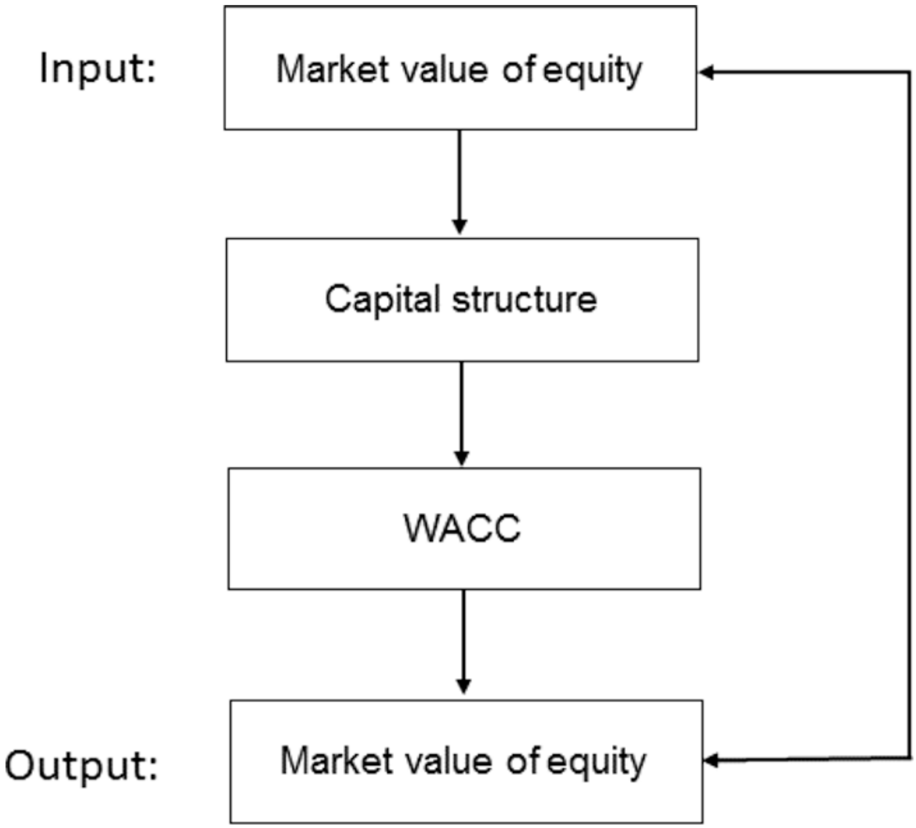


Fig. 10.42 Circularity problem

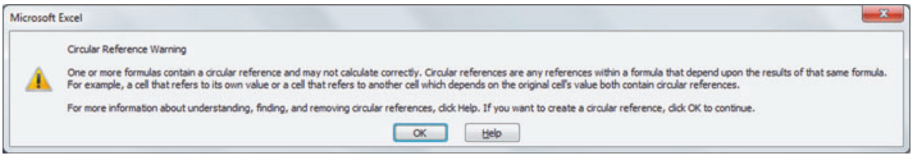


Fig. 10.43 Error message for the circularity problem

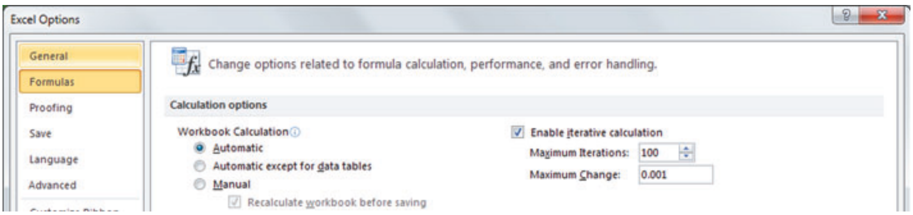


Fig. 10.44 Solving the circularity problem with Excel

Position	Links	Excel implementation
Equity ratio based on market values (=Cost_of_Capital_(1)!E36)	Linked with the market value of equity of the DCF valuation using the WACC approach = (Enterprise value – Interest-bearing liabilities) / Enterprise value	=('DCF Valuation (1)'!E23-'DCF Valuation (1)'!E31)/'DCF Valuation (1)'!E23
WACC (=DCF_Valuation_(1)!E15)	Link to the WACC calculation in the worksheet Cost of Capital (1).	='Cost of Capital (1)'!E42
Beta (levered) (=Cost_of_Capital_(1)!E16)	Link to beta (unlevered) = beta (unlevered) * (1 + (1 – Tax rate on the valuation date) * Interest-bearing liabilities / (Enterprise Value - Interest-bearing liabilities))	=E15*(1+(1-Assumptions!E240)*'DCF Valuation (1)'!E31/('DCF Valuation (1)'!E23-'DCF Valuation (1)'!E31))

Fig. 10.45 Linking WACC and calculation of the company value

Position	Formulas	Excel implementation
Cost of equity (=Cost_of_Capital_(1)!E19)	$= r_f +$ Business risk $= r_f + \beta^l * \text{MRP}$	=E14+E16*E17

Fig. 10.46 Calculating the cost of equity

DCF_Valuation_1 (WACC approach at market values) and the worksheet Cost_of_Capital_(1) (see Fig. 10.45):

Now that the values for the risk-free rate of return, the market risk premium and the beta factor (levered) have been determined for Pharma Group, the cost of equity can be calculated in a next step. The cost of equity of Pharma Group is equal to 6.59% and is calculated as follows (see Fig. 10.46):

Determining the Cost of Debt

The cost of debt consists of two components:

1. the risk-free rate of return and
2. a risk premium.

Position	Formula	Excel implementation
Cost of debt before taxes (=Cost_of_Capital_(1)!E27)	$=r_f$ + Risk premium debt	=E24+E25

Fig. 10.47 Calculating the cost of debt before taxes

The risk premium which depends on the credit rating of the borrower is also called spread.

The determination of the risk-free rate of return was already discussed. But how can the financial modeler obtain the information about the risk premium and its current market price?

Two approaches for determining the level of the cost of debt are available for persons that are external to the company, depending on whether the valuation object has a rating or not.

If the company is rated, the cost of debt can be determined from the risk-free rate of return plus the spread (risk premium) for corporate bonds.

In the second approach, the actual payment of interest (interest expenses) is divided by the sum of the individual interest-bearing liabilities. This figure is interpreted as the average cost of debt financing.

$$r_d = \frac{\text{Interest expenses}}{\text{Interest - bearing liabilities}}$$

The cost of debt before taxes of Pharma Group is calculated as follows (see Fig. 10.47):

Tax Advantage of Debt Financing

The interest rate on debt represents the return requirement of the providers of that form of capital. However, this return requirement is not equal to the cost of debt of the company. Due to the fact that interest expenses are tax deductible, the use of debt lowers the amount of

Position	Formula	Excel implementation
Cost of debt after taxes (=Cost_of_Capital_(1)!E31)	= r_d before taxes – Tax reduction due to the cost of debt	=E27-E29

Fig. 10.48 Calculating the cost of debt after taxes

taxes due. This effect is called tax shield. The cost of debt is therefore equal to interest that ought to be paid reduced by all tax deductions for the company:

Formula for the Effective Cost of debt

$$\text{Cost of debt} = r_d \cdot (1 - t)$$

with
r_d = Return requirement of the providers of debt
t = Corporate tax rate

The cost of debt after taxes is calculated as follows (see Fig. 10.48):The tax rate used is the rate prevailing on the valuation date of 24.3%.

Determining the Weighted Capital Structure

The basic model of the WACC approach assumes a discount rate that is constant over the life of the company.

In addition to constant rates for debt and equity, this also assumes a constant capital structure, in other words a constant ratio of equity to debt based on market values. This means that the capital structure of the company on the valuation date is also the future capital structure. This assumption is valid only if no major changes in the capital structure are planned.

When determining the market value of debt, book values of the interest-bearing liabilities as listed on the balance sheet are usually utilized. In case the agreed interest rates are not equal to the current market conditions or deviate significantly, the market value can be calculated by discounting all future payments of interest and amortization over the maturity of the debt. If this method is chosen, the discount rate should be equal to the current market interest rate of a comparable refinancing operation of similar risk and identical maturity.

> It is important to recognize that the calculation of the capital structure in the WACC only considers the market value of equity which corresponds to the operating assets.

The discounted cash flows and the discounted terminal value are derived from the operating assets and determine the enterprise value. After subtracting interest-bearing liabilities from the enterprise value, the market value of equity from operating assets follows. Cash & cash equivalents that are not needed for operations, non-operating assets as well as investments accounted for using the equity method that are also not considered as relevant for operations are not taken into account when calculating the capital structure.

Calculating the WACC

Once the cost of equity and debt has been calculated and the capital structure has been derived, the WACC can be calculated in the next step (see Fig. 10.49):

The derivation of the WACC is shown in Fig. 10.50. The WACC of Pharma Group is 5.95%.

Position	Formula	Excel implementation
WACC (=Cost_of_Capital_(1)!E42)	$=r_e * e/(e+d) + r_d * (1 - t) * d/(e+d)$	=E19*E36+E31*E37

Fig. 10.49 Calculating the WACC

Cost of Equity (levered)	t_0
Risk-free rate of return	1.80%
Beta (unlevered)	0.83
Beta (levered)	0.96
Market risk premium	5.00%
Cost of equity (levered)	**6.59%**

Cost of debt + cost of pensions	t_0
Risk-free rate of return	1.80%
Risik premium (spread)	2.00%
Cost of debt and pensions before taxes	3.80%
Taxation	0.92%
Cost of debt and pensions after taxes	**2.88%**

Capital structure	t_0
Equity ratio at market values	82.87%
Debt ratio at market values	17.13%

Weighted Average Cost of Capital (WACC)	t_0
WACC	5.95%

Fig. 10.50 Derivation of the WACC (Excel File Corporate Finance, Worksheet Cost of Capital (1))

If the financing plan of a company is not based on a constant capital structure, the model for the Pharma Group will yield an incorrect valuation result. The solution is to calculate the precise capital structure for each planning period and to determine the period-specific WACCs (see Section 4.2.5 Period-Specific WACC Approach).

Practical Tip

What to do if Excel crashes?

- If the iteration function in Excel has not been turned on from the very beginning, it frequently happens that the calculation of the values is done incorrectly.
- There will especially be mistakes in the worksheets `Cost_of_Capital_(1)` and `Cost_of_Capital_(2)` as well as `DCF_Valuation_(1)` and `DCF_Valuation_(2)` for the WACC and the APV approach.
- Sometimes these mistakes occur even without apparent reason.
- In most cases, turning on the iteration function after the fact does not solve the problem.

The following approach has so far always proven successful in applied work:

1. Step: Turn on the iterative function.
2. Step: Simply enter manually the value of 10% in the worksheet `DCF_Valuation_(1)` in the cell for the value of the WACC `(Cell E15)`. The calculation is then based on that value.
3. Step: Now establish a link between the value of the WACC from the worksheet `DCF_Valuation_(1)` and the worksheet `Cost_of_Capital_(1)`.

Fundamental recommendation: In order to limit the unpleasant consequences of a crash of Excel for the financial modeler, we urge you to save the Excel model after each programming step. The file should also be saved in a new version at regular intervals.

Now the iteration and the calculation of the values should be correct. The same approach should be chosen for the APV approach and the corresponding cost of capital.

4.2.4 Calculating the Company Value

Now that the relevant operating free cash flow for the planning period has been determined and the calculation of the WACC has been explained, the company value can be calculated. But before taking that step, it needs to be established whether the lifespan of the company is limited to the planning period or whether a longer time period should be considered.

> Normally it is assumed in company valuation that the company is infinitely lived (going concern).

For the time period past the planning period, the terminal value is calculated. It is the discounted value of all the cash flows that occur after the detailed planning period as of the end of the detailed planning period.

To determine the terminal value, it is usually assumed that all cash flows that are relevant for the valuation are growing at a constant rate g. The derivation of the growth rate g is of major importance when conducting a DCF valuation. In this context, we will not elaborate on this point, since the approach is not suitable for a presentation from the perspective of financial modeling. More details about the derivation of the growth factor can be found in Devlin/Patwardhan 2013; Kaplan/Ruback 1995, pp. 1059-1093; Pratt, 2008; Rotkowski/Clough 2013, pp. 9-20; Trugman, 2008. The terminal value (TV) can be determined with the formula for the present value of a perpetuity (with constant growth) and by incorporating the growth factor as follows:

$$TV = \frac{oFCF_{TV}}{(WACC - g)}$$

with

$oFCF_{TV}$ = Normalized amount of operating free cash flow in the first year following the detailed planning period

WACC = Discount rate

g = Expected growth rate of the cash flows relevant for valuation

For Pharma Group, growth of 2% is assumed for calculating the terminal value. The input for the growth rate is provided in the worksheet `Assumptions` in cell `K201`.

It is customary in applied valuation work to use the last cash flow from the detailed planning period as the relevant cash flow to determine the terminal value. But this assumes that the growth scenarios during the detailed planning period and the following infinite period are identical and that the growth rate during the entire period of analysis is identical. However, in many cases the growth rate during the detailed planning period is assumed to be higher than during the following infinite period. Only a smaller share of the earnings needs to be reinvested in this case to achieve this comparably lower growth rate. If this change in the investment amount in property, plant and equipment and net current assets is ignored, a systematic and at times large error will be made in the determination of the resulting company value.

If a stepwise transition from the growth scenario in the detailed planning phase to the growth scenario underlying the terminal value is needed, a three stage convergence model can bridge the gap between the two phases. The convergence model is suitable to model declining growth rates, which are expected to result from competitive dynamics.

Practical Tip

Suggestions for choosing the growth factor

A careful determination of the terminal value is absolutely essential for any valuation, since it frequently accounts for 80% of the entire company value!

- For a conservative company valuation the growth factor could take on a value of 1 %.
- Any increase of the growth rate implies explosive growth of the terminal value, which is subject to great uncertainty in planning.

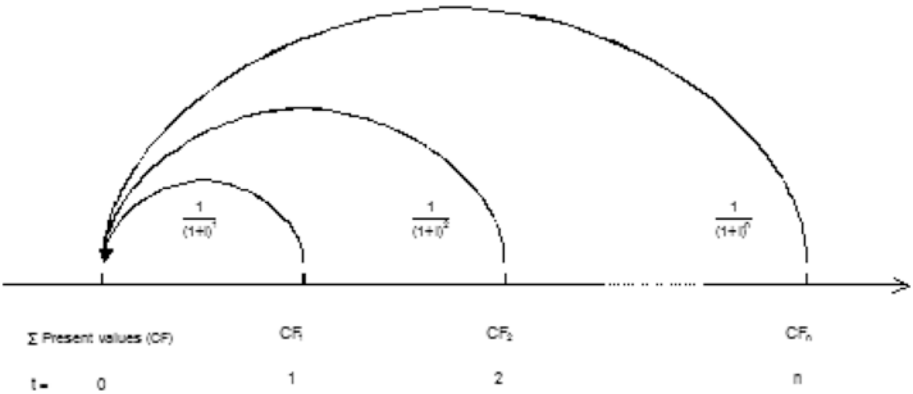


Fig. 10.51 Determining the present value of the cash flows via discounting

Once the terminal value has been calculated, the company value can be established. The company value is the present value of all operating activities of the company. It is derived by discounting all relevant cash flows including the terminal value at the consistent cost of capital. To simplify the calculations it is assumed that all cash flows fully accrue at the end of the financial year.

Figure 10.51 clarifies the essence of discounting.

If the company valuation is done as of the end of the financial year, only complete years enter the analysis. Thus the formula for calculating the company value using the WACC approach is:

$$PV = \sum_{t=1}^{n} \frac{oFCF_t}{(1 + WACC)^t} + \frac{TV_{oFCF}}{(1 + WACC)^n}$$

The most important items in the calculation of the company value are presented with reference to the year t_1 and the terminal value in Fig. 10.52:

Figure 10.53 outlines the calculation of the company value of the Pharma Group in accordance with the WACC approach.

Position	Formulas	Excel implementation
WACC (=DCF_Valuation_(1)!E15)	=WACC from the sheet Cost of Capital	='Cost of Capital (1)'!E42
Discount factor (=DCF_Valuation_(1)!F16)	$=1 / (1 + \text{WACC})^1$	=1/(1+$E$15)^Assumptions!F211
Operating free cash flows (=DCF_Valuation_(1)!F17)	=oFCF t_1 from the sheet Cash Flow Statement	='Cash Flow Calculation'!F31
Terminal value (=DCF_Valuation_(1)!K18)	=oFCF t_{TV} /(WACC – Growth rate (TV))	=K17/(E15-Assumptions!K219)
Present value of the free cash flows (=DCF_Valuation_(1)!F20)	=Discount factor t_1 * oFCF t_1	=F16*F17
Present value of the terminal value (=DCF_Valuation_(1)!K21)	=Discount factor t_{TV} * TV	=K16*K18
Enterprise value (=DCF_Valuation_(1)!E23)	=Present value of the operating free cash flows t_1 to t_5 + Present value TV	=SUM(F20:J20)+K21
Non-operating assets (=DCF_Valuation_(1)!E25)	=Non-operating assets t_0	=Assumptions!E203
Cash & cash equivalents (=DCF_Valuation_(1)!E26)	=Cash & cash equivalents t_0	=Assets!E19
Investments accounted for using the equity method (=DCF_Valuation_(1)!E27)	=Investments accounted for using the equity method t_0	=Assets!E10
Entity value (=DCF_Valuation_(1)!E29)	=Enterprise value t_0 + Non-operating assets t_0 + Cash & cash equivalents t_0 + Investments accounted for using the equity method t_0	=E23+E25+E26+E27
Interest-bearing liabilities t_0 (=DCF_Valuation_(1)!E31)	=Pension provisions & Other provisions t_0 + Noncurrent financial liabilities t_0 + Current financial liabilities t_0	='Auxiliary Calculations'!E63
Equity value (incl. equity attributable to non-controlling interest) (=DCF_Valuation_(1)!E33)	=Entity value – Interest-bearing liabilities t_0	=E29-E31
Equity attributable to non-controlling interest (=DCF_Valuation_(1)!E35)	=Equity attributable to non-controlling interest t_0	='Equity and Liabilities'!E11
Equity value (=DCF_Valuation_(1)!E37)	=Equity value (incl. equity attributable to non-controlling interest) – Equity attributable to non-controlling interest t_0	=E33-E35

Fig. 10.52 Determination of the company value (Excel File Corporate Finance, Worksheet DCF Valuation (1))

Discounted Cash Flow (DCF) Valuation in accordance with the WACC Approach

€ million	Actual t_0	Plan t_1	Plan t_2	Plan t_3	Plan t_4	Plan t_5	Plan TV
WACC	5,95%						
Discount factors		0,944	0,891	0,841	0,794	0,749	0,749
Operating free cash flows		2.952	3.083	3.268	3.464	4.219	4.303
Terminal value							108.861
Present value of operating free cash flows		2.786	2.747	2.748	2.749	3.160	
Present value of terminal value							81.528
Enterprise value	95.717						
+ Non operating assets	-						
+ Cash and cash equivalents	1.662						
+ Investments accounted for using the equity method	203						
Entity value	97.582						
- Interest-bearing liabilities	16.399						
Equity value (incl. equity attributable to non-controlling interest)	81.183						
- Equity attributable to non-controlling interest	86						
Equity value	81.097						

Fig. 10.53 Calculation of the Company value in Accordance with the WACC Approach for the Pharma Group (Excel File Corporate Finance, Worksheet DCF Valuation (1))

The **Enterprise Value** is the value of the company derived from operating activities (core business). It is calculated by discounting the operating free cash flows and the terminal value as of the valuation date. The enterprise value for the WACC approach amounts to €95.717 million. (`=DCF_Valuation_(1)!E23`).

The **Entity Value** is the value of the company derived from operating activities (core business) and non-operating activities. It is calculated by adding to the enterprise value the non-operating assets (such as the art collection of an entrepreneur), cash & cash equivalents (which are defined as non-operating in the model and the shares in participations valued at equity (which are also considered as non-operating in the model). The entity value for the WACC approach amounts to €97.582 million. (`=DCF_Valuation_(1)!E29`).

The **Equity Value (version 1: based on operating business activities)** is the market value of equity which follows from the operating activities. This value is used in the WACC formula and when calculating the unlevered and levered beta, since the WACC serves to discount the cash flows from operations. The equity value (version 1) is calculated by deducting from the enterprise value the interest-bearing liabilities and equity attributable to non-controlling interest. The equity value of operative business activities is used for example when calculating the equity ratio based on market values (`=Cap_Rates_(1)!E36`) and is equal to €79.318 million.

The Equity Value (version 2: based on operating and non-operating business activities) is the market value of equity which follows from the operating and

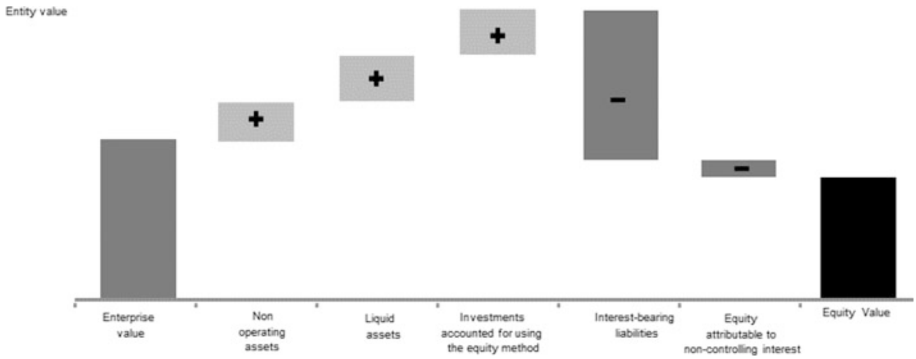


Fig. 10.54 Difference between equity value and enterprise value

non-operating activities. This value is relevant for example, if all parts of a company, without making a differentiation between operating and non-operating assets, are valued during the sales process. The equity value (version 2) is calculated by deducting from the entity value the interest-bearing liabilities and equity attributable to non-controlling interest. The equity value of the operative and non-operative business activities is equal to €81.183 million. (`=DCF_Valuation_(1)!E33`).

Furthermore a distinction must be made between an equity value which includes non-controlling interests as the result of a complete consolidation and an equity value which is stated for the shareholders of the company after non-controlling interests have been subtracted. The fully consolidated equity value amounts to €81.183 million (`=DCF_Valuation_(1)!E33`). The equity value for the providers of equity of the company amounts to €81.097 million (`=DCF_Valuation_(1)!E37`).

As Fig. 10.53 makes clear, the enterprise value is calculated by discounting all operating cash flows during the planning period and the perpetuity are discounted to t_0 and added. Figure 10.54 provides a schematic overview of the derivation of the entity value and equity value from the enterprise value. These linkages are important especially for the multiple approaches presented below.

In order to get from the enterprise value to the equity value, non-operating assets, cash & cash equivalents and shares in participations valued at equity are added and interest-bearing liabilities and equity attributable to non-controlling interest are subtracted.

4.3 Period-Specific WACC Approach

If the capital structure of a company is expected to change during the planning period, it is mandatory to utilize the period-specific WACC approach.

Changes in the capital structure can arise for example when companies are purchased using acquisition financing, in the case of major investments or changes in the ownership structure. Since debt and equity have differing costs of capital, such changes in the capital structure will have significant implications for the company value.

In any model that uses the period-specific calculation of the WACC, the financial modeler determines the company value in a retrograde manner: from the terminal value to the valuation date.

Step 1: Calculating the WACC for the terminal value
The terminal value is calculated in a first step. For the terminal value the assumption of a constant target capital structure is maintained. It follows:

$$TV = \frac{oFCF_{TV}}{WACC_{TV} - g}$$

$WACC_{TV}$ = Period-specific WACC for the terminal value

By substituting the formula for the WACC

$$WACC_{TV} = r_e \cdot \left(1 - \frac{d_{TV}}{TV}\right) + r_d \cdot \frac{d_{TV}}{TV}$$

d_{TV} = Amount of debt in the terminal value
the terminal value can be calculated as follows:

$$TV = \frac{oFCF_{TV} + (r_e - r_d) \cdot d_{TV}}{r_e - g}$$

Once the financial modeler has calculated the value for the terminal value, he can use the above formula to determine the capital structure and the WACC in the terminal value. No circularity problem arises in this case.

Step 2: Calculating the WACC for the detailed planning phase
In the second step, the WACC for the last detailed planning year and the value for the beginning of the corresponding year are determined. The financial modeler obtains the value for the end of the period by adding the operating free cash flow of period n to the terminal value. Thus the value at the beginning of the year is obtained as

$$
\begin{aligned}
Value_{1.1.n} &= \frac{Value_{31.12.n}}{(1 + WACC_n)} \\
&= \frac{TV + oFCF_n}{(1 + WACC_n)}
\end{aligned}
$$

$WACC_n =$ Period-specific WACC for period n

Substituting the formula for the WACC yields

$$
WACC_n = r_e \cdot \left(1 - \frac{d_{1.1.n}}{value_{1.1.n}}\right) + r_d \cdot \frac{d_{1.1.n}}{value_{1.1.n}}
$$

$d_{1.1.n}$ = Amount of debt at the beginning of the period n
r_d = Cost of debt after taxes

The value at the beginning of period n is obtained as follows:

$$
value_{1.1.n} = \frac{value_{31.12.n} + (r_e - r_d) \cdot d_{1.1.n}}{1 + r_e}
$$

With the help of the value at the beginning of the year it is again possible to derive the capital structure and thus the WACC for the period n.

Step by step the financial modeler calculates the value at the beginning of the year in a retrograde manner until he reaches the valuation date. It holds that:

$$
value_{31.12.t(0)} = oFCF_{t(0)} + value_{1.1.(t+1)}
$$

The value which is obtained for the valuation date is equal to the present value of the cash flows plus the terminal value. In order to arrive at the equity value of the company, the same approach that was already used in the WACC approach with constant WACC needs to be employed again.

Figure 10.55 shows the most important positions of the calculation of the company value using the approach of the period-specific WACC.

Positionen	Formulas	Excel implementation
Cost of equity (=Periodic_WACC_(1)!E7)	=Cost of equity	='Cost of Capital (1)'!$E$19
Cost of debt after taxes (=Periodic_WACC_(1)!E8)	=Cost of debt after taxes	='Cost of Capital (1)'!$E$31
Interest-bearing liabilities t_{TV} (=Periodic_WACC_(1)!J9)	=Provisions for pensions and other post-employment benefits t_{TV} + Noncurrent and current financial liabilities t_{TV}	='Auxilliary Calculations'!J63
Periodic debt ratio t_{TV} (=Periodic_WACC_(1)!J10)	=Interest-bearing liabilities t_{TV} / TV	=J9/J24
Periodic equity ratio t_{TV} (=Periodic_WACC_(1)!J11)	=1 - Interest-bearing liabil-ities t_{TV} / TV	=1-(J9/J24)
Periodic WACC in the TV (=Periodic_WACC_(1)!J12)	$=r_e$ * Periodic equity ratio t_{TV} * r_d * (1 - Periodic equity ratio t_{TV})	=J7*J11+J8*J10
Periodic WACC 01.01.t_5 (=Periodic_WACC_(1)!I12)	$=r_e$ * Periodic equity ratio $t_{01.01.t5}$ + r_d * Period-specific debt ratio $t_{01.01.t5}$)	=I7*I11+I8*I10
Value 01.01.t_6 (=TV) (=Periodic_WACC_(1)!J24)	=(oFCF$_{TV}$ + (r_e - r_d) * d_{TV}) / (r_e - g)	=(J25+(J7-J8)*J9)/(J7-Assumptions!K219)
Value 01.01.t_5 (=Periodic_WACC_(1)!I22)	=(TV + oFCF t_5 + (r_e - r_d) * d t_5) / (1 + r_e)	=(J24+I25+(I7-I8)*I$9)/(1+I7)
Value 01.01.t_4 (=Periodic_WACC_(1)!H20)	=((Wert $t_{01.01.t5}$ + oFCF t_4 + (r_{EK} - r_{FK}) * d t_4) / (1 + r_{EK})	=(I22+H25+(H7-H8)*H$9)/(1+H7)
Operating free cash flow (31.12.n) (=Periodic_WACC_(1)!E25)	Link to the worksheet Cash Flow Statement	='Cash Flow Calculation'!F31

Fig. 10.55 The most important positions in the calculation of the company value in accordance with the approach of the period-specific WACC

Enterprise value (=Periodic_WACC_(1)!E27)	Link to the value on 01.01.t_1	=E14
Non-operating assets (=Periodic_WACC_(1)!E29)	Link to the worksheet Assumptions	=Assumptions!E203
Cash & cash equivalents (=Periodic_WACC_(1)!E30)	Link to the worksheet Assets	=Assets!E19
Investments accounted for using the equity method (=Periodic_WACC_(1)!E31)	=Investments accounted for using the equity method t_0	=Assets!E10
Entity value (=Periodic_WACC_(1)!E33)	= Enterprise value + Non-operating assets t_0 + Cash & cash equivalents t_0 + Investments accounted for using the equity method t_0	=E27+E29+E30+E31
Interest-bearing liabilities t_0 (=Periodic_WACC_(1)!E35)	= Provisions for pensions and other post-employment benefits t_0 + Noncurrent financial liabilities t_0 + Current financial liabilities t_0	='Auxilliary Calculations'!E63
Equity value (incl. equity attributable to non-controlling interest) (=Periodic_WACC_(1)!E37)	= Entity value – Interest-bearing liabilities t_0	=E33-E35
Equity attributable to non-controlling interest (=Periodic_WACC_(1)!E39)	= Equity attributable to non-controlling interest t_0	='Equity and Liabilities'!E11
Equity value (=Periodic_WACC_(1)!E41)	= Equity value (incl. equity attributable to non-controlling interest) – Equity attributable to non-controlling interest t_0	=E37-E39

Fig. 10.55 (Continued)

Figure 10.56 shows the calculation of the company value of the Pharma Group using the period-specific WACC.

Discounted Cash Flow (DCF) Valuation in accordance with the Periodic WACC Approach

I million	01.01.t_1 = 31.12.t_0	01.01.t_2 = 31.12.t_1	01.01.t_3 = 31.12.t_2	01.01.t_4 = 31.12.t_3	01.01.t_5 = 31.12.t_4	01.01.t_6 = TV
Cost of equity	6,6%	6,6%	6,6%	6,6%	6,6%	6,6%
Cost of debt after taxes	2,88%	2,88%	2,88%	2,88%	2,88%	2,88%
Interest-bearing liabilities	16.399	16.855	17.440	18.157	19.013	19.393
Periodic debt ratio	17,0%	17,0%	17,1%	17,4%	17,7%	17,7%
Periodic equity ratio	83,0%	83,0%	82,9%	82,6%	82,3%	82,3%
Periodic WACC	5,96%	5,96%	5,95%	5,94%	5,93%	5,93%
Value 01.01.t1	96.186					
Value 01.01.t2		98.962				
Value 01.01.t3			101.774			
Value 01.01.t4				104.564		
Value 01.01.t5					107.315	
Value 01.01.t6 (= TV)						109.462
Operating free cash flow (31.12.t+1)	**2.952**	**3.083**	**3.268**	**3.464**	**4.219**	**4.303**
Enterprise Value	**96.186**					
+ Non operating assets	-					
+ Cash and cash equivalents	1.662					
+ Investments accounted for using the equity method	203					
Entity Value	**98.051**					
- Interest-bearing liabilities	16.399					
Equity value (incl. equity attributable to non-controlling interest)	**81.652**					
- Equity attributable to non-controlling interest	86					
Equity value	**81.566**					

Fig. 10.56 Period-specific WACC (Excel File Corporate Finance, Worksheet Periodic WACC (1))

4.4 APV Approach

4.4.1 The Rational for the APV Approach

Considering the Capital Structure at the Level of Cash Flows

The Adjusted Present Value (APV) approach just like the WACC approach is an entity approach. Similar to the WACC approach, the cash flows which accrue to all providers of capital are discounted. It is distinct from the WACC approach because of the different treatment of the influence of the capital structure on the company value. While the WACC approach completely separates the operating and the financing dimension, the capital structure is considered at the level of the cash flows in the APV approach.

> In the Adjusted Present Value (APV) approach, the market value of the total capital is determined in a first step under the assumption of complete equity financing. In a second step, the effect of debt financing on the company value is considered in the form of the so-called tax shield. It captures the tax savings which result from the tax deduction for interest paid on debt.

The APV valuation follows these steps:

1. As in the WACC approach, the operating free cash flows are determined.
2. The operating free cash flows are discounted exclusively at the return requirement of the providers of equity (even in the presence of debt), precisely at the cost of equity for the (fictitiously) unlevered company.
3. In order to arrive at the enterprise value, the present value of the so-called tax shield needs to be added, by explicitly calculating the favorable effect of debt financing on the total tax burden of the company.
4. If non-operating assets, cash & cash equivalents and investments accounted for using the equity method are added to the enterprise value, the entity value results.
5. In order to arrive at the equity value including equity attributable to non-controlling interest, the financial modeler subtracts the interest-bearing liabilities from the entity value.

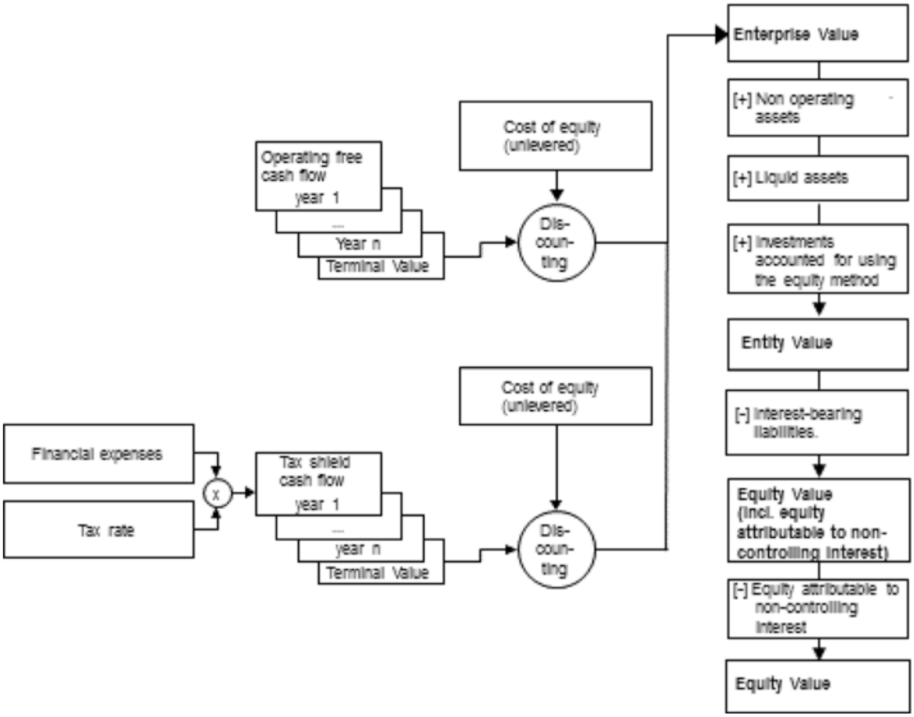


Fig. 10.57 Discounted cash flow method in accordance with the APV approach

6. The equity value (market value of the equity) of the shareholders follows once the equity attributable to non-controlling interest is subtracted.

The structure of the APV approach is illustrated in Fig. 10.57.

4.4.2 Calculating the Operating Free Cash Flow

For the APV approach the same operating free cash flows as in the WACC approach are used. The tax shield is calculated by multiplying

Position	Formulas	Excel implementation
Tax shield cash flow (=DCF_Valuation_(1)!F57)	=Interest expenses t_1 * Tax rate t_1	=F55*F56

Fig. 10.58 Calculating the tax shield cash flows

the interest expenses times the tax rate. The value indicates the tax savings that result from debt financing.

The calculation of the tax shield cash flow for year t_1 is shown in Fig. 10.58:

4.4.3 Calculating the Cost of Capital

> Since it is assumed when determining the cash flows that the company is completely financed with equity, the appropriate discount rate is the cost of equity (unlevered).

The cost of equity (unlevered) can also be derived from the CAPM.

In contrast to the WACC approach, which requires the use of a beta factor of a company that also holds debt, the beta factor of a company which has no debt must be used under the assumption of no leverage. In our case of the Pharma Group, the unlevered beta is equal to 0.83.

The main positions in the calculation of the company value are presented with reference to the example of the year t_1 and the terminal value in Fig. 10.59.

The calculation of the cost of equity (unlevered) can be seen in Fig. 10.60.

Position	Formulas	Excel implementation for t_1
Cost of equity (unlevered) (=DCF_Valuation_(1)!E45)	=Cost of equity (unlevered) from the sheet Cost of Capital (1)	='Cost of Capital (1)'!E55
Discount factors (=DCF_Valuation_(1)!F46)	=1/(1+Cost of equity (unlevered))^1	=1/(1+$E$45)^Assumptions!F211
Operating free cash flows DCF_Valuation_(1)!F47)	=oFCF t_1 from the sheet Cash Flow Calculation	='Cash Flow Calculation'!F31
Terminal value of the operating free cash flows (=DCF_Valuation_(1)!K48)	=oFCF t_{TV}/(Cost of equity (unlevered) – Growth rate)	=K47/(E45-Assumptions!K219)
Present value of the operating free cash flows (=DCF_Valuation_(1)!F50)	= Discount factor t_1 * oFCF t_1	=F46*F47
Present value of the terminal value (=DCF_Valuation_(1)!K51)	=Discount factor t_{TV} * TV	=K46*K48
Cost of equity (unlevered) (=DCF_Valuation_(1)!E53)	=Cost of equity (unlevered) from the sheet Cost of Capital (1)	='Cost of Capital (1)'!E55
Discount factors (=DCF_Valuation_(1)!F54)	=1/(1+Cost of equity (unlevered))^1	=1/(1+$E$53)^Assumptions!F211
Financial expenses (=DCF_Valuation_(1)!F55)	=Interest expenses t_1 from the sheet Income Statement	='Income Statement'!F23
Tax rate (=DCF_Valuation_(1)!F56)	=Income taxes t_1 from the sheet Assumptions	=Assumptions!$F$135
Tax shield cash flows (=DCF_Valuation_(1)!F57)	=Interest expenses t_1 × Tax rate	=F55*F56
Terminal value of the tax shields (=DCF_Valuation_(1)!K58)	=Tax shield t_{TV}/(Cost of equity (unlevered) – Growth rate)	=K57/(E45-Assumptions!K219)
Present value of the tax shield cash flows (=DCF_Valuation_(1)!F60)	=Discount factor t_1 * Tax shield t_1	=F46*F57
Present value of the terminal value (=DCF_Valuation_(1)!K61)	=Discount factor t_{TV} * TV	=K46*K58

Fig. 10.59 The main positions in the calculation of the company value using the example of year t_1 and the terminal value

Sum of the present values of the operating free cash flows and the terminal value (=DCF_Valuation_(1)!E63)	=Present values of the operating free cash flows t_1 to t_5 + Present value of oFCF$_{TV}$	=SUM(F50:K50)+K51
Sum of the present values of the tax shield cash flows and the terminal value (=DCF_Valuation_(1)!E64)	=Present values of the tax shield cash flows t_1 to t_5 + Present value tax shield t_{TV}	=SUM(F60:K60)+K61
Enterprise value (=DCF_Valuation_(1)!E65)	=Present value of the operating free cash flows t_1 to t_5 + Present value oFCF$_{TV}$ + Present value of the tax shield cash flows t_1 to t_5 + Present value tax shield t_{TV}	=E63+E64
Non-operating assets (=DCF_Valuation_(1)!E67)	=Non-operating assets t_0	=Assumptions!E203
Cash and cash equivalents (=DCF_Valuation_(1)!E68)	=Cash and cash equivalents t_0	=Assets!E19
Investments accounted for using the equity method (=DCF_Valuation_(1)!E69)	=Investments accounted for using the equity method t_0	=Assets!E10
Entity value (=DCF_Valuation_(1)!E71)	=Enterprise value + Non-operating assets t_0 + Cash and cash equivalents t_0 + Investments accounted for using the equity method t_0	=E65+E67+E68+E69
Interest-bearing liabilities (=DCF_Valuation_(1)!E73)	=Provisions for pensions and other post-employment benefits t_0 + Noncurrent financial liabilities t_0 + Current financial liabilities t_0	='Auxilliary Calculations'!E63
Equity value (incl. equity attributable to non-controlling interest) (=DCF_Valuation_(1)!E75)	=Entity value – Interest-bearing liabilities t_0	=E71-E73
Equity attributable to non-controlling interest (=DCF_Valuation_(1)!E77)	=Equity attributable to non-controlling interest t_0	='Equity and Liabilities'!E11
Equity value (=DCF_Valuation_(1)!E79)	=Equity value (incl. equity attributable to non-controlling interest) – Equity attributable to non-controlling interest t_0	=E75-E77

Fig. 10.59 (Continued)

	A	B	C	D	E
46					
47		**APV Approach**			
48					
49		**Cost of Equity (unlevered)**			t_0
50					
51		Risk-free rate of return			1.80%
52		Beta (unlevered)			0.83
53		Market risk premium			5.00%
54					
55		**Cost of equity (unlevered)**			**5.94%**

Fig. 10.60 Calculating the cost of equity (unlevered) (Excel File Corporate Finance, Worksheet Cost of Capital (1)

4.4.4 Calculating the Company Value

Now that the operating free cash flows and tax shields which are relevant for the valuation during the planning period and the cost of capital of the fictitiously unlevered company have been established, the company value can be determined.

The present values of the free cash flows and the tax shield (always including the terminal value) are added up to yield the enterprise value. The formula for the calculation of the company value according to the APV approach is:

$$\text{Present value} = \sum_{t=1}^{n} \frac{oFCF_t}{(1+r_e^u)^t} + \underbrace{\frac{oFCF_{TV}}{(r_e^u - g)}}_{=TV_{oFCF}} x \frac{1}{(1+r_e^u)^n} + \sum_{t=1}^{n} \frac{Tax\ rate \cdot r_d \cdot d}{(1+r_e^u)^t}$$
$$+ \underbrace{\frac{Tax\ rate \cdot r_d \cdot d_{TV}}{(r_e^u - g)}}_{=TV_{TaxShields}} x \frac{1}{(1+r_e^u)^n}$$

$$= \sum_{t=1}^{n} \frac{oFCF_t}{(1+r_e^u)^t} + \frac{TV_{oFCF}}{(1+r_e^u)^n} + \sum_{t=1}^{n} \frac{Tax\ rate \cdot r_d \cdot d_t}{(1+r_e^u)^t} + \frac{TV_{TaxShields}}{(1+r_e^u)^n}$$

The present values of the free cash flows, the tax shields and the respective terminal values as well as the non-operating assets, cash & cash equivalents and investments accounted for using the equity method make up the entity value. From this value, the interest-bearing liabilities and equity attributable to non-controlling interest need to be deducted to arrive at the market value of equity (=equity value).

Figure 10.61 shows the calculation of the company value of the Pharma Group according to the APV approach.

Discounted Cash Flow (DCF) Valuation in accordance with the APV Approach

I million	Acutal t_0	Plan t_1	Plan t_2	Plan t_3	Plan t_4	Plan t_5	Plan TV
Cost of equity (unlevered)	5.94%						
Discount factors		0.944	0.8910	0.841	0.794	0.749	0.749
Operating free cash flows		2,952	3,083	3,268	3,464	4,219	4,303
Terminal value							109,206
Present value of operating free cash flows		**2,787**	**2,747**	**2,749**	**2,750**	**3,161**	
Present value of terminal value							**81,835**
Cost of equity (unlevered)	5.94%						
Discount factors		0.944	0.891	0.841	0.794	0.749	0.749
Financial expenses		632	652	676	706	730	744
Tax rate		24%	24%	24%	24%	24%	24%
Tax shield cash flows		153	158	164	171	177	181
Terminal value							4,584
Present value of tax shield cash flows		**145**	**141**	**138**	**136**	**133**	
Present value of terminal value							**3,435**
Sum of present values of operating free cash flows and TV	96,029						
Sum of present values of tax shield cash flows and TV	4,128						
Enterprise value	**100,157**						
+ Non operating assets	0						
+ Cash and cash equivalents	1,662						
+ Investments accounted for using the equity method	203						
Entity value	**102,022**						
- Interest-bearing liabilities	16,399						
Equity value (incl. equity attributable to non-controlling interest)	**85,623**						
- Equity attributable to non-controlling interest	86						
Equity value	**85,537**						

Fig. 10.61 Calculating the company value according to the APV approach (Excel File Corporate Finance, Worksheet DCF Valuation (1))

4.5 Equity Approach

4.5.1 The Structure of the Equity Approach

In contrast to the entity approaches, the market value of equity (equity value) is directly determined in the equity approach. Accordingly, the equity approach works with cash flows that are available exclusively to the providers of equity. These cash flows are called cash flows to equity. The cash flows to equity are discounted using the cost of equity.

> In the equity approach only those cash flows which are available exclusively to the providers of equity are discounted. Discounting is thus done at the cost of equity (levered). The equity value follows directly from this method.

The equity approach involves the following steps:

1. The cash flows to equity are determined. These are available to the providers of equity.
2. The cash flows to equity are discounted at cost of equity (levered) (in the APV approach this was the return expectation for the fictitiously unlevered company).
3. Summation of the present value of the cash flows to equity and the terminal value determined in that manner as well as non-operating assets, cash & cash equivalents and investments accounted for using the equity method yields the equity value (market value of equity).

The company valuation according to the equity approach is again summarized in Fig. 10.62.

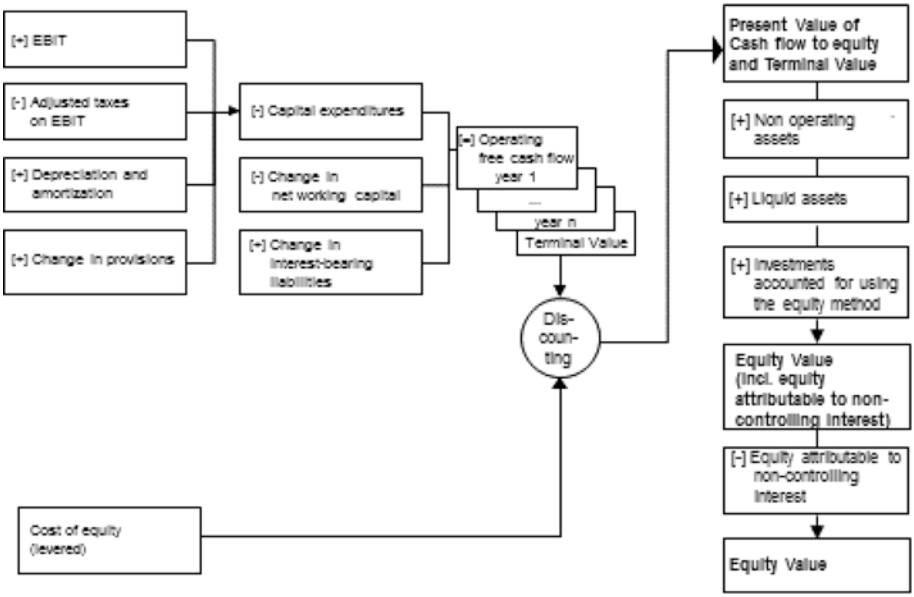


Fig. 10.62 Discounted cash flow method according to the equity approach

4.5.2 Calculating the Cash Flow to Equity

Cash Flow to Equity belongs exclusively to the Providers of Equity

The equity approach requires the calculation of those cash flows used in the valuation which only belong to the providers of equity. The cash flows resulting from debt financing, such as future interest on debt (including the resulting tax effects) as well as any change in the level of debt (borrowing and repayment debt) are included in the calculations in contrast to the determination of the oFCF. The cash flows calculated in that manner are called cash flows to equity (CFtE).

In the equity approach, no separation of the operating and financing activities, which is familiar from the entity approach, takes place.

The cash flow to equity is determined according to the following scheme. The items which differ from the operating free cash flow are marked in bold. This general scheme again needs to be aligned to the specific circumstances of the valuation at individual companies:

	Earnings before interest and taxes (EBIT)
-	**Interest expense**
=	Operating earnings before taxes (EBT)
-	**Taxes on operating earnings before taxes**
=	Operating earnings after taxes
+	Depreciation and amortization
+	Change in provisions
-	Investments in property, plant and equipment
-	Change in net working capital
+	**Change in noncurrent financial liabilities**
+	**Change in current financial liabilities**
=	Cash flow to equity (CFtE)

First, interest payments must be subtracted from the operating earnings before interest and taxes. In the following, the corporate taxes are calculated on the basis of the resulting operating earnings before taxes. The calculation of the corporate taxes thus includes the savings from the interest payment on debt. This means that in contrast to the operating free cash flows, the tax savings (tax shield) are captured at the appropriate place, namely as part of the cash flows. As an additional difference to the entity approach, the change in interest-bearing debt are also taken into consideration. Debt repayments reduce the cash flow to equity, while the issuance of fresh debt leads to an increase. The forecast of the cash flows to equity thus requires exact planning of the development of debt.

The calculation of the cash flow to equity is presented with reference to year t_1 in Fig. 10.63.

Figure 10.64 shows the calculation of the cash flows to equity using the example of the Pharma Group.

Position	Formulas	Excel implementation for t_1
Earnings before interest and taxes (EBIT) (=Cash Flow Calculation!F40)	=EBIT t_1 from the sheet Income Statement	=Income Statement!F19
Interest expense (=Cash Flow Calculation!F41)	=Interest expenses t_1	= Income Statement!F23
Operating earnings before taxes (EBT) (=Cash Flow Calculation!F43)	=EBIT t_1 - Interest expenses t_1	=F40-F41
Taxes on operating earnings before taxes (=Cash Flow Calculation!F45)	=EBT t_1 * Tax rate t_1	=F43*Assumptions!F135
Operating earnings after taxes (=Cash Flow Calculation!F47)	=EBT t_1 - Taxes t_1	=F43-F45
Depreciation and amortization (=Cash Flow Calculation!F49)	= Depreciation and amortization t_1	= Auxiliary Calculations!F33
Change in other provisions (=Cash Flow Calculation!F50)	=Other provisions t_1 – Other provisions t_0	= Auxiliary Calculations!F76- Auxiliary Calculations!E76
Investment in long-term assets (with the exception of deferred taxes) (=Cash Flow Calculation!F51)	= Investment from the sheet Auxiliary Calculations	='Auxiliary Calculations'!F18

Fig. 10.63 Calculating the cash flow to equity

Change in net working capital (=Cash Flow Calculation!F52)	= Net working capital from the sheet Auxiliary Calculations	='Auxiliary Calculations'!F49 - 'Auxiliary Calculations'!E49
Change in other noncurrent liabilities (=Cash Flow Calculation!F53)	= Other noncurrent liabilities t_1 – Other noncurrent liabilities t_0	='Equity and Liabilities'!F18-'Equity and Liabilities'!E18
Change in deferred taxes and income tax liabilities (=Cash Flow Calculation!F54)	= Deferred taxes and income tax liabilities t_1 – Deferred taxes and income tax liabilities t_0	='Auxiliary Calculations'!F90 - 'Auxiliary Calculations'!E90
Change in pension provisions (=Cash Flow Calculation!F55)	=Pension provisions t_1 – Pension provisions t_0	='Equity and Liabilities'!F15-'Equity and Liabilities'!E15
Change in noncurrent financial liabilities (=Cash Flow Calculation!F56)	=Noncurrent financial liabilities t_1 - Noncurrent financial liabilities t_0	='Equity and Liabilities'!F17-'Equity and Liabilities'!E17
Change in current financial liabilities (=Cash Flow Calculation!F57)	=Current financial liabilities t_1 - Current financial liabilities t_0	='Equity and Liabilities'!F25-'Equity and Liabilities'!E25
Cash flow to equity (=Cash Flow Calculation!F59)	=Operating earnings after taxes + Depreciation and amortization + Change in other provisions + Investment in long-term assets (with the exception of deferred taxes) + Change in other noncurrent liabilities + Change in deferred taxes and income tax liabilities + Change in pension provisions + Change in noncurrent financial liabilities + Change in current financial liabilities	=F47+F49+F50-F51-F52+F53+F54+F55+F56+F57

Fig. 10.63 (Continued)

Cash flow to Equity

€ million	Plan t_1	Plan t_2	Plan t_3	Plan t_4	Plan t_5	Plan TV
Operating result (EBIT)	4,757	5,043	5,345	5,666	5,779	5,895
- Financial expenses	632	652	676	706	730	744
Earnings before taxes (EBT)	**4,126**	**4,391**	**4,669**	**4,960**	**5,050**	**5,151**
- Income taxes	1,001	1,066	1,133	1,204	1,226	1,250
Earnings after taxes	**3,124**	**3,326**	**3,536**	**3,756**	**3,824**	**3,901**
+ Depreciation and amortization	2,896	2,896	2,896	2,896	2,896	2,896
+ Change in other provisions	0	0	0	0	134	137
- Capital expenditures	2,896	2,896	2,896	2,896	2,896	2,896
- Change in net working capital	651	736	780	827	292	298
+ Change in other liabilities (noncurrent)	0	0	0	0	0	0
- Change in deferred taxes (asset side), deferred taxes (liabilities side), and income tax liabilities	0	0	0	0	0	0
+ Change in provisions for pensions and other post-employment benefits	737	810	892	981	216	220
+ Change in noncurrent financial liabilities	-487	-445	-406	-371	78	79
+ Change in current financial liabilities	206	219	232	246	87	89
Cash flow to Equity	2,930	3,174	3,474	3,785	4,046	4,127

Fig. 10.64 Calculating the cash flow to equity (Excel File Corporate Finance, Worksheet Cash Flow Statement)

4.5.3 Calculating the Cost of Equity

When determining the cost of equity, it is assumed that the company holds debt as in the WACC approach. Correspondingly, the determination of the cost of equity is based on the CAPM as in the WACC approach. In the example of the Pharma Group, the cost of equity (levered) is equal to 6.6%.

4.5.4 Calculating the Company Value

Once the relevant cash flows to equity for the planning periods have been determined and the calculation of the cost of equity has been completed, the company value can be calculated.

In line with the procedure chosen in the WACC approach and the APV approach, the cash flow of the last planning period in the equity approach also needs to be adjusted to meet the growth scenario for the terminal value.

Position	Formulas	Excel implementation in t_1
Cost of equity of the indebted company (=DCF_Valuation_(1)!E88)	=Cost of equity (indebted)	='Cost of Capital (1)'!E69
Discount factors (=DCF_Valuation_(1)!F89)	=1/(1 + Cost of equity (indebted))[1]	=1/(1+$E$88)^Assumptions!F211
Cash flow to equity (=DCF_Valuation_(1)!F90)	=CFtE t_1	='Cash Flow State-ment'!F59
Terminal Value (=DCF_Valuation_(1)!K91)	=CFtE t_{TV}/(Cost of equity (indebted) – Growth rate)	=K90/(E88-Assumptions!K219)
Present values of the cash flows to equity (=DCF_Valuation_(1)!F93)	=Discount factor t_1 * CFtE t_1	=F89*F90
Present value of the terminal value (=DCF_Valuation_(1)!K94)	= Discount factor t_{TV} * TV	=K89*K91
Sum of the present values of the cash flows to equity and the terminal value (=DCF_Valuation_(1)!E96)	=Present values of the CFtE t_1 to t_5 + Present value of the terminal value	=SUM(F93:K93)+K94
Non-operating assets (=DCF_Valuation_(1)!E98)	= Non-operating assets t_0 from the sheet Assumptions	=Assumptions!E203
Cash & cash equivalents (=DCF_Valuation_(1)!E99)	= Cash & cash equivalents t_0 from the sheet Assets	='Assets'!E19
Investments accounted for using the equity method (=DCF_Valuation_(1)!E100)	= Investments accounted for using the equity method t_0	='Equity and Liabili-ties'!E10
Equity value (incl. equity attributable to non-controlling interest) (=DCF_Valuation_(1)!E102)	= Sum of the present values of the cash flows to equity and the terminal value t_0 + Non-operating assets t_0 + Cash & cash equivalents t_0 + Investments accounted for using the equity method t_0	=E96+E98+E99+E100
Equity attributable to non-controlling interest (=DCF_Valuation_(1)!E104)	= Equity attributable to non-controlling interest t_0	=Equity and Liabili-ties!E11
Equity value (=DCF_Valuation_(1)!E106)	= Equity value (incl. equity attributable to non-controlling interest) – Equity attributable to non-controlling interest t_0	=E102-E104

Fig. 10.65 The most important positions in the calculation of the company value according to the equity approach

Discounted Cash Flow (DCF) Valuation in accordance with the Equity Approach

€ million	Actual t_0	Plan t_1	Plan t_2	Plan t_3	Plan t_4	Plan t_5	Plan TV
Cost of equity (levered)	6.59%						
Discount factors		0.938	0.8802	0.826	0.775	0.727	0.727
Cash flows to equity		2,930	3,174	3,474	3,785	4,046	4,127
Terminal value							89,947
Present value of cash flows to equity		2,749	2,794	2,868	2,933	2,941	
Present value of terminal value		-	-	-	-	-	65,378
Sum of present values of cash flows to equity and TV	79,663						
+ Non operating assets	0						
+ Cash and cash equivalents	1,662						
+ Investments accounted for using the equity method	203						
Equity value (incl. equity attributable to non-controlling interest)	81,528						
- Equity attributable to non-controlling interest	86						
Equity value	81,442						

Fig. 10.66 Calculating the company value according to the equity approach (Excel File Corporate Finance, Worksheet DCF_Valuation_(1))

The present values of the cash flows to equity and the terminal value combined represent the company value. The formulas to calculate the market value of equity (equity value) are as follows:

$$\text{Present Value} = \sum_{t=1}^{n} \frac{CFtE_t}{(1+r_e)^t} + \frac{TV_{CFtE}}{(1+r_e)^n}$$

Finally the non-operating assets, cash & cash equivalents, and investments accounted for using the equity method are added and equity attributable to non-controlling interest is deducted.

The most important positions in the calculation of the company value using the example of the year t_1 and the terminal value are found in Fig. 10.65.

Figure 10.66 presents the calculation of the company value of the Pharma Group according to the equity approach.

4.6 Sensitivity Analysis

As presented in the chapter Excel Workshop and the chapter Model Review, the analysis phase is of decisive importance in the financial modeling process. No unique numerical solution can be expected for complex tasks such as the valuation of a company. Instead it is the task of the financial modeler to assess and interpret the results and to draw appropriate conclusions. The method of sensitivity analysis provides support to the financial modeler in this regard.

> The sensitivity analysis considers the effects of possible changes in the most important value drivers on the company value.

It provides information about possible ranges of the value drivers and the effect of changes on the company value. This in turn provides valuable information about value drivers that are particularly relevant in a company valuation. Thus the sensitivity analysis is a key instrument that can be used to justify the results obtained and to assess the stability of a valuation model.

As discussed in the Excel workshop, Excel offers the possibility to create data tables, a useful instrument to compare results of an equation if one of the parameters is changed. This method is thus very well suited to conduct a sensitivity analysis involving two value drivers.

Using the example of the Pharma Group, we provide a sensitivity analysis for the WACC approach with constant WACC, the APV approach, the equity approach and the period-specific WACC approach on the following value drivers:

- WACC/Cost of equity of the levered company /Cost of equity of the unlevered company and
- Growth rate in the terminal value

When conducting a sensitivity analysis using data tables, it must be assured that the calculation of the company value and the sensitivity analysis are on the same worksheet. Therefore we initially copied the worksheet `DCF_Valuation_(1)` and renamed it to `DCF_(1)_Sensitivity_Analysis`.

In the rows `18`, `50`, `61` and `95` an additional row Growth of the Terminal Value was added, since every value driver must be entered as a cell in the worksheet. After that, the tables for the sensitivity analysis were set up. Using the example of the WACC approach, this will be presented in the following.

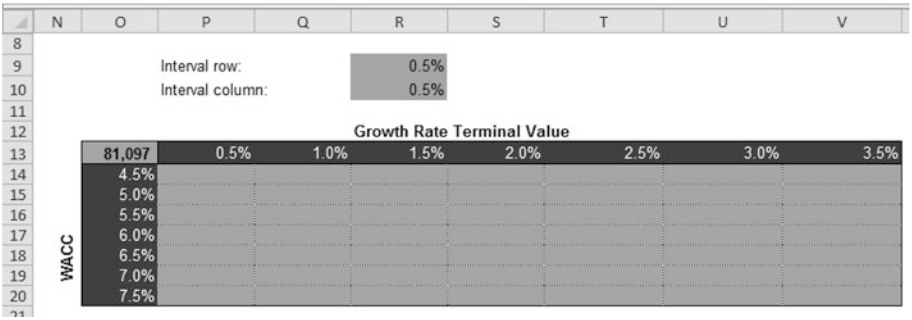
The cell `O13` was linked with the cell `E38` in order to display the equity value (market value of equity). In the cells `P13` to `V13` different values were entered for the value driver "Growth of the Terminal Value" and in the cells `O14`to `O20` different values were entered for the value driver "WACC." The intervals for the rows and columns can be adjusted individually and can be found in the assumptions.

The table to conduct the sensitivity analysis now looks as follows (see Fig. 10.67):

The following steps are needed to conduct the sensitivity analysis (see Fig. 10.68):

1. Mark the area `O13:V20`.
2. Go to the function *Data Tables via Data* ➲ *Data Tools* ➲ *What-If-Analysis* ➲ *Data Table*.
3. In the dialogue field *Values from Row,* enter the row for the growth of the terminal value `$K$18` and for *Values from Column,* enter the cell of the WACC `$E$15`.

As a result, you will receive a table with two variables. Targeted variations in the growth rate of the terminal value and the WACC help



Interval row:	0.5%						
Interval column:	0.5%						
			Growth Rate Terminal Value				
81,097	0.5%	1.0%	1.5%	2.0%	2.5%	3.0%	3.5%
4.5%							
5.0%							
5.5%							
6.0%							
6.5%							
7.0%							
7.5%							

Fig. 10.67 Table to conduct the sensitivity analysis (Excel File Corporate Finance, Worksheet DCF (1) Sensitivity Analysis)

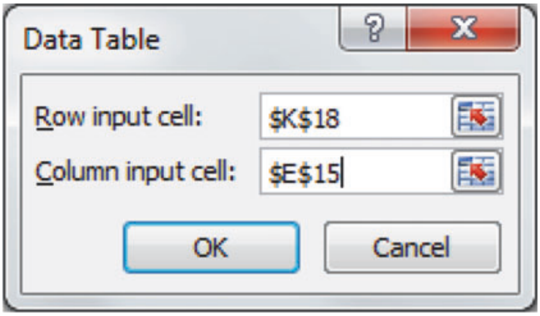
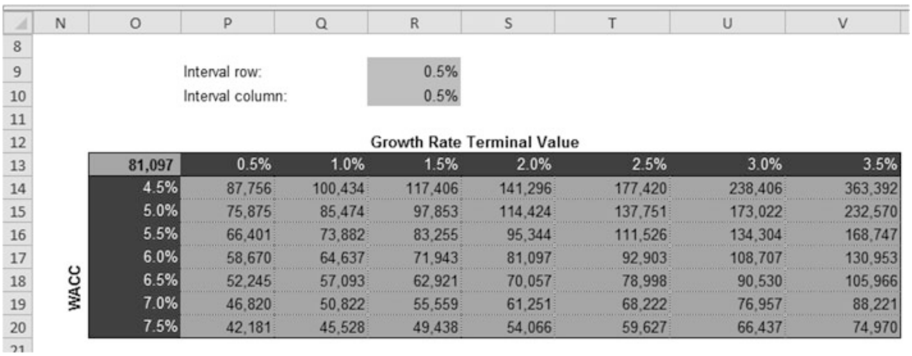


Fig. 10.68 Sensitivity analysis in two steps



Interval row:	0.5%						
Interval column:	0.5%						
			Growth Rate Terminal Value				
81,097	0.5%	1.0%	1.5%	2.0%	2.5%	3.0%	3.5%
4.5%	87,756	100,434	117,406	141,296	177,420	238,406	363,392
5.0%	75,875	85,474	97,853	114,424	137,751	173,022	232,570
5.5%	66,401	73,882	83,255	95,344	111,526	134,304	168,747
6.0%	58,670	64,637	71,943	81,097	92,903	108,707	130,953
6.5%	52,245	57,093	62,921	70,057	78,998	90,530	105,966
7.0%	46,820	50,822	55,559	61,251	68,222	76,957	88,221
7.5%	42,181	45,528	49,438	54,066	59,627	66,437	74,970

Fig. 10.69 Table with completed sensitivity analysis (Excel File Corporate Finance, Worksheet DCF (1) Sensitivity Analysis)

to assess the effects on the company value. Figure 10.69 shows the table once the sensitivity analysis has been conducted.

4.7 Scenario Analysis

The scenario analysis was initially presented in the chapter `Excel Workshop` and again discussed in the chapter `Model Review`.

Initially we want to present a scenario analysis

- with the Excel Scenario-Manager and then
- without the Excel Scenario-Manager.

4.7.1 Scenario Analysis with the Excel Scenario-Manager

In the scenario analysis with the Excel Scenario-Manager we follow the approach described in the chapter Excel Workshop. We use the example of the discounted cash flow (DCF) valuation with the WACC approach (market values) for the scenario analysis. The scenario analysis can also be used for the other DCF valuation methods.

Starting point for the scenario analysis with the Excel Scenario-Manager is the calculation of the company value with the WACC approach from the worksheet `DCF_Valuation_(1)`, which was copied into the worksheet `DCF_(1)_Scenario analysis`.

In addition, the cells which are changed during the scenario analysis are the WACC and the operating free cash flows. The equity value was chosen for the result cell (see Fig. 10.70).

The scenario analysis is started via *Data* ➲ *Data Tools* ➲ *What-If Analysis* ➲ *Scenario-Manager.* Then the values are entered for the scenarios as explained in the Excel Workshop.

The scenario report is compiled on a separate worksheet as presented in Fig. 10.71.

Changing Cells	Base Case	Worst Case	Best Case
WACC	5.95%	5.95%	5.95%
Operating free cash flows t1	2,952	3,000	3,100
Operating free cash flows t2	3,083	3,100	3,200
Operating free cash flows t3	3,268	3,300	3,400
Operating free cash flows t4	3,464	3,500	3,600
Operating free cash flows t5	4,219	4,200	4,300
Operating free cash flows tTV	4,303	4,300	4,400

Result Cell	
Equity value	81,097

Fig. 10.70 Changing cells and result cell for the scenario analysis (Excel File Corporate Finance, Worksheet DCF (1) Scenario analysis)

Scenario Summary	Current Values:	Base Case	Worst Case	Best Case
Changing Cells:				
WACC	5.95%	5.95%	5.95%	5.95%
Operating_free_cash_flows_t1	2,952	2,952	2,900	3,100
Operating_free_cash_flows_t2	3,083	3,083	3,000	3,200
Operating_free_cash_flows_t3	3,268	3,268	3,200	3,400
Operating_free_cash_flows_t4	3,464	3,464	3,400	3,600
Operating_free_cash_flows_t5	4,219	4,219	4,200	4,300
Operating_free_cash_flows_tTV	4,303	4,303	4,300	4,400
Result Cells:				
Equity_Value	81,097	81,097	80,791	83,454

Fig. 10.71 Scenario report (Excel File Corporate Finance, Worksheet DCF (1) Scenario Report)

4.7.2 Scenario Analysis without the Excel Scenario-Manager

It is also possible to conduct a scenario analysis without the support of the Excel Scenario-Manager (see PwC, 2010, pp. 38 following). This somewhat more elaborate method allows for variable scenario values and is particularly meaningful if a large number of scenarios are to be evaluated or assessed.

The scenario analysis relies on the following five steps:

1. Initially the input parameters and their values in the various scenarios are determined. Again we will work with the three scenarios worst case, base case and best case.
2. In the next step we compile a table of scenarios which is structured as shown in Fig. 10.72. The input values are identical to those from the Excel Scenario-Manager. Column C is initially left blank.
3. In the next step, the *INDEX* function is applied. The *INDEX* function makes it possible to quickly and comfortably select the various scenarios.

   The *INDEX* function returns a value or the link to a value from a table or a range. The function INDEX exists in two versions: the array form and the reference form. In our scenario analysis we use the array form.

   The *INDEX* function is entered in the cells `C5` to `C12`. The cell `C5` determines the scenario to be displayed in Column `C` (see Fig. 10.73).

	A	B	C	D	E	F	G
1							
3							
4		Scenarios					
5		Select scenario	Base Case		Worst Case	Base Case	Best Case
6		WACC	5.95%	%	5.95%	5.95%	5.95%
7		Operating free cash flows t1	2,952	€ million	2,900	2,952	3,100
8		Operating free cash flows t2	3,083	€ million	3,000	3,083	3,200
9		Operating free cash flows t3	3,268	€ million	3,200	3,268	3,400
10		Operating free cash flows t4	3,464	€ million	3,400	3,464	3,600
11		Operating free cash flows t5	4,219	€ million	4,200	4,219	4,300
12		Operating free cash flows tTV	4,303	€ million	4,300	4,303	4,400

Fig. 10.72 Structure of the scenario table (Excel File Corporate Finance, Worksheet DCF (1) Scenario analysis (2))

Position	Formeln	Excel-Umsetzung
Determination of the scenario (=DCF_(1)_Scenario analysis_(2)!C5)	=INDEX(Matrix;Row;Column)	=INDEX(E5:G5;1;$C$3)
Determination of the scenario values (=DCF_(1)_Scenario analysis_(2)!C6)	=INDEX(Matrix;Row;Column)	=INDEX(E6:G6;1;$C$3)

Fig. 10.73 Implementation of the INDEX function

The syntax of the *INDEX* function is: =INDEX(Matrix;Row;Column)

The *INDEX* function =INDEX(E5:G5;1;$C$3) can be explained as follows:

- Matrix is the cell range, in which the search takes place. In our example: E5:G5
- Row provides the position of the row in the matrix, from which the value is to be taken. In our example: 1 stands for the first row of the matrix, which only consists of one row.
- Column gives the number of the column from which the target value is to be returned. In our example: $C$3. Here the numbers 1, 2 or 3 can be entered, which represent the scenarios Worst Case, Base Case und Best Case.

4. In the next step we insert a combo box for the convenient selection of the scenarios. Combo boxes are already familiar from the Excel Workshop. They are selected as follows: *Developer* ➲ *Insert* ➲ *Combo Box.*

   The combo box is moved to cell C3. It is important to note that this cell may not be deleted!

   Right-clicking with the mouse on the combo box allows the formatting as shown in Fig. 10.74.

5. Finally the values of the cells C6 to C12 are connected to the model with the help of a simple link. Once the scenario has been selected, the model calculates the corresponding company value.

Figure 10.75 provides an overview of the scenario analysis.

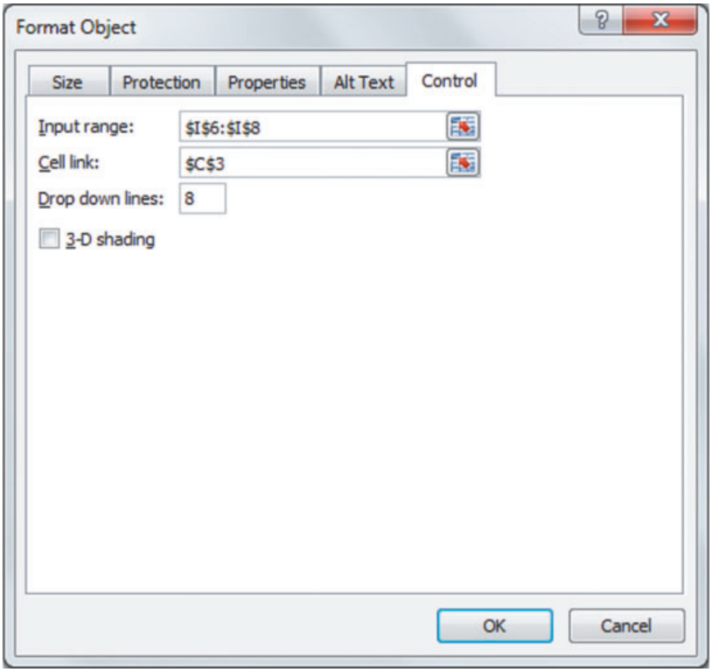
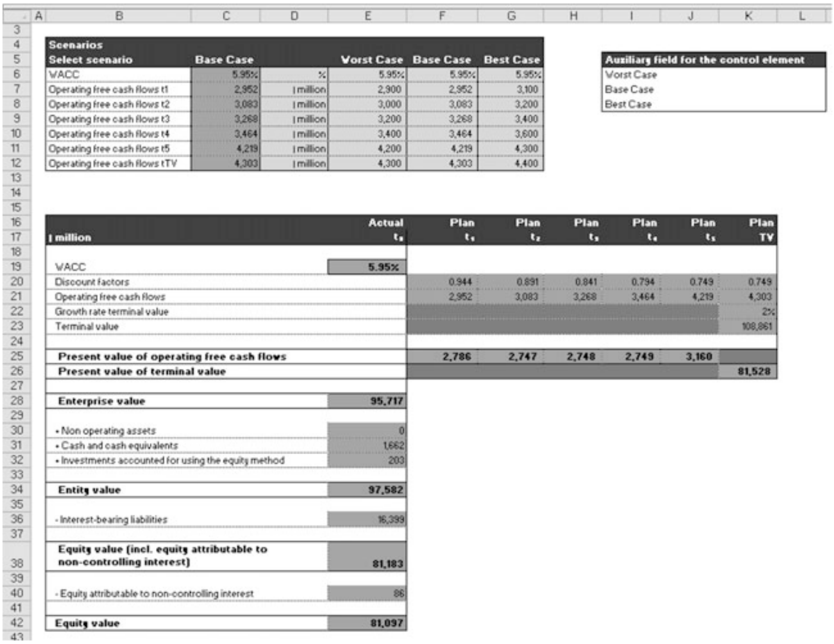


Fig. 10.74 Formatting the combo box (Excel File Corporate Finance, Worksheet DCF (1) Scenario analysis (2))



Scenarios					
Select scenario	Base Case		Vorst Case	Base Case	Best Case
VACC	5.95%	%	5.95%	5.95%	5.95%
Operating free cash flows t1	2,952	I million	2,900	2,952	3,100
Operating free cash flows t2	3,083	I million	3,000	3,083	3,200
Operating free cash flows t3	3,268	I million	3,200	3,268	3,400
Operating free cash flows t4	3,464	I million	3,400	3,464	3,600
Operating free cash flows t5	4,219	I million	4,200	4,219	4,300
Operating free cash flows tTV	4,303	I million	4,300	4,303	4,400

Auxiliary field for the control element
Vorst Case
Base Case
Best Case

I million	Actual t_0	Plan t_1	Plan t_2	Plan t_3	Plan t_4	Plan t_5	Plan TV
VACC	5.95%						
Discount factors		0.944	0.891	0.841	0.794	0.749	0.749
Operating free cash flows		2,952	3,083	3,268	3,464	4,219	4,303
Growth rate terminal value							2%
Terminal value							108,861
Present value of operating free cash flows		**2,786**	**2,747**	**2,748**	**2,749**	**3,160**	
Present value of terminal value							**81,528**
Enterprise value	**95,717**						
+ Non operating assets	0						
+ Cash and cash equivalents	1,662						
+ Investments accounted for using the equity method	203						
Entity value	**97,582**						
- Interest-bearing liabilities	16,399						
Equity value (incl. equity attributable to non-controlling interest)	**81,183**						
- Equity attributable to non-controlling interest	86						
Equity value	**81,097**						

Fig. 10.75 Overview of the scenario analysis (Excel File Corporate Finance, Worksheet DCF (1) Scenario analysis (2))

4.8 Company Valuation for Professionals

A comparison of the three valuation methods surprisingly reveals that they lead to different values, even though all three methods should theoretically yield identical results. Figure 10.76 compares the results of the different approaches in one table:

Method of company valuation	Interest rate	Value
Discounted cash flow (DCF) valuation using the WACC approach (market values)	5.95%	81,097
Discounted cash flow (DCF) valuation according to the APV approach	5.94%	85,537
Discounted cash flow (DCF) valuation according to the equity approach	6.59%	81,442
DCF valuation according to the period-specific WACC approach with constant cost of capital		81,566

Fig. 10.76 Brief overview of the company results up to this point

In the following, it will be explained why there are deviations in the company value and which assumptions are needed to obtain identical results. As an example, these adjustments can be reproduced in the worksheets `Cost_of_Capital_(2)` and `DCF_Valuation_(2)`.

4.8.1 Financing Assumptions

> The requirements needed to arrive at an identical company value in the WACC, APV and equity approach relate to the cost of capital.

In the WACC approach (standard and period-specific) and the equity approach there is a difference in the calculation of interest on the interest-bearing liabilities. In the WACC approach, the nominal rate on debt is used in the formula. In the equity approach, meanwhile, the effective cost of debt is applied. This difference is one reason for divergent company values. In order to work with the same interest rate on debt in both approaches, we recommend that the **effective interest rate on debt** is also used in the WACC approach. It is determined specifically for each period as the ratio of interest expenses at the end of the period and the interest-bearing liabilities at the beginning of the period.

In addition, the riskiness of the debt, the so-called **debt beta** enters the determination of the cost of capital.

In the CAPM it is assumed that every company can borrow without limit at the risk-free rate of interest. This means that the interest rate on debt is equal to the risk-free rate of interest. This assumption is in line with the theory of Modigliani/Miller.

In applied work in corporate finance everybody is aware of the fact that debt is also risky. If the providers of debt assume parts of the operating risk, they receive compensation in the form of a risk-adjusted premium on the risk-free rate of interest. This spread depends on the rating of the company.

If an interest rate on debt is assumed in the model that deviates from the risk-free rate of interest, it is implied that a portion of the operating risk assumed by the providers of equity has been transferred to the providers of debt. This effect must be reflected in the cost of equity and the formula for the determination of the cost of equity.

Incorporation of the debt beta allows quantification of the risks assumed by the providers of debt. The conversion from unlevered to levered beta factor must be expanded to include the debt beta. As a result, the inclusion of the debt beta leads to a reduction in the cost of equity.

The period-specific debt beta is calculated as follows:

$$DebtBeta = \beta_{\mathrm{d}} = \frac{(Effective\ rate\ on\ debt\ capital - Riskless\ return)}{Market\ risk\ premium}$$

The calculation of the period-specific levered beta is done with the help of the following formula. In this formula it is assumed that the tax benefits are uncertain and are therefore not considered:

$$\beta_{\mathrm{e}}^{\mathrm{l}} = \beta_{\mathrm{e}}^{\mathrm{u}} + \left(\beta_{\mathrm{e}}^{\mathrm{u}} - \beta_{\mathrm{d}}\right) \frac{d}{e}$$

4.8.2 Calculating the Cost of Capital

The capitalization rates are determined period-specific both for the WACC approach and the equity approach.

Position	Formulas	Excel implementation
Risk-free return (=Cost_of_Capital_(2)!E15)	= Risk-free return from the sheet Assumptions	=Assumptions!$E$228
Beta (unlevered) (=Cost_of_Capital_(2)!E16)	= Beta (levered) / (1 + (1 – Tax rate) * Interest-bearing liabilities / market capitalization	= Assumptions!E233/(1+(1-Assumptions!E240) * Auxiliary Calculations!E63/(Assumptions!E259*Assumptions!E260
Market value of equity (=Cost_of_Capital_(2)!E17)	= Market value of equity from the sheet DCF Valuation (2)	='DCF Valuation (2)'!E89
Market value of debt (=Cost_of_Capital_(2)!E18)	= Interest-bearing liabilities t_0	= Auxiliary Calculations!E63
Degree of leverage (=Cost_of_Capital_(2)!E19)	= Market value of debt / Market value of equity	=E18/E17
Effective interest rate on debt before taxes (=Cost_of_Capital_(2)!E20)	= Interest expenses / Interest-bearing liabilities	=E32
Debt beta (=Cost_of_Capital_(2)!E21)	= (Effective interest rate on debt – Risk-free rate of return) / Market risk premium	=(E20-E15)/E22
Market risk premium (=Cost_of_Capital_(2)!E22)	= Market risk premium from the sheet Assumptions	=Assumptions!$E$230
Beta (levered) (=Cost_of_Capital_(2)!E23)	= Beta unlevered + (Beta unlevered - Debt beta) * Debt/Equity	=E16+(E16-E21)*E19
Risk premium (=Cost_of_Capital_(2)!E24)	= Beta levered * Market risk premium	=E22*E23
Cost of equity (levered) (=Cost_of_Capital_(2)!E26)	= Risk-free return + Risk premium – Growth discount	=E15+E24

Fig. 10.77 Determination of the period-specific cost of equity (levered) (Excel File Corporate Finance, Worksheet Cost of Capital (2))

Determining the Cost of Equity

The most important positions in the calculation of the cost of equity (levered) are presented for the example of the year t_1, unless stated otherwise, in Fig. 10.77:

The positions for the calculation of the cost of equity of the company without debt are also, unless stated otherwise, presented with reference to the year t_1 in Fig. 10.78:

Figure 10.79 shows the calculation of the period-specific cost of equity of the Pharma Group.

Position	Formulas	Excel implementation
Risk-free return (=Cost_of_Capital_(2)!E59)	=Risk-free return from the sheet Assumptions	=Assumptions!$E$228
Beta (unlevered) (=Cost_of_Capital_(2)!E60)	= Beta (levered)/(1+(1-Tax rate)*Interest-bearing liabilities/Market capitalization	=Assumptions!E223/(1+(1- Assumptions!E240)*auxiliary calculations!E63/(Assumptions!E259*Assumptions!E260))
Market risk premium (=Cost_of_Capital_(2)!E61)	= Market risk premium from the sheet Assumptions	= Assumptions!$E$230
Risk premium (=Cost_of_Capital_(2)!E62)	= Beta unlevered * Market risk premium	=E60*E61
Cost of equity (unlevered) (=Cost_of_Capital_(2)!E64)	= Risk-free return + Risk premium	=E59+E62

Fig. 10.78 Determination of the period-specific cost of equity (levered) (Excel File Corporate Finance, Worksheet Cost of Capital (2))

Periodic Cost of Capital

Cost of equity (levered)	01.01.t_1 – 31.12.t_0	01.01.t_2 – 31.12.t_1	01.01.t_3 – 31.12.t_2	01.01.t_4 – 31.12.t_3	01.01.t_5 – 31.12.t_4	01.01.t_6 – TV
Risk-free rate of return	1.80%	1.80%	1.80%	1.80%	1.80%	1.80%
Beta (unlevered)	0.83	0.83	0.83	0.83	0.83	0.83
Market value of equity	83,758	86,146	88,439	90,579	92,546	94,397
Market value of debt	16,399	16,855	17,440	18,157	19,013	19,393
Gearing ratio	19.58%	19.57%	19.72%	20.05%	20.54%	20.54%
Effective cost of debt	3.85%	3.87%	3.88%	3.89%	3.84%	3.84%
Debt beta	41.06%	41.32%	41.56%	41.79%	40.76%	40.76%
Market risk premium	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%
Beta (levered)	0.910	0.909	0.909	0.910	0.914	0.914
Risk premium (spread)	4.55%	4.55%	4.55%	4.55%	4.57%	4.57%
Cost of equity	6.35%	6.35%	6.35%	6.35%	6.37%	6.37%

Fig. 10.79 Period-specific cost of equity (Excel File Corporate Finance, Worksheet Cost of Capital (2))

Determining the Cost of debt

The most important positions in the calculation of the cost of debt are presented using the year t_1 as an example in Fig. 10.80:

Fig. 10.81 shows the calculation of the period-specific cost of debt of the Pharma Group.

Positions	Formulas	Excel implementation
Cost of debt before tax (=Cost_of_Capital_(2)!E32)	= Interest expenses t_1 / Interest-bearing liabilities t_0	=Income Statement !F23/Auxiliary calculations!E63
Tax rate (=Cost_of_Capital_(2)!E33)	= Tax rate from the sheet Assumptions	=Assumptions!F135
Taxes on debt (=Cost_of_Capital_(2)!E34)	= Tax rate * Debt and pension provisions before tax	=E32*E33
Cost of debt after taxes (=Cost_of_Capital_(2)!E36)	= Debt and pension provisions before tax – Corporate taxes	=E32-E34

Fig. 10.80 Determination of the period-specific cost of debt

Cost of debt	01.01.t_1 = 31.12.t_0	01.01.t_2 = 31.12.t_1	01.01.t_3 = 31.12.t_2	01.01.t_4 = 31.12.t_3	01.01.t_5 = 31.12.t_4	01.01.t_6 = TV
Cost of debt before taxes	3.85%	3.87%	3.88%	3.89%	3.84%	3.84%
Tax rate	24.27%	24.27%	24.27%	24.27%	24.27%	24.27%
Taxation	0.94%	0.94%	0.94%	0.94%	0.93%	0.93%
Cost of debt after taxes	2.92%	2.93%	2.94%	2.95%	2.91%	2.91%

Fig. 10.81 Period-specific cost of debt (Excel File Corporate Finance, Worksheet Cost of Capital (2))

Position	Formulas	Excel implementation
Cost of equity (levered) (=Cost_of_Capital_(2)!E42)	= Cost of equity from the calculation of the cost of equity	=E26
Cost of debt after taxes (=Cost_of_Capital_(2)!E43)	= Cost of debt from the calculation of the cost of debt	=E36
Equity ratio (=Cost_of_Capital_(2)!E44)	= Market value of equity / Enterprise value	=E17/E49
Debt ratio (=Cost_of_Capital_(2)!E45)	= Interest-bearing liabilities / Enterprise value	=E50/E49
Weighted Average Cost of Capital – WACC (=Cost_of_Capital_(2)!E47)	= Cost if equity * Equity ratio + Cost of debt after taxes * Debt ratio	=E42*E44+E43*E45
Enterprise value (=Cost_of_Capital_(2)!E49)	= Market value of equity + market value of debt	=E18+E17
Interest-bearing liabilities (=Cost_of_Capital_(2)!E50)	=Interest-bearing liabilities t_0	=Auxiliary calculations!E63

Fig. 10.82 Determination of the period-specific WACC

Calculating the WACC

The most important positions in the calculation of the period-specific WACC are presented using the year t_1 as an example in Fig. 10.82:

Weighted Average Cost of Capital - WACC - periodic	01.01.t_1 = 31.12.t_0	01.01.t_2 = 31.12.t_1	01.01.t_3 = 31.12.t_2	01.01.t_4 = 31.12.t_3	01.01.t_5 = 31.12.t_4	01.01.t_6 = TV
Cost of equity (levered)	6.35%	6.35%	6.35%	6.35%	6.37%	6.37%
Cost of debt after taxes	2.92%	2.93%	2.94%	2.95%	2.91%	2.91%
Equity ratio	83.63%	83.64%	83.53%	83.30%	82.96%	82.96%
Debt ratio	16.37%	16.36%	16.47%	16.70%	17.04%	17.04%
Weighted average cost of capital - WACC	**5.79%**	**5.79%**	**5.79%**	**5.78%**	**5.78%**	**5.78%**
Enterprise value	100,157	103,001	105,878	108,736	111,559	113,791
Markt value of interest-bearing liabilities and pensions	16,399	16,855	17,440	18,157	19,013	19,393

Fig. 10.83 Period-specific WACC (Excel File Corporate Finance, Worksheet Cost of Capital (2))

Figure 10.83 shows the calculation of the period-specific WACC. For the period-specific WACC of the terminal value, the growth discount was already applied.

4.8.3 Calculating the Company value

Period-Specific WACC Approach

As in the case of the previously discussed WACC approach, the calculation of the company value requires a retrograde approach, which starts at the terminal value and works backwards to the valuation date.

Step 1: Calculating the terminal value
Since the period-specific determination of the WACC is already available from the calculation of the cost of capital, the terminal value can immediately be calculated with the familiar formula:

$$TV = \frac{oFCF_{TV}}{WACC_{TV} - g}$$

$WACC_{TV}$ = Period-specific WACC for the terminal value

The terminal value is equal to the enterprise value as of the end of year t_5. The market value of debt as of the end of year t_5 can now be deducted from the enterprise value to obtain the equity value as of the end of year t_5.

Step 2: Calculating the company value for the detailed planning period

In a second step, the combined company values as of the beginning of the year of the detailed planning period are determined. The value for the end of the year t_5 is obtained by adding the operating free cash flow as of the end of the year t_5 to the terminal value. Thus the value at the beginning of year t_5 or respectively the beginning of period *n* is:

$$Value_{1.1.n} = \frac{Value_{31.12.n}}{(1 + WACC_n)}$$

The value at the beginning of year t_5 is equal to the enterprise value. Deducting the interest-bearing liabilities as of the beginning of year 01.01.t_5 leads to the equity value at the beginning of year t_5.

Step by step, the value for the beginning of the previous period is determined in a retrograde fashion by the financial modeler until the valuation date has been reached.

The resulting market value of equity as of the valuation date is equal to the equity value of the operating business. In order to arrive at the equity value of the company, non-operating assets, cash & cash equivalents and investments accounted for using the equity method are added and equity attributable to non-controlling interest is subtracted.

Figure 10.84 shows the positions of the company valuation according to the approach of the period-specific WACC using the year t_1 as an example, unless stated otherwise.

Figure 10.85 shows the calculation of the company value of the Pharma Group in accordance with the period-specific WACC approach.

APV Approach

The calculation of the company value according to the APV approach is not period-specific. This means that a constant cost of equity of the unlevered company is used for discounting of the operating free cash flows as well as the tax shields (see 4.4 APV Approach). For that reason there is no deviation in the results from the previous calculation of the equity value according to the APV approach. We merely adjusted the presentation of the method to the period-specific WACC approach. Figure 10.86 shows the calculation of the company value using the

APV approach.

$$= \frac{TV + oFCF_n}{(1 + WACC_n)}$$

Position	Formulas	Excel implementation
Weighted Average Cost of Capital – WACC (=DCF_Valuation_(2)!E15 to J15)	= Period-specific WACC from the sheet Cost of capital (2)	='Cost of Capital(2)'!E47 to J47
Operating free cash flow – oFCF(t-1) (=DCF_Valuation_(2)!E16 to J16)	=Operating free cash flows from the sheet Cash Flow Calculation	='Cash Flow Calculation'!F31 to K31
Terminal value (=DCF_Valuation_(2)! J17)	=oFCF t_{TV} / (WACC t_{TV} – g)	=J16/(J15-Assumptions!K219)
Value of the terminal value plus operating free cash flow 01.01.t_5 (=DCF_Valuation_(2)!I18)	= (TV + oFCF t_5) / (1+ WACC t_5)	=(J17+J18+I16)/(1+I15)
Value 01.01.t_4 (=DCF_Valuation_(2)!H18)	= (Value 01.01.t_5 + oFCF t_4) / (1 + WACC t_4)	=(I17+I18+H16)/(1+H15)
Value 01.01.t_1 (=DCF_Valuation_(2)!E18)	= (Value 01.01.t2 + oFCF t_1) / (1 + WACC t_1)	=(F17+F18+E16)/(1+E15)
Enterprise value 01.01.t_1 (=DCF_Valuation_(2)!E19)	Value as of 01.01.t_1	=(E17+E18)
Interest-bearing liabilities 01.01.t_1 (=DCF_Valuation_(2)!E20)	=Interest-bearing liabilities 01.01.t_1)	='Cost of Capital (2)'!E18

Fig. 10.84 The most important positions in the calculation of the company value in accordance with the approach of the period-specific

Market value of equity (needed for operations) (=DCF_Valuation_(2)!E21)	= Enterprise Value 01.01.t_1 - Interest-bearing liabilities	= E17+E18-E20
Non-operating assets (=DCF_Valuation_(2)!E25)	Link to the worksheet Assumptions	=Assumptions!E203
Cash & cash equivalents (=DCF_Valuation_(2)!E26)	Link to the worksheet Assets	='Assets'!E19
Investments accounted for using the equity method (=DCF_Valuation_(2)!E27)	= Investments accounted for using the equity method t_0	='Assets'!E10
Equity value (incl. equity attributable to non-controlling interest) (=DCF_Valuation_(2)!E29)	= Market value of equity (operating) t_0 + Non-operating assets t_0 + Cash & cash equivalents t_0 + Investments accounted for using the equity method t_0	=E23+E25+E26+E27
Equity attributable to non-controlling interest (=DCF_Valuation_(2)!E31)	= Equity attributable to non-controlling interest t_0	=Equity and Liabilities!E11
Equity value (=DCF_Valuation_(2)!E33)	= Equity value (incl. equity attributable to non-controlling interest) – Equity attributable to non-controlling interest t_0	=E29-E31

Fig. 10.84 (Continued)

Period-Specific Equity Approach

In contrast to the previous calculation of the company value according to the equity approach (see section Equity Approach), specific values for individual periods are needed. Accordingly the retrograde approach is again utilized.

Step 1: Calculating the terminal value

With the cash flows to equity and the period-specific cost of equity (levered), which were established in Section 4.5.2, the terminal value

Discounted Cash Flow (DCF) Valuation in accordance with the Periodic WACC Approach

€ million	01.01.t_1 – 31.12.t_0	01.01.t_2 – 31.12.t_1	01.01.t_3 – 31.12.t_2	01.01.t_4 – 31.12.t_3	01.01.t_5 – 31.12.t_4	01.01.t_6 – TV
Weighted average cost of capital - WACC	5.79%	5.79%	5.79%	5.78%	5.78%	5.78%
Operating free cash flows (t+1)	2,952	3,083	3,268	3,464	4,219	4,303
Terminal value (TV)						113,791
Value (terminal value and operating free cash flows)	100,157	103,001	105,878	108,736	111,559	
Enterprise value	100,157	103,001	105,878	108,736	111,559	113,791
Interest-bearing liabilities	16,399	16,855	17,440	18,157	19,013	19,393
Market value of equity (operating)	83,758	86,146	88,439	90,579	92,546	94,397

Market value of equity (operating)	83,758
+ Non operating assets	0
+ Cash and cash equivalents	1,662
+ Investments accounted for using the equity method	203
Equity value (incl. equity attributable to non-controlling interest)	85,623
- Equity attributable to non-controlling interest	86
Equity value	85,537

Fig. 10.85 Period-specific WACC (Excel File Corporate Finance, Worksheet DCF Valuation (2))

Discounted Cash Flow (DCF) Valuation in accordance with the APV Approach

I million	01.01.t_1 – 31.12.t_0	01.01.t_2 – 31.12.t_1	01.01.t_3 – 31.12.t_2	01.01.t_4 – 31.12.t_3	01.01.t_5 – 31.12.t_4	01.01.t_6 – TV
Cost of equity (unlevered)	5.94%	5.94%	5.94%	5.94%	5.94%	5.94%
Operating free cash flows (t+1)	2,952	3,083	3,268	3,464	4,219	4,303
Terminal value (TV)						109,206
Value (terminal value and operating free cash flows)	96,029	98,782	101,566	104,332	107,065	
Value of unlevered company	96,029	98,782	101,566	104,332	107,065	**109,206**
Cost of equity (unlevered)	5.94%	5.94%	5.94%	5.94%	5.94%	5.94%
Financial expenses	632	652	676	706	730	744
Tax rate	24.3%	24.3%	24.3%	24.3%	24.3%	24.3%
Tax shield cash flows (t+1)	153	158	164	171	177	181
Terminal value						4,584
Value (terminal value and tax shield cash flows)	4,128	4,220	4,312	4,404	4,494	
Value of tax shield	**4,128**	**4,220**	**4,312**	**4,404**	**4,494**	**4,584**
Enterprise value	100,157	103,001	105,878	108,736	111,559	113,791
Interest-bearing liabilities	16,399	16,855	17,440	18,157	19,013	19,393
Market value of equity (operating)	83,758	86,146	88,439	90,579	92,546	94,397

Enterprise value	**100,157**
+ Non operating assets	0
+ Cash and cash equivalents	1,662
+ Investments accounted for using the equity method	203
Entity value	**102,022**
- Interest-bearing liabilities	16,399
Equity value (incl. equity attributable to non-controlling interest)	**85,623**
- Equity attributable to non-controlling interest	86
Equity value	**85,537**

Fig. 10.86 Calculating the company value according to the APV approach (Excel File Corporate Finance, Worksheet DCF Valuation (2))

can initially be determined with the help of the following formula:

$$TV = \frac{CFtE_{TV}}{r_{e,TV} - g}$$

$r_{e,TV}$ = Period-specific cost of equity for the terminal value

Step 2: Calculating the company value for the years in the detailed planning period

In the second step, the market values of equity at the beginning of the years in the detailed planning period are determined. The value at the end of the period t_5 is obtained by adding to the terminal value the operating free cash flows for the period t_5. Thus the value at the beginning of the period is:

$$Value_{1.1.n} = \frac{Value_{31.12.n}}{(1 + r_{e,n})}$$

$r_{e,n}$ = Period-specific cost of equity in period n.

Step by step the value at the beginning of the previous period is calculated in a retrograde manner by the financial modeler until the valuation date has been reached.

The value which results from this method for the valuation date is equal to the market value of equity of the operating business. Since the cash flows are discounted at the cost of equity of the levered company, non-operating assets, cash & cash equivalents and investments accounted for using the equity method must be added and equity attributable to non-controlling interest must be subtracted in order to arrive at the equity value of the corporation.

Figure 10.87 shows the most important positions of the calculation of the company value according to the period-specific equity approach.

Figure 10.88 shows the calculation of the company value of Pharma Group according to the period-specific equity approach.

Comparison of the Results

A comparison of the results from the period-specific WACC approach, the APV approach and the period-specific equity approach reveals that they are identical.

Position	Formulas	Excel implementation
Cost of equity (levered) (=DCF_Valuation_(2)!E85 to J85)	= Cost of equity of the levered company (period-specific) from the sheet Cost of Capital (2)	='Cost of Capital (2)'!E26 to J26
Cash flow to equity – CftE (=DCF_Valuation_(2)!E86 to J86)	=Cash flows to equity from the sheet Cash Flow Statement	='Cash Flow Statement'!F59 to K59
Terminal value (=DCF_Valuation_(2)!J87)	=CFtE (TV) / Cost of equity of the levered company (period-specific) (TV) – g)	=J86/(J85-Assumptions!K219)
Company value always at the beginning of the year t_1 (=DCF_Valuation_(2)!E88 to I88)	= Link to the value of the year of the next year	=(F87+E86+F88)/(1+E85)
Market value of equity and the terminal value (operating) (=DCF_Valuation_(2)!E89)	= TV + Value 01.01.	=E87+E88
Non-operating assets (=DCF_Valuation_(2)!E93)	Link to the worksheet Assumptions	=Assumptions!E203

Fig. 10.87 The most important positions in the calculation of the company value according to the period-specific equity

Cash & cash equivalents (=DCF_Valuation_(2)!E94)	Link to the worksheet Assets	`='Assets'!E19`
Investments accounted for using the equity method (=DCF_Valuation_(2)!E95)	Link to the worksheet Assets	`='Assets'!E10`
Equity value (incl. equity attributable to non-controlling interest) (=DCF_Valuation_(2)!E97)	= Market value of equity (operating) t_0 + Non-operating assets t_0 + Cash & cash equivalents t_0 + Investments accounted for using the equity method t_0	`=E91+E93+E94+E95`
Equity attributable to non-controlling interest (=DCF_Valuation_(2)!E99)	= Equity attributable to non-controlling interest t_0	`='Equity and Liabilities'!E11`
Equity value (=DCF_Valuation_(2)!E101)	= Equity value (incl. equity attributable to non-controlling interest) - Equity attributable to non-controlling interest t_0	`=E97-E99`

Fig. 10.87 (Continued)

Discounted Cash Flow (DCF) Valuation in accordance with the Periodic Equity Approach

€ million	01.01.t_1 – 31.12.t_0	01.01.t_2 – 31.12.t_1	01.01.t_3 – 31.12.t_2	01.01.t_4 – 31.12.t_3	01.01.t_5 – 31.12.t_4	01.01.t_6 – TV
Cost of equity (levered)	6.35%	6.35%	6.35%	6.35%	6.37%	6.37%
Cash flows to equity (t+1)	2,930	3,174	3,474	3,785	4,046	4,127
Terminal value						94,397
Market value of equity (operating)	83,758	86,146	88,439	90,579	92,546	
Market value of equity and terminal value (operating)	83,758	86,146	88,439	90,579	92,546	94,397
Market value of equity (operating)	**83,758**					
+ Non operating assets	0					
+ Cash and cash equivalents	1,662					
+ Investments accounted for using the equity method	203					
Equity value (incl. equity attributable to non-controlling interest)	**85,623**					
- Equity attributable to non-controlling interest	86					
Equity value	**85,537**					

Fig. 10.88 Period-specific equity approach (Excel File Corporate Finance, Worksheet DCF Valuation (2))

Company valuation methods	Value
Discounted cash flow (DCF) valuation according to the period-specific WACC approach	85,573
Discounted cash flow (DCF) according to the APV approach	85,573
Discounted cash flow (DCF) valuation according to the period-specific equity approach	85,573

Fig. 10.89 Results of the company valuation s after adjusting the financing assumptions (Excel File Corporate Finance, Worksheet Executive_Summary)

Thus the model fulfills the demand of the theory of company valuation: all three methods lead to identical results if the modeling is precise.

Figure 10.89 gives an overview of the results for the company values after adjusting the financing assumptions.

5 Summary

In this corporate finance part, the financial modeler has gained insights into the methods and approaches of company valuation:

- The following five methods of company valuation can be distinguished:
    - DCF method
    - Trading multiples
    - Transaction multiples
    - Book value
    - Market capitalization
- The DCF approaches can be broken down into WACC, period-specific WACC, APV and equity approach.

Planning:

- All DCF approaches are based on detailed and integrated income statement and balance sheet planning.
- Planning is based on the analysis of annual reports of at least the past three years.
- Planning is based on a number of assumptions, which need to be plausible with regard to the company, the industry, the market and the broader economic environment.
- Detailed business knowledge is required to set up a planning model. The implementation in Excel is less problematic.

- The planning values enable the financial modeler to derive the relevant cash flows for the valuation.

Cash flows:

- For the WACC, period-specific WACC and APV approach, the operating free cash flow is relevant for the valuation. For the equity approach this is the cash flow to equity.
- When calculating the operating free cash flows, exclusively the operating cash flows, in other words the cash flows derived from operating assets, are considered.
- These are cash flows before financing activities, such as interest payment and debt repayment and dividends are considered.
- Following the explicit planning period, the terminal value is calculated in the WACC approach with reference to perpetuity with constant growth rate.
- In the year of the terminal value, a normalized cash flow must be used, which captures the valuation object in a state of equilibrium.

WACC approach:

- The cost of capital in the WACC approach is generally called WACC (Weighted Average Cost of Capital), since it takes the capital structure of the company into consideration.
- The weights for the cost of equity and debt are based on market values or a target structure in the WACC formula.
- The sum of the present values of the operating free cash flows yields the value of the company derived from all operating assets (enterprise value). To arrive at the entity value of the company, the value of non-operating assets, cash and cash equivalents and investments accounted for using the equity method must be added.
- The market value of equity can be determined by subtracting the interest-bearing liabilities as well as the equity attributable to non-controlling interest from the entity value.
- In contrast to the simple WACC, the period-specific cost of capital is calculated in the period-specific WACC to capture changes in the capital structure.
- The period-specific WACC is required in all cases where the capital structure changes during the planning stage.

APV approach:

- The APV approach explicitly focuses on the effects of the capital structure at the level of the cash flows.

  In the adjusted present value approach (APV approach) the market value of the total capital is determined in a first step under the assumption that the company uses no debt and is completely equity financed. In a second step, the effects of debt financing on the company value in form of the so-called tax shield are taken into consideration. It reflects the tax savings that are available since interest is a tax deductible expense.

Equity approach:

- In the equity approach (net approach) only those cash flows are discounted, which accrue to the providers of equity. They are called cash flows to equity.
- Discounting is therefore done at the cost of equity of the company.
- This method directly yields the value of equity.

Professional company valuation:

- If identical assumptions about financing are made in all DCF valuation approaches, the results are also identical.

Analysis phase:

- A sensitivity analysis and a scenario analysis are recommended for every company valuation in order to test the effects of individual value drivers on the company value.

Notes

1. An increase in noncurrent financial liabilities increases the free cash flow, either because cash is flowing in, or in the case of a provision, because it is linked to an expense that does not cause an outflow of cash.
2. An increase in deferred tax assets reduces the free cash flow while an increase in deferred tax liabilities increases the free cash flow.
3. An increase in income tax liabilities increases the free cash flow while a decrease in income tax liabilities decreases the free cash flow.

4. This formula for eliminating debt from the levered beta is used in most textbooks. It assumes certain tax shields and is based on the assumption of riskless debt (assumption of Modigliani/Miller). In the Section "Company Valuation for Professionals" this assumption is removed and replaced with the more realistic premise of uncertain tax shields.

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11

Corporate Finance Part II

1 Executive Summary

In this section the financial modeler will learn how to derive a valuation range for a company – here Pharma Group. The summary and presentation of the results of the various valuation methods rely on the so-called football field graph. As Fig. 11.1 reveals, the result of the company valuation – the valuation range of the listed company Pharma Group – is based on the following five valuation methods:

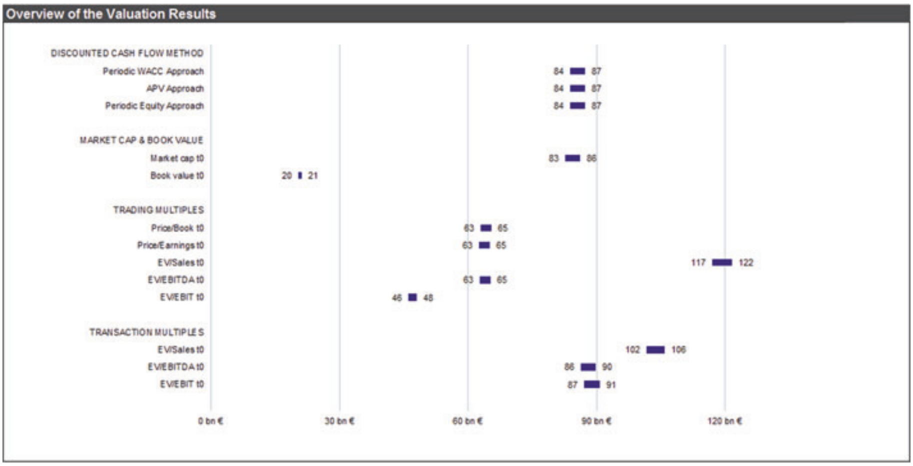

Fig. 11.1 The football field graph

J. Häcker and D. Ernst, *Financial Modeling*,
Global Financial Markets, DOI 10.1057/978-1-137-42658-1_11

- DCF method (Corporate Finance Part I, Chapter 10)
- Market capitalization (Corporate Finance Part II, Chapter 11)
- Book value (Corporate Finance Part II, Chapter 11)
- Trading multiples (Corporate Finance Part II, Chapter 11)
- Transaction multiples (Corporate Finance Part II, Chapter 11)

The **football field graph** provides an overview of the valuation results (Excel File Corporate Finance, Worksheet Executive_Summary)

The results of the three discounted cash flow approaches WACC approach, APV approach and equity approach (the first and last approach were implemented with a period-specific calculation) are exactly identical. The result is a market value of the equity of Pharma Group of € 85.5 billion. However, the financial modeler never reports results up to the last cent. Due to the volatility of the value drivers, he conducts a sensitivity analysis of the final results and provides a range to his clients. Here the value range is between € 83.6 billion and € 87.0 billion. Compared to the other methods used here, the DCF approach is the key method in company valuation.

The **market capitalization** is equal to € 84.4 billion at time t_0. If the investor is interested in purchasing 100% of Pharma Group, the market capitalization gives the minimum purchase price which the buyer must pay in order to conduct such a transaction.

The **book value** of Pharma Group is equal to € 20.7 billion at time t_0 and can generally be considered as the absolute low boundary of the valuation. In general no seller is willing to dispose of his company below the book value.

The peer group of Pharma Group comprises a total of seven publicly listed companies. The results are based on the multiples price/book, price/earnings, EV/EBITDA and EV/EBIT and are significantly below the market capitalization. The reason for this is the low profitability of Pharma Group compared to the other seven companies in the peer group. Since the median of the peer group multiples is multiplied with the low earnings figures of Pharma Group, a relatively low result is obtained for Pharma Group. Relative to the peer group, a lower corporate value would result.

Contrasting results are obtained with the EV/sales multiple. The range of results from € 117 billion to € 122 billion would lead to a higher corporate value compared to the peer group. This is explained by the strong sales performance of Pharma Group compared to the seven other companies. The median EV/sales multiple of the peer group is 3.3. Since this multiple is multiplied by the above average sales of Pharma Group, an above average corporate value is obtained. While the EV/sales multiple is least affected by differences in tax systems and accounting standards, the result should be ignored in this context. The use of sales as a point of reference cannot be recommended, since no information about costs or profitability is provided.

This example also demonstrates the importance of selecting the correct peer group. For that reason, the financial modeler should also possess excellent knowledge about the industry, the business model and macroeconomic interrelations in addition to strong skills in corporate valuation.

The results for the two **transaction multiples** EV/EBITDA and EV/EBIT are between €86.0 billion and €90.5 billion. Just like the trading multiples, the high result from the EV/sales multiple must be excluded from the valuation. The results obtained with the transaction multiples are higher than the results from the trading multiples. This is explained by the fact that takeover premiums are usually paid for acquisitions of companies.

If a potential buyer of Pharma Group has given a mandate to the financial modeler to conduct a company valuation, the financial modeler will provide him with a valuation range and a walk-away-price. Once all the data has been carefully condensed in a bottom up process, the art is to turn this into a final result. It is ultimately true that valuation is much more an art than a science. In this current case, the financial modeler will most likely provide the client with the valuation range of €84 billion to €90 billion. The market capitalization and the lower end of the valuation range from the DCF method support the value of Ă 84 billion. The upper end is supported by the results based on EV/EBITDA and EV/EBIT from the method of transaction multiples. Inside this range is the result of the DCF method which was subject to a sensitivity analysis. The two EV/sales multiples are to be excluded as discussed above. Only the result from the trading multiples suggests a value below the valuation range. In applied work, the financial modeler will now turn to a detailed analysis of the entire business model of Pharma Group and a comparison with the peer group. This may result in an adjustment of the valuation range.

Ultimately, the client is not interested in a value, but rather in a price. A potential buyer would like to know how far he can go in a bidding process. The walk-away-price helps him to optimally design his behavior (price in the letter of intent, in the binding offer and in the purchase contract) and negotiating tactics. In the case of Pharma Group, the walk-away-price is € 100 billion, which implies a takeover premium of close to 20% based on the current market capitalization.

2 Introduction, Structure, Learning Outcomes and Case Study

Structure

The chapter Corporate Finance Part II serves as an introduction to corporate finance and company valuation and answers the following questions:

- What is the relevance of market capitalization and book value in company valuation?
- How are trading multiples used in company valuation?
- How is a valuation conducted using transaction multiples?
- How can results be presented professionally with the football field graph?

Learning Outcomes

The financial modeler

- Is able to correctly interpret the market capitalization of publicly listed companies;
- Can check the results of the DCF valuation method for plausibility with the help of trading multiples and transaction multiples.
- Can professionally present and discuss the results of the company valuation using a football field graph.

Case Study

The financial model for the case study can be found in the Download Section in the Excel-Sheet `Corporate Finance Part II`. Use the contents of the download section together with the text:

- The individual learning steps are broken down into small units and found on separate worksheets.
- All calculations are done directly in Excel. This assures traceability of the calculations.
- All assumptions which serve as input data used for calculations in the financial model are found in the worksheet `Assumptions`.
- All input data is marked in the color light orange. These are values which are assumed by the valuation expert and can be set individually.
- All calculations and output data use the color light gray. These are values which result from calculations.
- Mixed formulas that contain both numerical values and cell references are highlighted using green font.
- For better traceability Income Statement, Assets Equity and Liabilities, Auxiliary Calculations and Cash Flow Calculations are done on separate sheets.
- The part on company valuation starts with a calculation of the cash flow.
- This and the following sheets refer to the discounted cash flow (DCF) approaches as well as to the multiple approaches.
- In the first step, the cash flows necessary for the DCF valuation are derived.
- In the following, the different discount rates are calculated.
- In the next step, the valuations of the company based on the methods WACC, APV and equity approach are calculated.
- As a refinement of the WACC approach, company valuation based on a period-specific WAAC is presented.
- For these approaches a sensitivity analysis and a scenario analysis are conducted.
- In the next step it is described how adjustments can be used to assure that all DCF valuation approaches produce identical results.
- Finally, the corporate valuation is conducted using book value, market capitalization, as well as trading and transaction multiples.

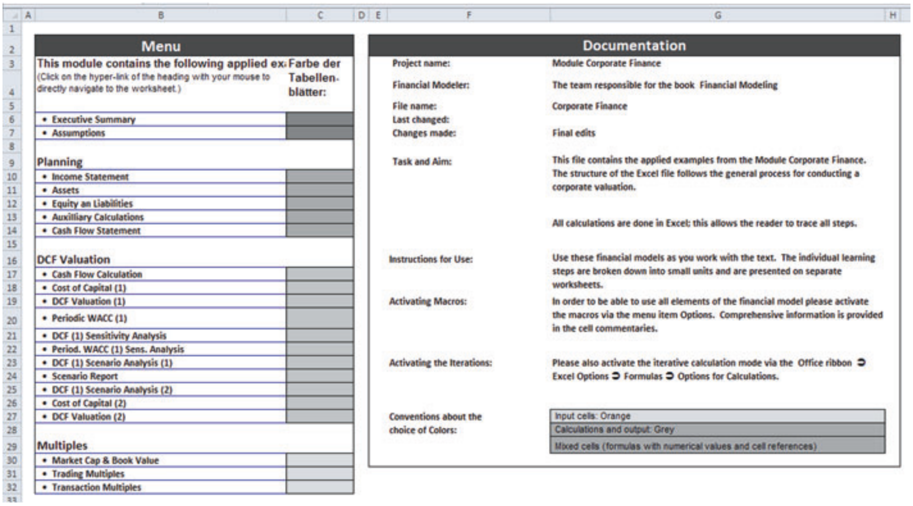

Fig. 11.2 Menu and Documentation (Excel File Corporate Finance, Worksheet Menu and Documentation)

Figure 11.2 shows the menu and the documentation of the Excel file `Corporate Finance Part II`.

> The applied example of the Pharma Group illustrates all steps in the chapter Corporate Finance Part II

Pharma Group

The corporate planning and valuation which is conducted on the following pages is based on the example of Pharma Group, a global leader in the fields of pharmaceuticals, agriculture and high-end materials. The financial reporting of Pharma Group is based on IFRS and uses the cost of sales method. The owners want to assess the value of the company. Consequently, a company valuation is conducted in a first step by an M&A department of a bank. This initially involves planning for a five year period, which serves as the basis for the DCF valuation. The corporate planning is an important component of the potential prospectus. The highest possible degree of precision of corporate planning is therefore of major importance to arrive at an accurate valuation.

3 Company valuation Using Market Capitalization and Book Value

3.1 Overview of Market Capitalization

The market capitalization can only be calculated for listed companies

The current market capitalization can be used as price for the valuation of listed companies. Under the assumption that the efficiency hypothesis of Fama is valid (current prices reflect all available information about the company),[1] the price of a company (in this case the market capitalization) is equal to the company value as determined by the DCF method. In imperfect markets (which can currently be observed) a distinction must be made between company value (from the DCF valuation) and corporate price (from the multiple approach).

In addition to these issues, experience also shows that the market capitalization fails to be a reliable approximation for the company value if the following situations arise:

- Low trading volumes
- Industry focus of investors

Low trading volume: A low trading volume can result from the following developments:

- Companies with a low free float only have a small number of tradable shares and the possibilities for involvement by institutional investors are limited.
- By providing relevant information, analysts increase the informational efficiency of capital markets which also raises the profile of the company covered. If we invert the argument, this also means that companies without analyst coverage are less well known and the shares consequently have a lower trading volume.

The lower trading volumes are, the harder it is for market participants to trade shares at a specific price and during a given time period. For that reason, many investors avoid shares characterized by low trading volume. The scarcity of shares can drive up prices to levels that are not justified and represent an overvaluation. At the same time, low demand can mean that the share price settles at a level that is too low. This implies an undervaluation.

Industry focus of investors: Certain industries can become the focus of investors due to differences in the business cycle or because of subjective investor assessments. An example for the unusual interest of investors in a specific sector is the hype surrounding internet companies around the turn of the millennium, when almost all shares were clearly overvalued. The use of market capitalization as an indicator for company value is therefore not suitable for industries in a boom phase.

DAMODARAN has also reviewed the market capitalization as a proxy for the company value. He points out that the market capitalization should not be used as the company value in the following situations[2]:

- For listed companies which have issued several types of shares that are not all trading at an exchange. Due to differences in voting rights and dividend rights, the value of these shares cannot be determined reliably.
- In the case of outstanding equity options for the management. These are not traded, but still have a value which is not considered in the market capitalization.
- In the case were a company has issued debt which can be converted into equity at a later point in time (such as convertible bonds). In this situation, the components subject to conversion should be treated as belonging to equity and not debt. If this is ignored, the true company value is underestimated.

3.2 Overview of Book Value

> In applied valuation work, the book value serves as the long-term lower bound for the valuation

The book value of equity can be considered as a long-term lower bound for the value of a company. The book value is backward looking and does not establish a link to the future earnings power or growth prospects of a corporation. For that reason, the stock market valuation of companies (market capitalization) is usually higher. With a market capitalization of €84.354 billion and a book value of €20.718 billion, Pharma Group is currently trading significantly in excess of its book value (P/B 4.1x).

DAMODARAN calls the book value of equity an accounting device which is of limited importance as a proxy for the company value.[3] It is impossible to discover hidden reserves or charges when only the book value of equity is considered.

3.3 Valuation Process with Market Capitalization and Book Value

The calculation of the market capitalization and the book value can be separated into two steps:

- **Step 1:** Collection of the required data.
- **Step 2:** Calculation of the equity value.

3.3.1 Collection of the Required Data

In contrast to other valuation methods, the amount of data required for the calculation of the market capitalization and the book value of equity is low.

Market capitalization: Needed for the calculation of the market capitalization are the current share price and the number of shares out of the company. The current share price is available from the homepage of the company (investor relations area) or in information portals such as Bloomberg or Reuters. The current number of shares out can be obtained by the financial modeler from the most recent annual or quarterly report or from a current investor presentation. It is not recommended to take the number of shares out or the market capitalization from financial portals, since the information found on these sites is frequently outdated or incorrect.

Book value: The calculation of the book value requires data on the equity position and minority interest, which can be found in the annual reports of the company that needs to be valued.

Once all data has been obtained from the various sources, it is saved in the worksheet `Assumptions`.

3.3.2 Calculating the Market Capitalization

In the following, the market capitalization of the Pharma Group is calculated for t_0. The share price at time t_0 is the closing price from the previous trading day. Frequently the volume-weighted average price of the past ninety days is used instead. Figure 11.3 displays the data collected for the market capitalization in the worksheet `Market_Cap_&_Book_Value`.

Figure 11.4 shows the calculation of the market capitalization in Excel.

Figure 11.5 displays the result for the market capitalization at time t_0.

Market Cap - Underlying data of Pharma Group			Pharma Group t_0
Share price in €			102
Number of shares in m.			827

Fig. 11.3 Data required for calculating the market capitalization (Excel File Corporate Finance, Worksheet Market_Cap_&_Book_Value)

Positions in Excel	Formulas	Excel implementation
Market capitalization t_0 (='Market capitalization & Book value'!E11)	= Share price t_0 * Number of shares out t_0	=E5*E6

Fig. 11.4 Excel implementation of the calculation of the market capitalization

Equity value of Pharma Group using Market Cap			Pharma Group t_0
Market Cap (in €m)			84,354

Fig. 11.5 Market capitalization of Pharma Group (Excel File Corporate Finance, Worksheet Market_Cap_&_Book_Value)

3.3.3 Calculating the Book Value

To calculate the book value, the balance sheet item "Equity" from the current annual report is used and equity attributable to non-controlling interest is subtracted. Equity attributable to non-controlling interest is subtracted from the equity position since it is attributable to third parties, which hold shares in the equity position of subsidiaries.

Figure 11.6 shows the data which serves as the basis for the calculation of the book value.

The implementation of the calculation of the book value can be reconstructed in Fig. 11.7.

Figure 11.8 shows the book value of equity of Pharma Group.

Book Value - Underlying data of Pharma Group			Pharma Group t_0
Equity (in €m)			20,804
Minority interest (in €m)			86

Fig. 11.6 Data needed for the calculation of the book value (Excel File Corporate Finance, Worksheet Market_Cap_&_Book_Value)

Positions in Excel	Formulas	Excel implementation
Book value t_0 (='Market capitalization & Book value'!E23)	= Equity t_0 – Minority interest t_0	=E17-E18

Fig. 11.7 Excel implementation of the calculation of the book value

Equity Values of Pharma Group using Book Value			Pharma Group t_0
Book value (in €m)			20,718

Fig. 11.8 Book value of Pharma Group (Excel File Corporate Finance, Worksheet Market_Cap_&_Book_Value)

4 Trading Multiples

4.1 Overview of Trading Multiples

> The Valuation with the help of Trading Multiples reflects current market conditions and perceptions.

The valuation based on trading multiples is an approach with a market orientation. The company valuation with the help of multiples is frequently used in applied work, since the method is relatively simple and provides a quick first indication of value/price.

Multiples can be used for the following purposes:

- **As an independent valuation method**
- **To provide additional evidence** concerning company valuations that are based on different methodologies (such as the DCF approach)

> During the company valuation with multiples, the unknown value of the valuation object is determined with the help of multiples which are derived from the known market values of other companies that are similar to the valuation object.

The following principle holds for the valuation with multiples:

The method of multiples is based on the assumption that comparable companies should be trading at comparable company values, since they share important characteristics, such as the business model.

4.2 Valuation Process with Trading Multiples

The valuation process with trading multiples follows these 5 steps:

> 1. **Derivation of the peer group:** In the first step, companies are identified that are comparable to the valuation object. A peer group is established.
> 2. **Selection of appropriate multiples:** Based on different criteria, the appropriate multiples are selected in the second step.

3. **Collection of the required data:** In the third step, all required data for the appropriate multiples is collected and prepared.
4. **Calculation of the multiples:** In the fourth step, the derived multiples of the comparable companies are combined into one multiple by calculating the median.
5. **Application to the target company:** In the last step, the aggregated multiples are applied to the company and the company value of the target company is calculated.

4.2.1 Derivation of the Peer Group

The careful selection of peers is of major importance for the quality of the valuation

The selection of a peer group which is as homogeneous as possible constitutes the foundation for the valuation with trading multiples. Depending on the valuation object, the intensity required during this process can vary greatly. Especially for companies that are active in niche markets and do not face direct competition, it can be rather time-consuming to identify comparable companies.

Initially, the financial modeler needs to determine whether a relevant peer group has already been defined internally. Alternatively he can also access available databases (such as Thomson Reuters or Bloomberg) in order to study analysts' reports, which frequently have already identified the relevant peers.

Figure 11.9 shows an excerpt from a research report by J.P. Morgan Cazenove, which lists the relevant companies in the European pharmaceutical sector.[4]

To facilitate the selection of comparable companies, it is also possible to use the Standard Industrial Classification System (SIC). The SIC system, which is used by the SEC (US-stock exchange supervisor) has a multidimensional structure and consists of SIC-codes with up to four digits.[5] In order to derive a peer group from the SIC system, the 4-digit SIC-code should be utilized. If it does not contain a sufficient number of peer companies, a SIC-code with fewer digits should be

Company	Ticker	Rating	Mkt cap $ bn	Closing Price of	Target Price	Upside / Downside
Large Cap						
AstraZeneca	AZN LN	UW	58.4	2,914p	2,970p	2%
GlaxoSmithKline	GSK LN	UW	105.8	1,346p	1,450p	8%
Novartis	NOVN VX	N	152.1	SFr57.45	SFr62.70	9%
Roche	ROG VX	OW	174.2	SFr184	SFr210	14%
Sanofi	SAN FP	OW	123.2	€70.73	€78	10%
Bayer AG	BAYN GR	OW	78.6	€71.89	€80	11%
Novo Nordisk	NOVOB DC	N	89.0	DKr917	DKr850	-7%
Mid Cap						
Actelion	ATLN VX	N	5.6	SFr43.53	SFr49	13%
Hikma	HIK LN	OW	2.4	754p	860p	14%
Ipsen	IPN FP	OW	2.5	€22.69	€29	28%
Merck KGaA	MRK GR	N	28.7	€99.83	€97	-3%
Shire plc	SHP LN	OW	16.9	1,895p	2,200p	16%
UCB	UCB BB	OW	11.4	€43.79	€51	16%
Small Caps						
Active Biotech	ACTI.ST	N	0.6	SEK55	SEK53	-4%
Algeta	ALGETA NO	OW	1.1	NOK155	NOK230	49%
BTG	BGC LN	OW	1.5	334p	425p	27%
Vectura	VEC LN	OW	0.4	83p	130p	57%
Other Healthcare						
Grifols Voting	GRF SM	N	8	€25.60	€27.80	9%
Grifols Non-Voting	GRF /P	N	2.5	€18.90	€20.80	10%
Lonza	LONN VX	N	2.8	SFr49.36	SFr40	-19%

Fig. 11.9 Deriving the peers from analysts' reports

Business model	Financial profile
• Sector	• Size/Market capitalization
• Products/Services	• Earnings structure/Margins
• Market Presence	• Degree of indebtedness
• Distribution Channels	• Growth profile
• Customers (B2B, B2C)	

Fig. 11.10 Criteria for the selection of comparable companies

used. However, it needs to be kept in mind that the comparability is reduced as the number of digits goes down. KIM and RITTER point out that the classification sometimes lacks clarity in the case of multi-product companies.[6] Regardless of the source, the financial modeler is therefore required to check the companies obtained for comparability concerning the criteria listed in Fig. 11.10.

In order to arrive at a statistically valid conclusion, the peer group should consist at least of five companies. However, in many cases only a small number of ultimately comparable companies exist and the criteria for comparable companies could be softened. This reduction in the fit between comparable companies and target companies lowers the precision of the valuation. A valuation based on companies that cannot be compared is not meaningful and leads to wrong results.

4.2.2 Selection of Appropriate Multiples

> When multiples are used, consistency of denominator and numerator is important

Company values can generally be either equity or enterprise values. The equity value describes the company value from the perspective of the providers of equity (shareholders). The enterprise value describes the company value from the perspective of both providers of equity and debt. In the valuation with multiples, a distinction is made between equity value and enterprise value. The equity value is the market value of equity of a company. For listed companies, it corresponds to the current market capitalization (in other words the product of shares out and share price). The enterprise value is defined as the value of the entire operations of a company. This enterprise value corresponds to the present value of the operating free cash flows determined in the DCF entity approach. The operating business includes all fully consolidated subsidiaries in the group.

Either the equity or enterprise value can be utilized for constructing a multiple. In general, a multiple consists of a numerator and a denominator (see Fig. 11.11). It is important that numerator and denominator represent the same providers of capital. If the enterprise value is used in the numerator, the denominator must also refer to a gross value. For the enterprise value in the numerator, the reference value in the denominator could be sales, EBITDA or EBIT for example. If the equity value is in the numerator, the denominator must be an equity based value, from which payments to providers of debt have been excluded.

In the following sections, the most frequently used enterprise and equity multiples in applied work will be presented in detail.

$$\text{Multiple} = \frac{\text{Value}}{\text{Reference figure}}$$

Fig. 11.11 Construction of the multiple

$$\text{EV/Sales} = \frac{\text{Enterprise value}}{\text{Sales}}$$

Fig. 11.12 Construction of the EV/Sales multiple

Advantages	Disadvantages
• Numerous estimates available • Not influenced by differences in tax systems and accounting standards • Can be used in case of negative earnings	• Does not consider earnings power • Depends on the definition of sales

Fig. 11.13 Advantages and disadvantages of the EV/Sales multiple

Enterprise Value Multiples

- **EV/Sales multiple**

The EV/Sales multiple presented in Fig. 11.12 is influenced least by creative accounting and differences in accounting standards. While this would seem to suggest at first glance that it is an ideal valuation measure, differences in the point in time when sales are recognized and in the classification of sales can result from differences in accounting standards.

The EV/Sales multiple is quite suitable if no other data is available or if the earnings of the company are negative. This is the case, for example, for startup companies that witness growing sales but may not yet generate earnings. It is furthermore used when differences in accounting standards or tax systems must be addressed.

A disadvantage of multiples on the basis of sales is the fact that they ignore the earnings power of a company. This is problematic, as the value of a company is not based on sales but rather on earnings that can be paid out. Any valuation on the basis of the EV/Sales multiple should therefore only be conducted in case other multiples are not available.

Advantages and disadvantages of the EV/Sales multiple are summarized in Fig. 11.13.

- **EV/EBITDA multiple**

The EV/EBITDA multiple relates the enterprise value to earnings before interest, taxes, depreciation and amortization (see Fig. 11.14).

$$\text{EV/EBITDA} = \frac{\text{Enterprise value}}{\text{EBITDA}}$$

Fig. 11.14 Construction of the EV/EBITDA multiple

Advantages	Disadvantages
• Considers the earnings power • Limited influence of differences in tax systems and accounting standards	• Not applicable if EBITDA is negative • Does not consider differences in investment intensity

Fig. 11.15 Advantages and disadvantages of the EV/EBITDA multiple

$$\text{EV/EBIT} = \frac{\text{Enterprise value}}{\text{EBIT}}$$

Fig. 11.16 Construction of the EV/EBIT multiple

In contrast to the EV/Sales multiple, EBITDA considers the earnings power of a company, since not only sales, but also costs of production as well as distribution costs and general administrative overhead are considered. Since some of these costs are treated differently under the respective accounting standards, EBITDA may be distorted. One example is the treatment of provisions, where different rules for recognition and reversals are in place.

Still, the EV/EBITDA multiple is the earnings multiple which is least affected by accounting and valuation standards. In applied work, the EBITDA multiple is the most frequently used multiple approach. It is supported by the facts that EBITDA is independent of the capital structure and differences in tax rates and that distortions arising from differences in the treatment of depreciation and amortization are avoided. If the interest-bearing liabilities vary within the peer group, no adjustment is needed since EBITDA is not affected by interest payments to providers of debt.[7]

EBITDA is not suitable as a reference value for companies with differing investment intensities, since the resulting differences in the depreciation and amortization volume are not considered by EBITDA (Fig. 11.15).

Advantages	Disadvantages
• Considers the earnings power • Can also be used in the case of different investment intensities (compared to EV/EBITDA) • Limited influence of differences in tax systems and accounting standards	• Not applicable if EBIT is negative • Different treatment of depreciation and amortization will influence EBIT

Fig. 11.17 Advantages and disadvantages of the EV/EBIT multiple

$$\text{Price/Earnings} = \frac{\text{Share price}}{\text{Earnings per share}}$$

Fig. 11.18 Construction of the P/E multiple

- **EV/EBIT multiple**

The difference between EBITDA and EBIT arises from the deduction of depreciation of tangible assets and amortization of intangible assets from EBITDA (see Fig. 11.16). D&A is treated differently in the various accounting standards. This can lead to distorted comparisons if the companies in the peer group base their publications on different accounting systems. Just as the EV/EBITDA multiple, the EV/EBIT multiple is not influenced by differences in tax rates and interest-bearing liabilities of a company. In contrast to EBITDA, EBIT includes depreciation and amortization. The advantages and disadvantages of the EV/EBIT multiple are summarized in Fig. 11.17.

Equity Value Multiples

- **P/E multiple**

The Price/Earnings multiple (P/E) is among the equity multiples (net multiples) and is one of the best known trading multiples. The P/E multiple is a widely used reference for valuation, especially for listed companies. It relates the market value of equity to earnings after taxes and is calculated either on the basis of one share (share price /earnings per share) (see Fig. 11.18) or on the basis of ratios that are relevant for the entire company (market capitalization /earnings after taxes).

Compared to EBIT, the financial figure “earnings after taxes” is mainly influenced by two additional factors: capital structure and tax system. The amount of interest payments depends on the national level of interest rates and the credit standing of the company. Tax payments are influenced by country-specific tax laws. The Price/Earnings multiple is therefore influenced by more factors than the EV/EBIT multiple.

When using P/E multiples, a problem arises if a company does not pay any taxes due to losses carried forward. The earnings after taxes of such a company are higher and the multiple is lower compared to a company with identical EBT that does pay taxes. In such a case it is advisable to work with fictitious taxes based on the regular national tax rate, in order to reestablish comparability. Additional adjustments should be made for one time charges (such as restructuring charges) Fig. 11.19.

- **P/B multiple**

The P/B multiple is calculated by relating the market value of equity (market capitalization) to the book value of equity. Alternatively it can be determined on the basis of one share (share price /book value per share) (see Fig. 11.20).

In general, multiples on the basis of book values are rarely used, since they are backward looking and not related to the future earnings power of the company. In applied work, P/B multiples are used

Advantages	Disadvantages
• Focus on equity (important for the valuation of financial institutions)	• Strongly influenced by differences in accounting standards and tax systems
• Considers the earnings power	• Possibility of distortions due to losses carried forward or one-time charges
• Comprehensive consideration of company-specific factors	• Not applicable if net income is negative

Fig. 11.19 Advantages and disadvantages of the P/E multiple

$$\text{Price/Book value} = \frac{\text{Share price}}{\text{Book value per share}}$$

Fig. 11.20 Construction of the P/B multiple

Advantages	Disadvantages
• Focus on equity (important for the valuation of financial institutions)	• Does not consider future profitability • Can be easily influenced • Backward looking

Fig. 11.21 Advantages and disadvantages of the P/B multiple

specifically for the valuation of financial institutions.[8] For banks and insurance companies, reference values such as sales, EBITDA or EBIT cannot be used, since it is not possible to differentiate between operating activities and refinancing transactions (Fig. 11.21).

Industry-Specific Multiples

> Industry-specific multiples use value drivers that are functionally related to the company's operating activities

Industry-specific multiples are frequently used if the valuation with other multiples does not yield meaningful results. This is the case, for example, if a company has negative earnings or low sales and the company value needs to be derived via different benchmarks.

Depending on the industry of the valuation object, the use of different industry-specific multiples is possible. The enterprise value multiples, which up to this point were based on financial figures such as EBITDA, are now related to non-financial variables. These can be clicks on a web page or number of subscribers of a mobile phone provider.

As the name of these multiples already implies, they can only be used within a specific industry. Since they avoid differences in accounting standards, it is possible to assemble peer groups across countries. Again it needs to be assured that the non-financial reference values are comparable.

Usually no analyst estimates exist for industry-specific reference variables – therefore the multiples are based on historic data.
Fig. 11.22 lists a number of examples of industry-specific enterprise value multiples.

While sector-specific multiples have their advantages, they should be used with care. One problem in the context of industry-specific

Enterprise Value Multiples	Sector
Reference variable:	
EBITDAR (Earnings before interest, taxes, depreciation and amortization and Rent)	Airlines, Retailing, Shipping
EBITDAX (Earnings before interest, taxes, depreciation and amortization and exploration expenses)	Oil Gas
BOE/D (Barrels of oil equivalent per day)	
Assets under Management (AuM)	Asset management
Broadcast cash flow	Broadcasting Telecommunication
Number of beds	Hospitals Hospitality sector
Number of web clicks	Internet
Subscribers	Telecommunication Mobile phone sector Pay-TV
Area in square meters (such as living space)	Real estate Retailing
Production capacity in hectoliters	Brewing

Fig. 11.22 Examples of sector-specific multiples (see Rosenbaum, Pearl, 2013, p.47)

multiples is identified by DAMODARAN as the lack of a direct link between reference variable (such as number of clicks for a web page) and earnings potential.[9] Therefore the investor cannot assess whether the price which was derived for a company is appropriate. As we witnessed around the turn of the millennium, the application of industry-specific multiples can lead to the overvaluation of an entire industry. Overall, the use of industry-specific multiples should rather be discouraged.

4.2.3 Collection of the Required Data

> The availability of all relevant data for all peer companies is essential

The financial modeler must use different information sources in order to obtain the data required for the valuation. Figure 11.23 provides an overview of the sources consulted in applied work as well as the data available.

The collected data which serves as the foundation for the calculation of the multiples was saved and organized in the worksheet `Assumptions` in line with the procedures outlined in "Financial Modeling Standards." Figure 11.24 shows the example of the data for the comparable company AstraZeneca.

Company homepage Investor Relations	Data bases	Information service provider
Quarterly and annual reports eg. ► Sales ► EBITDA ► EBIT ► Net income ► Cash ► Interest bearing liabilities ► Equity ► Shares out Investor presentations Press declaration	eg.Thomson Reuters Research Reports ► Information on peer group companies ► One-time effects ► Expected balance sheet, p&l and cash flow statement for the next 5 years Common Research Estimates ► Mean of all estimates concerning balance sheet, p&l and cash flow statement	eg. Thomson Reuters, Bloomberg Market data eg: ► Historical and up-to-date share prices ► Interest rates ► Beta

Fig. 11.23 Overview of different data sources

Underlying Data of Peer Group € million	(a) t-1	(a) t0	AstraZeneca (e) t1	(e) t2	(e) t3
Share price in €	36	43	43	43	43
Difference between Equity Value and Enterprise Value	1,002	1,432	1,709	616	1,257
Enterprise Value	46,362	55,612	55,889	54,796.0	55,437
Equity	17,368	17,548	16,229	16,038	17,485
Book value per share	13.8	13.9	12.9	12.7	13.9
Sales	20,468	18,894	18,353	17,988	17,567
EBITDA	9,041	6,626	6,382	6,227	6,139
EBIT	7,632	5,159	4,898	4,822	4,860
EBT	4,607	2,893	3,018	3,051	3,169
Net income	4,660	3,098	3,185	3,298	3,359
Earnings per Share	3.7	2.5	2.5	2.6	2.7

Fig. 11.24 Data for the peer group - the example of AstraZeneca[10] (Excel File Corporate Finance, Worksheet Assumptions)

4.2.4 Calculation of the Trading Multiples

> The valuation based on trading multiples needs to be forward looking

When multiples are calculated, it is customary in applied work to use a forecast variable for the denominator.[11] Compared to historical multiples, the forward looking multiples are in line with investment theories and the DCF valuation where the company value is calculated as the present value of future cash flows from the company plus the value of the non-operating assets which needs to be determined separately. Additionally the forecasts of analysts are in most cases normalized, which means that one-time effects have been eliminated from the cash flows.[12] For that reason the results for the years t_1 to t_3 are shown in the following figures (see Fig. 11.25). In order to keep the case study simple, historical multiples are used in the example of Pharma Group and reported in the "football field."

Deriving the peer-group multiples	t_{-1}	t_0	AstraZeneca t_1	t_2	t_3
Price/Book	2.6x	3.1x	3.3x	3.4x	3.1x
Price/Earnings	9.7x	17.2x	17.2x	16.5x	15.9x
EV/Sales	2.3x	2.9x	3.0x	3.0x	3.2x
EV/EBITDA	5.1x	8.4x	8.8x	8.8x	9.0x
EV/EBIT	6.1x	10.8x	11.4x	11.4x	11.4x

Fig. 11.25 Calculating the multiples for the peer group - the example of AstraZeneca (Excel File Corporate Finance, Worksheet Trading_Multiples)

Positions in Excel	Formulas	Excel implementation
Price/Book Multipe t_0 (=Trading_Multiples!E5)	= Share price t_0 / Book value pro Share t_0	=Assumptions!E272/Assumptions!E276
Price/Earnings Multiple t_0 (=Trading_Multiples!E6)	= Share price t_0 / Earnings per Share t_0	=Assumptions!E272/Assumptions!E282
EV/Sales Multiple t_0 (=Trading_Multiples!E7)	= Enterprise Value t_0 / Sales t_0	=Assumptions!E274/Assumptions!E277
EV/EBITDA Multiple t_0 (=Trading_Multiples!E8)	= Enterprise Value t_0 / EBITDA t_0	=Assumptions!E274/Assumptions!E278
EV/EBIT Multiple t_0 (=Trading_Multiples!E9)	= Enterprise Value t_0 / EBIT t_0	=Assumptions!E274/Assumptions!E279

Fig. 11.26 Example for the Excel implementation of the calculation of multiples in the year to for Astra Zeneca

The multiples for the peer companies are combined in the next step to arrive at an aggregated multiple. When aggregating the multiple, the typical problem of having to choose among various ways of aggregation arises. Possible techniques include median, arithmetic mean and harmonic mean.

On balance, the arithmetic mean implies an overvaluation or undervaluation of the company, since outliers are also included in the average.[13] One alternative is the calculation of the median which eliminates maximum and minimum values. BAKER and RUBACK additionally consider the harmonic mean as a viable alternative.[14] This is particularly relevant in the case where an average of ratios needs to be calculated. HERRMANN and RICHTER conclude that the median can be considered as the best estimate for the potential market price.[15] In the concrete case of Pharma Group, we also utilize the median.

The individual multiples for the peer group are calculated with the help of the formulas already presented (Figs. 11.26 and 11.27). Since the worksheet `Assumptions` is only used to save all input data, the calculation of the trading multiples is done in the new worksheet `Trading_Multiples`.

Once the relevant multiples for the individual peer companies have been calculated, they are aggregated by determining the median. The implementation in Excel is illustrated in the following table. Figure 11.28 displays the aggregated median multiples of the peer companies.

Positions in Excel	Formulas	Excel implementation
Median Price/Book t_0 (=Trading_Multiples!E70)	= Median P/B of the peer group in t_0	=MEDIAN(E5;E14;E23;E32;E41;E50;E59)
Median Price/Earnings t_0 (=Trading_Multiples!E71)	= Median P/E of the peer group in t_0	=MEDIAN(E6;E15;E24;E33;E42;E51;E60)
Median EV/Sales t_0 (=Trading_Multiples!E72)	= Median EV/Sales of the peer group in t_0	=MEDIAN(E7;E16;E25;E34;E43;E52;E61)
Median EV/EBITDA t_0 (=Trading_Multiples!E73)	= Median EV/EBITDA of the peer group in t_0	=MEDIAN(E8;E17;E26;E35;E44;E53;E62)
Median EV/EBIT t_0 (=Trading_Multiples!E74)	= Median EV/EBIT of the peer group in t_0	=MEDIAN(E9;E18;E27;E36;E45;E54;E63)

Fig. 11.27 Excel implementation of the calculation of the median multiples

		Median				
Median peer-group multiples		t_{-1}	t_0	t_1	t_2	t_3
Price/Book		2.6x	3.1x	3.3x	3.4x	3.1x
Price/Earnings		17.6x	20.0x	17.3x	16.5x	15.5x
EV/Sales		2.9x	3.3x	3.3x	3.1x	3.2x
EV/EBITDA		8.2x	10.0x	9.4x	8.8x	9.0x
EV/EBIT		9.9x	12.5x	11.4x	11.4x	10.3x

Fig. 11.28 Overview of the median multiples of the peer group companies (Excel File Corporate Finance, Worksheet Trading_Multiples)

4.2.5 Application of the Trading Multiples to the Target Company

In the last step, the aggregated multiples are multiplied with the reference values of the target company in order to arrive at the company value with the help of trading multiples. In the case of equity value multiples, the financial modeler directly obtains the needed market value of equity. In the case of enterprise value multiples, the calculated company value still needs to be transformed into the market value of equity.

The calculation of equity and enterprise value of the target company is presented in Fig. 11.29.

Aggregated median multiples	×	Reference value of the target company	=	Equity value/Enterprise value of the target company

Fig. 11.29 Applying the multiple to the target company target company

Underlying data of Pharma Group (in €m)	Pharma Group t_{-1}	t_0	t_1	t_2	t_3
Difference between Equity Value and Enterprise Value	-16,953	-14,620	-15,028	-15,612	-16,330
Book value	18,451	20,718	22,155	23,696	25,348
Sales	39,741	40,157	42,566	45,120	47,828
EBITDA	6,916	7,830	7,653	7,939	8,241
EBIT	3,928	4,934	4,757	5,043	5,345
Net income	2,403	3,189	3,155	3,384	3,627

Fig. 11.30 Excel implementation of the calculation of the equity value

Deriving the equity value of Pharma Group (in €m)	Pharma Group t_{-1}	t_0	t_1	t_2	t_3
based on Price/Book	48,133	64,092	73,849	80,231	78,415
based on Price/Earnings	42,390	63,780	54,491	55,971	56,239

Deriving the enterprise value of Pharma Group (in €m)	Pharma Group t_{-1}	t_0	t_1	t_2	t_3
based on EV/Sales	116,199	133,876	139,419	140,257	150,932
Difference between Equity Value and Enterprise Value	-16,953	-14,620	-15,028	-15,612	-16,330
= Equity Value of Pharma Group	99,246	119,256	124,392	124,644	134,602
based on EV/EBITDA	56,596	78,603	72,018	69,988	74,422
Difference between Equity Value and Enterprise Value	-16,953	-14,620	-15,028	-15,612	-16,330
= Equity Value of Pharma Group	39,643	63,983	56,990	54,375	58,093
based on EV/EBIT	38,780	61,647	54,285	57,306	54,905
Difference between Equity Value and Enterprise Value	-16,953	-14,620	-15,028	-15,612	-16,330
= Equity Value of Pharma Group	21,827	47,027	39,257	41,693	38,575

Fig. 11.31 Comparison of trading and transaction multiples

The first step in applying multiples is the transfer of the data for the valuation object from the worksheet `Assumptions` to the output worksheet `Trading_Multiples` as shown in Fig. 11.30.

Individual adjustments of the starting values are still needed. As an example, depreciation and amortization needs to be added to EBIT in order to obtain EBITDA. The position *Difference between Equity Value and Enterprise Value* in t_0 in the amount of € 14.620 billion in cell `E79` is linked to the cell `E106` in the worksheet `Auxili-`

Positions in Excel	Formulas	Excel implementation
Application P/B Multiple t_0 (=Trading_Multiples!E89)	= Equity t_0 * P/B Multiple t_0	=E80*E70
Application P/E Multiple t_0 (=Trading_Multiples!E90)	= Net income t_0 * P/E Multiple t_0	=E84*E71
Application EV/Sales Multiple t_0 (=Trading_Multiples!E95)	= Sales t_0 * EV/Sales Multiple t_0	=E72*E81
Difference between Equity Value and Enterprise Value t_0 (=Trading_Multiples!E96)	= Difference between Equity Value and Enterprise Value t_0	='Auxilliary Calculations'!E106
Calculation Equity Value t_0 (=Trading_Multiples!E97)	= Enterprise Value t_0 + Difference between Equity Value and Enterprise Value t_0	=E95+E96
Application EV/EBITDA Multiple t_0 (=Trading_Multiples!E99)	= EBITDA t_0 * EV/EBITDA Multiple t_0	=E73*E82
Difference between Equity Value and Enterprise Value t_0 (=Trading_Multiples!E100)	= Difference between Equity Value and Enterprise Value t_0	='Auxilliary Calculations'!E106
Calculation Equity Value t_0 (=Trading_Multiples!E101)	= Enterprise Value t_0 + Difference between Equity Value and Enterprise Value t_0	=E99+E100
Application EV/EBIT Multiple t_0 (=Trading_Multiples!E103)	= EBIT t_0 * EV/EBIT Multiple t_0	=E74*E83
Difference between Equity Value and Enterprise Value t_0 (=Trading_Multiples!E104)	= Difference between Equity Value and Enterprise Value t_0	='Auxilliary Calculations'!E106
Calculation Equity Value t_0 (=Trading_Multiples!E105)	Equity Value t_0 = Enterprise Value t_0 + Difference between Equity Value and Enterprise Value t_0	=E103+E104

Fig. 11.32 Excel implementation of the calculation of the equity value

ary_Calculations. It becomes apparent that this difference was calculated in accordance with the DCF method. In order to get from the enterprise value to the equity value, non-operating assets, cash and cash equivalents and the shares investments accounted for using the equity method are added and interest bearing liabilities and minority interest (equity attributable to non-controlling interest) are subtracted.

The equity value is calculated in the next step, which is illustrated in Fig. 11.31. The underlying formulas for the year t_0 are shown in Fig. 11.32.

5 Transaction Multiples

5.1 Overview of Transaction Multiples

Transaction multiples are used frequently in applied work

The valuation of companies with the help of comparable transactions (transaction multiples) follows the same principle as the valuation with the help of trading multiples (comparable listed companies). Under the assumption that comparable companies should have similar company values, the unknown company value is derived with the help of multiples from historical transactions (transaction multiples).

In applied work, transaction multiples are rather popular, especially for upcoming M&A transactions. Reasons for the use of this method include the simple mathematical calculation and application as well as the focus on prices that were actually paid for companies in the past.

5.2 Comparison of Trading Multiples and Transaction Multiples

Trading multiples provide good results as long as current data is provided

Trading multiples provide a quick overview concerning the valuation of listed companies. Due to the requirement to publish annual reports combined with the easy availability of analyst reports it is possible to quickly conduct a valuation for the target company. An absolute requirement for the use of this method is a carefully selected group of comparable companies. In contrast to the method of transaction multiples it is much easier to assemble a comparable peer group, since information about listed companies is readily available.

In the M&A business, the current market capitalization represents the minimum price that must be paid in order to acquire a listed company. The current owners of the company would turn down any offer below the current market capitalization.

> Transaction multiples provide good results as long as a sufficient number of comparable transactions is available

Multiples for comparable transactions refer to a valuation based on historical transactions in a specific industry. A prerequisite for this valuation method is the accurate compilation of a list of comparable M&A transactions. The challenge is to identify a sufficiently large number of comparable transactions in the industry and to compile sufficient information about these transactions. It is quite possible that only a few comparable takeovers exist. Still, the goal is to obtain a broad base of transactions in order to exclude statistical outliers.

Compared to trading multiples, the prices from transaction multiples are usually higher. The main reason for this is the so-called takeover premium. During normal market conditions, the price is not equal to the company value, since the expected takeover premium can take on different values. The following formula holds: Value + Premium = Price. Among others, the takeover premium is influenced by the following factors:

- Type of transaction (friendly or hostile);
- Size of participation (minority or majority);
- Bidding situation (exclusive versus auction);
- Possible synergies (low versus high);
- Type of payment (cash, shares, options).

In applied work it is frequently not possible to compile a sufficient number of comparable transactions. On the one hand, this is due to the fact that there are times when the number of M&A transactions is low. On the other hand, there is frequently not much public information available about the details of the transaction. Especially in the case of transactions of companies that are not listed, information about

Trading multiples	Transaction multiples
• Trading valuation • No premium • Peer group consists of comparable listed companies • Peer group can be derived with relative ease • Financial data is available	• Transaction price • (Takeover-)premium • Peer group consists of transactions of comparable companies • Comparable transactions are relatively hard to identify • Transaction data is not always available

Fig. 11.33 Comparison of trading and transaction multiples

the price of the transaction and important financial figures are not published, because there is no legal requirement to do so.

The decisive difference to the trading multiples lies in the fact that not market prices serve as the basis for the valuation, but historically paid prices of completed takeovers and acquisitions. Just as the valuation with trading multiples, the mathematical application of this method is not very complex. The significantly larger challenge is posed by the collection of information. Things become problematic if there is an insufficient number of relevant transactions or if the quality of the published data is unsatisfactory.

Figure 11.33 summarizes the key characteristics of both approaches.

5.3 Valuation Process with Transaction Multiples

The Valuation with transaction multiples can be separated into four steps:

1. **Selection from the database:** In the first step, an initial selection of relevant M&A transactions from the database is made based on significant influencing factors.
2. **Reduction in Excel:** In the second step, the selected comparable transactions are imported into Excel and screened with regard to additional criteria (such as region and company size).
3. **Calculation of the transaction multiples:** In the third step, the multiples are calculated by finding the median.
4. **Application of the transaction multiples to the target company:** In the last step, the target company is valued by applying the calculated transaction multiples.

Fig. 11.34 Significant factors that influence the choice of comparable transactions

The factors listed in Fig. 11.34 are relevant and have a major influence on the number and quality of comparable transactions and ultimately on the result.

5.3.1 Selection from the Database

> Databases such as Thomson Reuters help the financial modeler to quickly identify a suitable universe

#	Date	Region of target	Name of Target	EV in $m	EV/Sales	EV/EBITDA	EV/EBIT
1	27.11.2013	West Europe	BCP Fluted Packaging Ltd.	27.2	np	-	np
2	26.11.2013	South East Europe	Constelex Tech Enablers Ltd.	1	np	-	np
17,252	16.03.1983	South Pacific	Hargreaves Fertilizers Ltd.	-	np	-	np
17,243	01.07.1982	North America	Produits Chimiques Usine	-	np	-	np
17,254	23.06.1982	West Europe	Lonza Ltd.	-	np	-	np

Fig. 11.35 Overview of available transactions in the fields of materials and healthcare (Excel File Corporate Finance, Worksheet Transaction_Multiples)

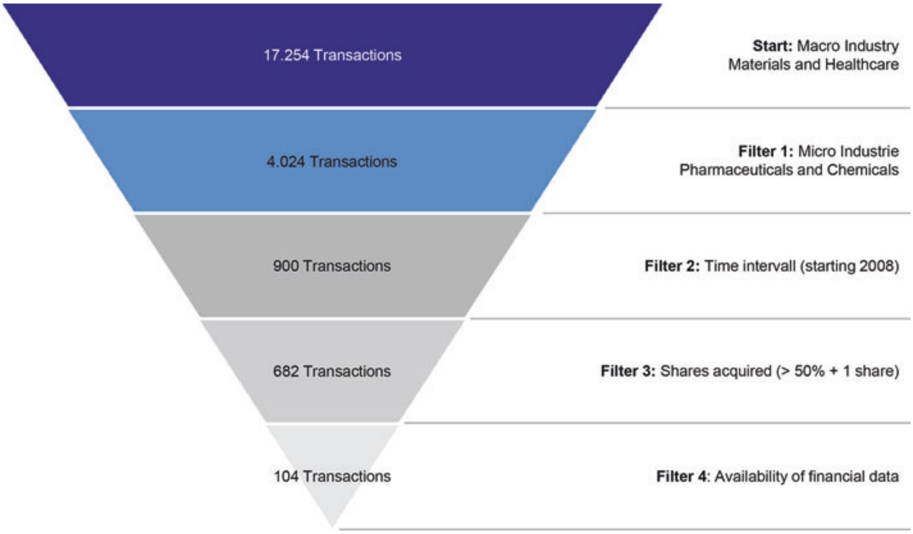

Fig. 11.36 Considering the significant factors at the level of the database

The data which serves as the basis for this example is extracted from Thomson Reuters. Additional well known databases include for example Bloomberg, Mergermarket or Dealogic.

Figure 11.35 shows an excerpt from the Thomson Reuters database about 17,254 transactions in the sectors materials and healthcare since the middle of the year 1982

In order to avoid the slowing down of the Excel model and to maintain transparency, the initial pre-selection is conducted within the database on the basis of a number of significant factors (selection process see Fig. 11.36).

Filter1: Limiting the sector in which the target company is active

Filter 1: A key question relates to the industry in which the target company is active. The comparable transactions must relate to the same industry as the valuation object. Several industry classifications exist in the market:

- Standard Industrial Classification (SIC);
- Global Industry Classification Standard (GICS);
- Industry Classification Benchmark (ICB).

In general, classification systems have a multi-dimensional structure. Initially all industries are broken down into so-called macro industries (such as "materials"). Within a macro industry, several sub-industries exist, which are also called micro industries. Initially an attempt should be made to find the comparable transactions among the matching sub-industries. Should the number of transactions be insufficient, related micro industries, respectively the higher-level macro industry can be used as substitutes. It must be assured that the industries share similar characteristics (such as markets, distribution channels). Otherwise comparability suffers and the valuation will be distorted. For our case study, 17,254 transactions are recorded for the macro industries materials and healthcare (listed and unlisted). But since several sub-industries exist in which the Pharma Group has no operations (such as the areas of mining or forest products), an additional filter is placed in Thomson Reuters for the relevant sub-industries pharmaceuticals and chemicals. This reduces the number of transactions to 4,024.

Filter 2: The time interval should normally be between 3 and 5 years

Filter 2: Recently completed M&A transactions provide the most current and representative data. For the method of transaction multiples it is frequently difficult to obtain a sufficient number of relevant

comparable transactions. The choice of a longer time interval can help to increase the number of comparable transactions. However, the time period chosen should not be too long, since market conditions change.

Still, this does not mean that older transaction should not be considered at all. Older transactions are useful if the acquired company is in the same stage of the business cycle as the target company. Following Rosenberg and Pearl, a suitable time interval for historical takeovers lies between three and five years in our opinion.[16] Following this recommendation, the time interval from the last 5 years is selected for our case study. The number of transactions is reduced from 4024 to 900 with this step.

> Filter 3: The percentage of acquired shares will affect the premium that must be paid

Filter 3: In addition to company-specific factors, factors specific to the transaction also play an important role, since they can influence the quality of the comparison. One factor that is specific to the transaction is the percentage of acquired shares, for example.

Initially it needs to be assessed whether the comparable transaction was a majority acquisition (50%+1 share) respectively a complete takeover or the acquisition of a minority stake. In the first case it must be assumed that the acquirer has paid a so-called takeover premium to obtain the controlling majority. This in turn will affect the multiples (the higher the premium, the higher the transaction value and the multiple). In the case of the Pharma Group, 100% of the shares are for sale. It follows from this consideration that acquisitions of minority stakes must be excluded, because their inclusion would imply an undervaluation.

The determination of the takeover premium is complicated by the fact that there have been cases of listed companies where rumors about a possible transaction were circulating several days before the announcement. In these cases, the share price already moves higher ahead of the announcement of the offer. This in turn makes it advisable to base the calculation of the takeover premium on a share price that was still unaffected by the rumors.

The takeover premium differs from transaction to transaction and depends on a number of factors. Depending on geographical focus (for example domestic or cross-border transaction), type of transaction (for example friendly or hostile), acquisition of shares (majority or minority transaction) or measured time period (weeks before the announcement of the transaction up to the day before the announcement), different results are obtained for premiums paid in the context of majority acquisitions,[17] for premiums for shares of the same company with different voting rights[18] or for the premium paid during block trades.[19] The approximate band for the premium ranges from 20% to 25%.

Filter 4: The calculation of the multiples requires financial data for the transaction

Filter 4: The most important consideration in the derivation of relevant transactions relates to the availability of financial data and ratios. In order to calculate multiples it is mandatory that specific transaction data is published. Especially in the cases of takeovers of companies that are not publicly listed or takeovers by financial investors, it is frequently agreed not to publish the transaction price and important key figures. When deriving suitable transaction multiples, only transactions which have all necessary data should be considered. As can be seen from Fig. 11.36, this filter reduces the number of transactions to 104.

After these steps, the number of transactions has reached an acceptable target value (17,254 → 104) and can now be used for final modeling in Excel.

5.3.2 Narrowing Down the Selection in Excel

Due to differences in tax rates and accounting standards in different regions, the selection of a suitable region is of major importance. Multiples with sales, EBITDA or EBIT in the denominator are not affected by changes in tax rates. But for equity multiples (such as P/E), which are based on earnings, the situation is different. The annual profit from the income statement is influenced by different depreciation and amortization rules and tax rates. This makes the P/E multiple less suitable for the method of comparing transactions if these transactions involve companies from different countries. Even within a country, different tax rates may be applicable (depending on the legal form or if losses from previous years are carried forward).

It is recommended for two reasons to look for comparable transactions in the same country or region where the valuation object is located. On the one hand, transactions in a specific industry and region are particularly comparable, since the acquired companies usually share important similarities with the target company. On the other hand, especially small firms are dependent on the prevailing economic situation in the region. A company in a booming region with high growth rates will be trading at higher multiples compared to a company located in a region which only shows weak growth.

Since premiums can differ strongly between regions, the region can have a decisive influence on the comparability of different transactions. Regional restrictions are less important for globally active companies (such as oil or aluminum), since the prices of raw materials are determined at the global level.

While Pharma Group is headquartered in Germany, it is globally active. In this case study, comparable transactions are selected from the regions Western Europa and North America.

How can the data be filtered in Excel? Excel offers two main options.

The Filter Function

The financial modeler gets to the filter function via the menu ➲ *Data* ➲ *Filter* (Fig. 11.37).

In the worksheet, a small arrow which is pointing down appears for each header. For region, the financial modeler can select the desired regions "North America" and "Western Europe" (see Fig. 11.38). In the column `Enterprise Value` the financial modeler can now go to *Number Filters* ➲ *Greater Than Or Equal To* and enter the number 10,000 Fig. 11.39.

This assures that only transactions are shown where the target company is in Western Europe or North America and the company value is € 10 billion or more.

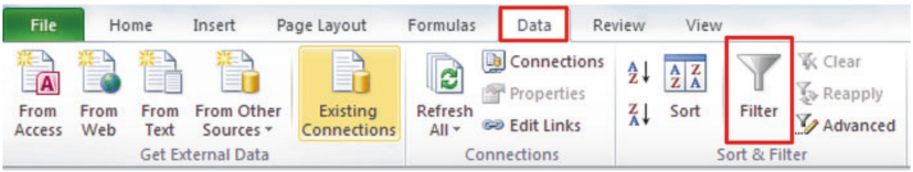

Fig. 11.37 Using the Filter function to filter data

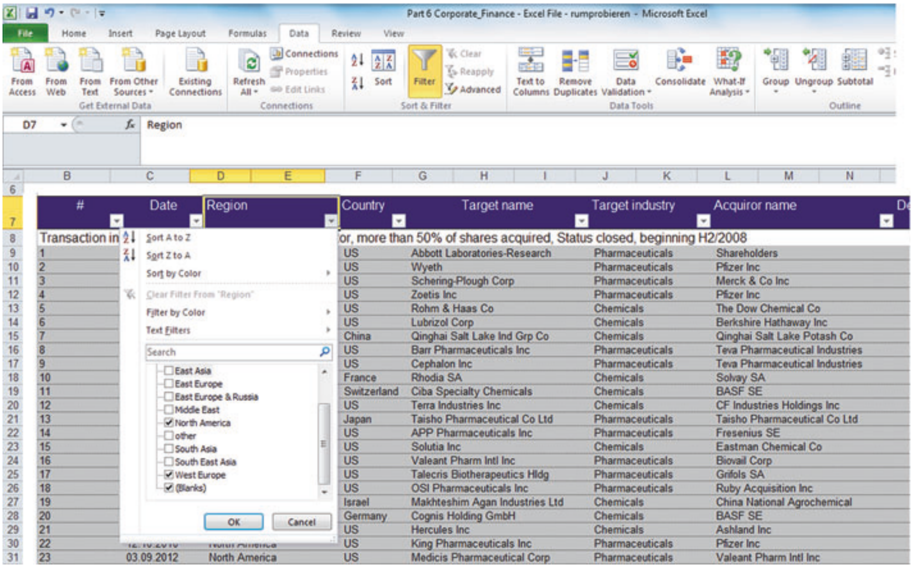

Fig. 11.38 Filter for the regions North America and Western Europe (Excel File Corporate Finance, Worksheet Transaction_Multiples)

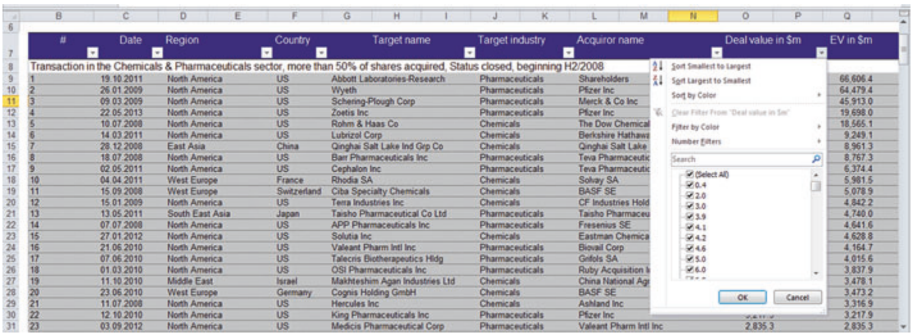

Fig. 11.39 Filter for a company value that is € 10 billion or more (Excel File Corporate Finance, Worksheet Transaction_Multiples)

This method is very suitable for smaller amounts of data in Excel. For larger amounts the financial modeler will use the advanced filter function.

The Advanced Filter Function

The Advanced Filter function is implemented by the financial modeler in the following 5 steps:

1) The financial modeler inserts a new worksheet "`Transaction Multiple`".

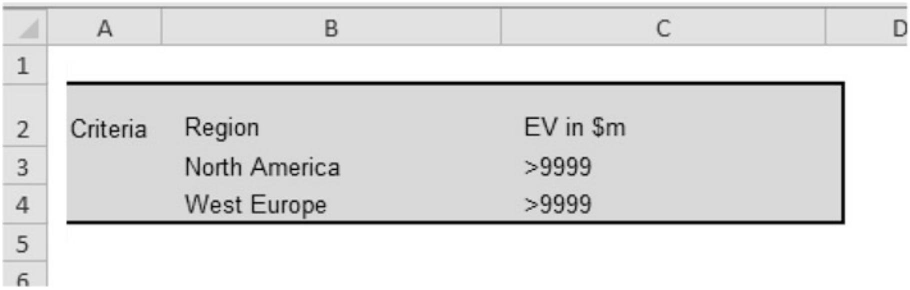

Fig. 11.40 Determination of the selection criteria in the selection box (Excel File Corporate Finance, Worksheet Transaction_Multiples)

2) He links the table with the 104 transactions from the input sheet with the worksheet "`Transaction Multiple`." The cells `C9:AC112` from the worksheet "`Transaction Multiple`" are linked with the cells `B402:AB505` from the worksheet "`Assumptions`". After that, the transactions are numbered in column .

3) The selection criteria are now defined as shown in Fig. 11.40. The description in the criteria box must exactly match the headers of the selected columns for the 104 transactions (row 7). This is best accomplished by transferring the selected contents to the selection box via copy/paste. This and the following operations constitute a deviation from the standards of financial modeling, which states that input data is to be entered exclusively into the worksheet `Assumptions`.

4) The financial modeler clicks on a cell inside the selection box (for example `A2`). After that he selects from the ribbon ➲ *Data* ➲ *Filter* (same as the previous case of the "Filter Function"). But now he selects the command ➲ *Advanced*, which can be found in the lower right corner of the filter mask. The following mask opens up (see Fig. 11.41):

   - The financial modeler selects the action: *Copy to another location.*
   - For *List range* he selects the entire table of all 104 transactions (`$B$7:$AC$112`).
   - For *Criteria range* he marks that he wants to select those transactions among the 104 records, where the target company is located in North America or Western Europe (Pharma Group is located in Germany, hence Western Europe. The prices that were

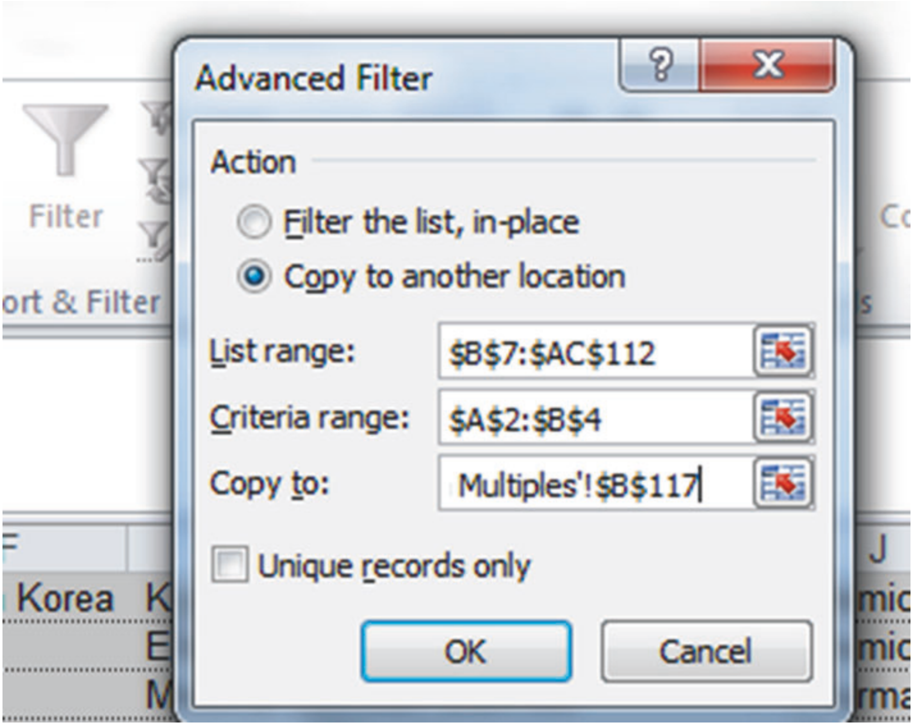

Fig. 11.41 Filter selection

paid for companies within the relevant sector for Pharma Group are relatively similar in North America or Western Europe). Thus he selects: (`$A$2:$B$4`).

- For *Copy to* he selects the cell `$B$117`.

The result is the following table (see Fig. 11.42):

It is apparent that the transactions 7 (East Asia – China), 13 (South East Asia – Japan) as well as 19 (Middle East – Israel) are no longer included among the Top 20.

5) The same procedure is repeated one more time with a slight modification. From the remaining set of 67 transactions with target companies in North America or Western Europe, those transactions need to be selected which have an enterprise value of € 10 billion or larger. The application of Benford's law in general suggests a break when moving from 9 to the next higher unit. Therefore threshold values in applied work are frequently set at € 10 million, € 100 million, € 1 billion, € 10 billion and so forth. For the case

#	Date	Region	Country	Target name
1	19.10.2011	North America	US	Abbott Laboratories-Research
2	26.01.2009	North America	US	Wyeth
3	09.03.2009	North America	US	Schering-Plough Corp
4	22.05.2013	North America	US	Zoetis Inc
5	10.07.2008	North America	US	Rohm & Haas Co
6	14.03.2011	North America	US	Lubrizol Corp
8	18.07.2008	North America	US	Barr Pharmaceuticals Inc
9	02.05.2011	North America	US	Cephalon Inc
10	04.04.2011	West Europe	France	Rhodia SA
11	15.09.2008	West Europe	Switzerland	Ciba Specialty Chemicals
12	15.01.2009	North America	US	Terra Industries Inc
14	07.07.2008	North America	US	APP Pharmaceuticals Inc
15	27.01.2012	North America	US	Solutia Inc
16	21.06.2010	North America	US	Valeant Pharm Intl Inc
17	07.06.2010	North America	US	Talecris Biotherapeutics Hldg
18	01.03.2010	North America	US	OSI Pharmaceuticals Inc
20	23.06.2010	West Europe	Germany	Cognis Holding GmbH

Fig. 11.42 Takeovers in the pharma industry in North America and Western Europe (Excel File Corporate Finance, Worksheet Transaction_Multiples)

#	Date	Region	Country	Target name	Target industry	Acquiror name	Deal value in $m	EV in $m
1	19.10.2011	North America	US	Abbott Laboratories-Research	Pharmaceuticals	Shareholders	66,606.4	66,606
2	26.01.2009	North America	US	Wyeth	Pharmaceuticals	Pfizer Inc	64,479.7	64,479
3	09.03.2009	North America	US	Schering-Plough Corp	Pharmaceuticals	Merck & Co Inc	45,913.3	45,913
4	22.05.2013	North America	US	Zoetis Inc	Pharmaceuticals	Pfizer Inc	13,248.5	19,698
5	10.07.2008	North America	US	Rohm & Haas Co	Chemicals	The Dow Chemical Co	18,565.1	18,565

Fig. 11.43 Takeovers in the pharma industry in North America and Western Europe with an enterprise value greater than €10 billion (Excel File Corporate Finance, Worksheet Transaction_Multiples)

of Pharma Group, the market capitalization is in the double-digit billions and the threshold value is therefore set at €10 billion. The financial modeler establishes this selection as follows:

- The financial modeler selects the action: *Copy to another location*.
- For *List range* he selects the entire table of all 67 transactions (`$B$117:$AC$184`).
- For *Criteria range* he selects: (`$A$2:$C$4`).
- For *Copy to* he selects the cell `$B$189`.

The result is the following table (see Fig. 11.43):

5.3.3 Calculating the Transaction Multiples

Once an adequate number of transactions have been derived, the financial modeler determines the transaction multiples in a next step and

	EV in $m	Equity in $m	Shares acquired in %	Deal Status	EV/SALES	EV/EBITDA	EV/EBIT
190	66,606	55,513	100.0	Completed	3.1x	8.7x	10.2x
191	64,479	67,285	100.0	Completed	2.9x	8.1x	9.3x
192	45,913	38,615	100.0	Completed	2.1x	15.2x	54.5x
193	19,698	16,520	80.2	Completed	3.8x	18.6x	23.0x
194	18,565	15,513	100.0	Completed	1.6x	13.1x	21.0x
195							
196			Median		2.9x	13.1x	21.0x

Fig. 11.44 Derivation of the multiples for the peer group (Excel File Corporate Finance, Worksheet Transaction_Multiples)

Positions in Excel	Formulas	Excel implementation
`=Transaction_Multiples!X196)`	= Median EV/Sales of the Peer Transactions	`=MEDIAN(X190:X194)`

Fig. 11.45 Calculating the EV/Sales multiple

applies them to the target company. Generally one-off effects need to be eliminated. These can be profits (such as reversals of provisions) or expenditures (such as restructuring charges) that are only expected once.

In our case the comparable transactions come from several regions. If the financial modeler were to use equity multiples such as P/E or P/B, the results would be influenced too strongly by differences in tax rates and accounting standards. Therefore only enterprise value multiples are included in the analysis in the case of Pharma Group.

The calculation of the aggregated multiples is clarified in the following with reference to EV/Sales in Figs. 11.44 and 11.45.

From Fig. 11.44 it follows that the application of the median leads to an EV/Sales multiple in cell `X196` of 2.9x. It is calculated as follows:

5.3.4 Application of the Transaction Multiples to the Target Company

> The quality of the valuation result varies with the quality of the peer group companies

In the last step, the financial modeler applies the derived multiples to the target company. From Figs. 11.46 and 11.47 it is apparent that in our example the enterprise value (€ 118.343 billion) is calculated by

data of Pharma group (in €m)	Pharma Group t_0
Difference between Equity Value and Enterprise Value	-14,620
Sales	40,157
EBITDA	7,830
EBIT	4,934

Median Multiples of Peer Group	Median t_0
EV/Sales	2.9x
EV/EBITDA	13.1x
EV/EBIT	21.0x

Applying the Median Multiples	Pharma Group t_0
Based on EV/Sales	118,343
Difference between Equity Value and Enterprise Value	-14,620
= Equity Value of Pharma Group	**103,723**

Fig. 11.46 Derivation of the equity value of Pharma Group (Excel File Corporate Finance, Worksheet Transaction_Multiples)

multiplying the number for the target company (here: sales of € 40.157 billion) with the multiple (here: 2.9x). In order to calculate the equity value, the enterprise value is adjusted by subtracting the item *Difference between Equity Value and Enterprise Value of Pharma Group* (€ 14.620 billion).

Positions in Excel	Formulas	Excel implementation
Enterprise Value of Pharma Group t_0 (=Transaction multiples!E216)	=(Sales * EV/Sales)	=(E202*E209)
Difference between Equity Value und Enterprise Value of Pharma Group t_0 (=Transaction multiples!E217)	= Difference between Equity Value and Enterprise Value of Pharma Group t_0	='Auxilliary Calculations'!E106
Equity Value of Pharma Group t_0 (=Transaction multiples!E218)	=(Enterprise Value t_0 + Difference between Enterprise Value and Equity Value t_0	=(E216+E217)

Fig. 11.47 Derivation of the equity value of Pharma Group based on the EV/Sales multiple

5.4 The Football Field Graph

5.4.1 Application of the Football Field Graph

Frequently the company valuation is conducted for the CEO or the major shareholder of the valuation object. At a bank, the company valuation, which was conducted by the associate and the analyst, supervised by the vice presidents, will frequently be reviewed by the managing director of a review Committee. This is also the case for major auditing firms (see the chapter Model Review). Before the results of the company valuation can be presented to clients, they must pass the review committee.

Now that the financial modeler has completed many complex steps in the bottom-up derivation of the results, it is important to arrive at a clear central message. A good financial modeler is not only able to clearly structure complex topics, but can also present them with the same clarity. In order to present the different valuation results in a comprehensive manner, the financial modeler can make use of the so-called football field graph.

5.4.2 The Modeling Process in Three Steps

The process of modeling the football field graph can be structured along the following three steps:

1. **Preparation of the data:** In the first step, the data necessary for the diagram is collected in a table

2. **Creation of the diagram:** In the second step, the diagram is created and the data is integrated
3. **Design of the diagram:** In the final step, adjustments are made in the diagram in order to achieve an optimal presentation

Preparation of the Data

The first step in the creation of the football field graph is the collection of all required data in a table (see Fig. 11.48). For the stacked bar chart used for the football field graph, the following data is required.

Data aggragation for the footballfield matrix				
in EUR billion	Min	Median	Max	Range
DISCOUNTED CASH FLOW METHOD				
Periodic WACC Approach	83.8	85.5	87.2	3.4
APV Approach	83.8	85.5	87.2	3.4
Periodic Equity Approach	83.8	85.5	87.2	3.4
MARKET CAP & BOOK VALUE				
Market cap t0	82.7	84.4	86.0	3.4
Book value t0	20.3	20.7	21.1	0.8
TRADING MULTIPLES				
Price/Book t0	62.8	64.1	65.4	2.6
Price/Earnings t0	62.5	63.8	65.1	2.6
EV/Sales t0	116.9	119.3	121.6	4.8
EV/EBITDA t0	62.7	64.0	65.3	2.6
EV/EBIT t0	46.1	47.0	48.0	1.9
TRANSACTION MULTIPLES				
EV/Sales t0	101.6	103.7	105.8	4.1
EV/EBITDA t0	86.2	88.0	89.8	3.5
EV/EBIT t0	87.1	88.9	90.7	3.6
Range				2%

Fig. 11.48 Data aggregation for the football field chart (Excel File Corporate Finance, Worksheet Transaction_Multiples)

Market capitalization	Formulas	Excel implementation
Minimum Market capitalization t_0 (=Management Summary!C41)	= Median * (1 - Range)	=D41*(1-$F$57)
Median Market capitalization t_0 (=Management Summary!D41)	= Company value based on Market capitalization in t_0	='Market capitalization & Book value'!E11/1000
Maximum Market capitalization t_0 (=Management Summary!E41)	= Median * (1 + Range)	=D41*(1+$F$57)
Range Market capitalization t_0 (=Management Summary!F41)	= Max – Min	=E41-C41

Fig. 11.49 Calculation of the data required for the diagram using the example of the market capitalization

- Minimum equity value (column C)
- Maximum equity value (column E)
- Median equity value (based on the underlying valuation method) (column D)
- Range of the equity value: maximum value – minimum value (row 57)

The required calculations in Excel for the setup of the table are illustrated in Fig. 11.49 using the example of the market capitalization.

In our case a range of 2% was assumed for the median equity value. Alternatively it is possible that particularly relevant and important companies from the peer group provide an indication about the range of the multiple for trading and transaction multiples.

Creation of the Diagram

A stacked 2-D bar chart is used for the football field graph

Once the table is competed, a stacked bar chart is created in the next step. To do so, the financial modeler goes to ➲ *Insert* ➲ *Bar* ➲

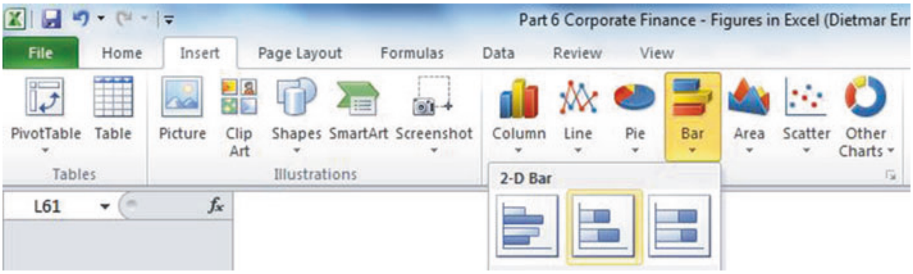

Fig. 11.50 Creating a stacked bar chart.

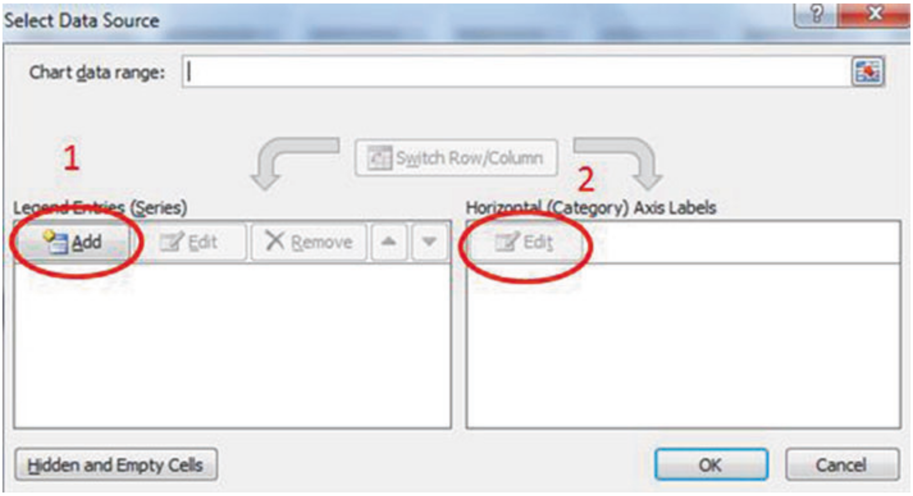

Fig. 11.51 Mask for data selection in Excel

2-D Bar ➲ *Stacked Bar*. The data from the table created in step 1 is incorporated in this diagram (Fig. 11.50).

A right-click in the diagram ➲ *Select data* takes the financial modeler to the following mask for selecting data in Excel (Fig. 11.51):

Step 1: In a first step, the financial modeler adds the data for the bars (rows). By clicking *Add,* the following mask opens up (see Fig. 11.52):

For *Series Name* the financial modeler enters the description *Min* and enters the following values for *Series Values*: `Management Summary'!$C$35:$C$54`. He then completes the task by hitting OK. The same procedure is repeated by clicking again on *Add* and entering the range and the maximum. Thus the following data is entered in step 1 (see Fig. 11.53):

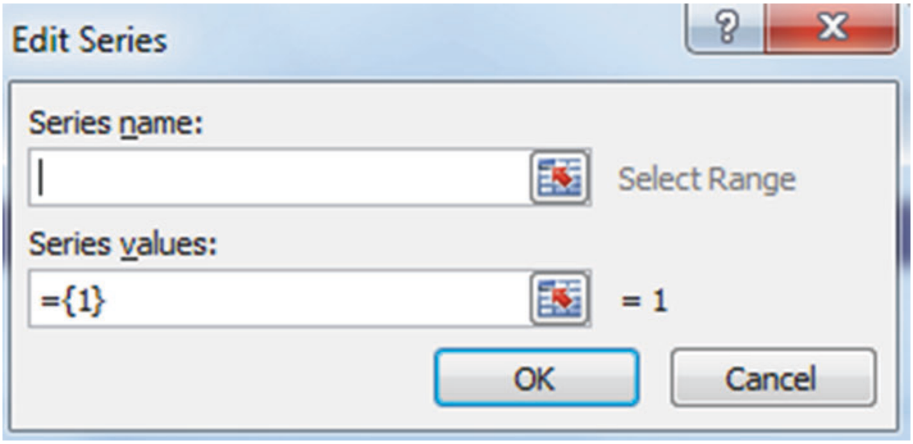

Fig. 11.52 Working with the data series

#	Row name	Row value
1	Min (=Management Summary!$C$34)	`= Management Summary'!$C$35:$C$54`
2	Range (=Management Summary!$F$34)	`= Management Summary'!$F$35:$F$54`
3	Max (=Management Summary!$E$34)	`= Management Summary'!$E$35:$E$54`

Fig. 11.53 Stepwise input of the data required for the bar charts

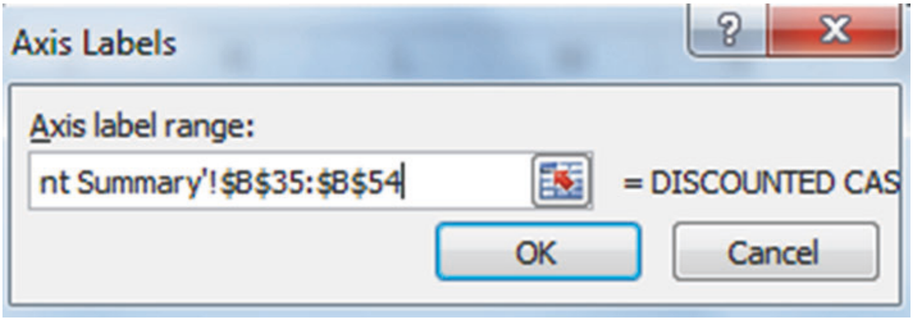

Fig. 11.54 Labeling the axis of the bar chart

Step 2: Next, the bars which were added in step 1 are labeled with the appropriate valuation method. For this purpose, the financial modeler clicks on the circled field *Edit* in Fig. 11.54 and inserts the following command for ➲*Axis label range*: `Management Summary'!$B$35:$B$54` (Fig. 11.54):

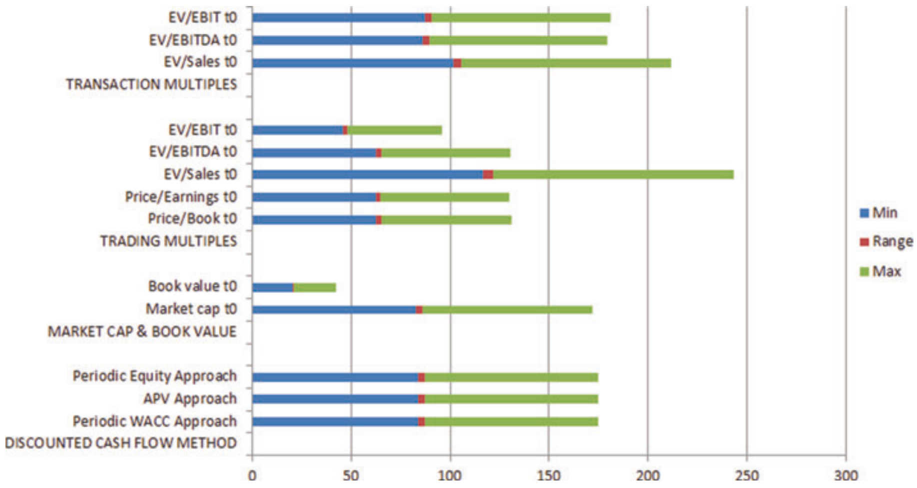

Fig. 11.55 Preliminary view of the football field graph once the data has been selected

The process of data selection and labeling is now complete. Figure 11.55 shows a preliminary view of the football field after all required data has been added to the diagram.

Design of the Diagram

In the following steps the diagram design is gradually optimized. The aim is to obtain a graph which shows at a glance the valuation range obtained for Pharma Group to the principal of the financial modeler.

- **Formatting the vertical axis**

As can be seen from the above figure, the bars and their labels are presented in reverse order relative to the table, which was initially created by the financial modeler to aggregate all the data. For that reason, the financial modeler reverses the labeling. He formats the vertical axis as follows (see Fig. 11.56): ➲ *Chart Tools* ➲ *Layout*➲ *Axis* ➲ *Vertical Primary Axis* ➲ *Additional Options*

Now *Categories in reverse order* and *At largest rubric* are selected. This assures that the bars are presented correctly as shown in the Fig. 11.57:

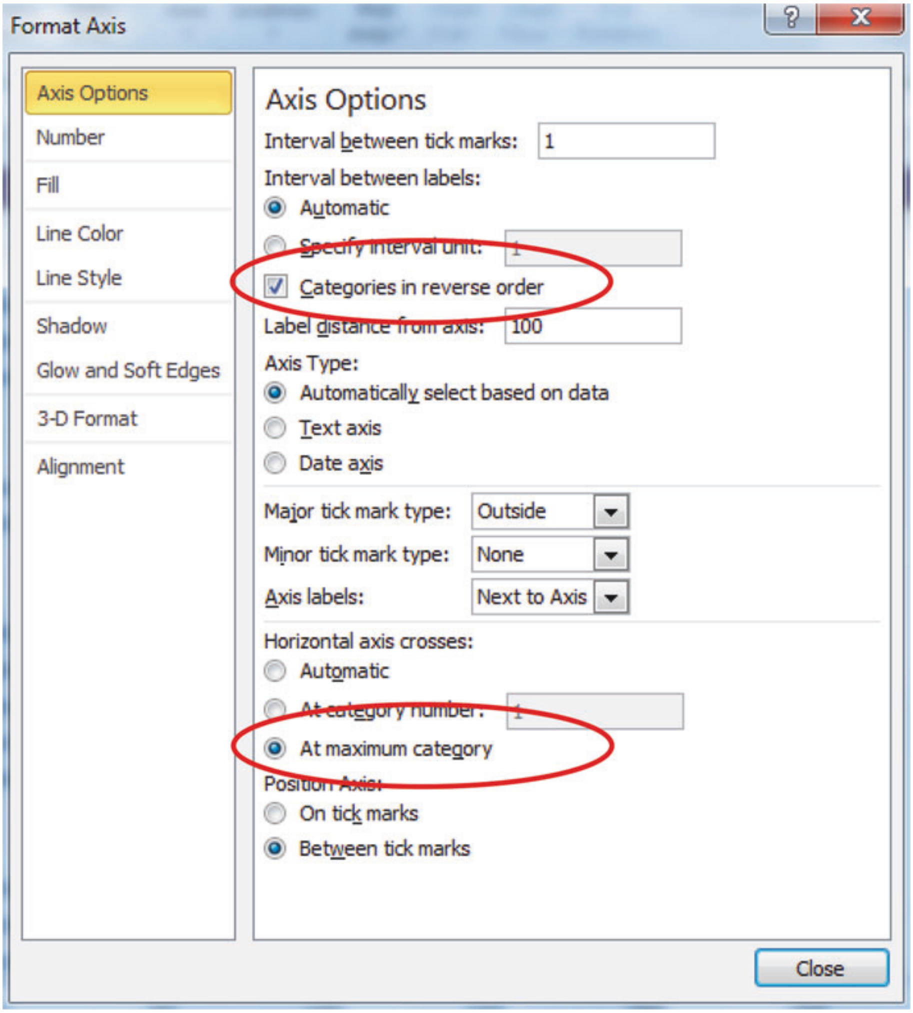

Fig. 11.56 Formatting the vertical axis

- **Formatting the horizontal axis**

In the following, the horizontal axis is adjusted as follows: ➲ *Chart Tools* ➲ *Layout* ➲ *Axis* ➲ *Horizontal Primary Axis* ➲ *Additional Options.*

The mask shown in Fig. 11.58 opens up:

The financial modeler has received a mandate from the potential acquirer of Pharma Group to conduct a company valuation. Buyers are

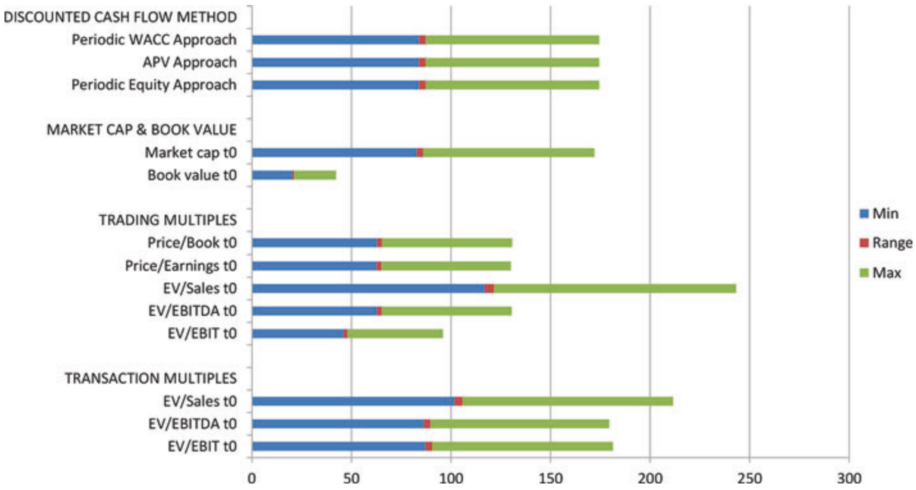

Fig. 11.57 Correct display of the data labels

interested in values that are as low as possible. Consequently the financial modeler sets a maximum value of € 140 billion. This is based on the maximum value from the data source (here: € 122 billion based on the EV/Sales multiple from the trading multiples). This way of presenting the data suggests that there is not much room to the upside. € 20 billion is selected as minor unit. He furthermore formats the values of the horizontal axis with the corresponding unit and currency ➲ *Number* ➲ *Custom* ➲ *#.##0 " € billion".*

- **Data Labeling**

Once the axes have been formatted, the data labels for the minimum and maximum bars are added as follows: ➲ *Right-click on the respective bar* ➲ *Add Data Labels.* In order to assure that the data labeling of the bars is directly next to the valuation range, the position of the data labels for both bars must be determined as follows: ➲ *Right-click on the respective bar* ➲ *Format Data Labels.* For the case of the minimum bars the financial modeler selects the field ➲ *End inside*. For the case of the maximum bars the financial modeler selects the field ➲ *Basis inside*. The use of decimal places is not recommended when labeling the data.

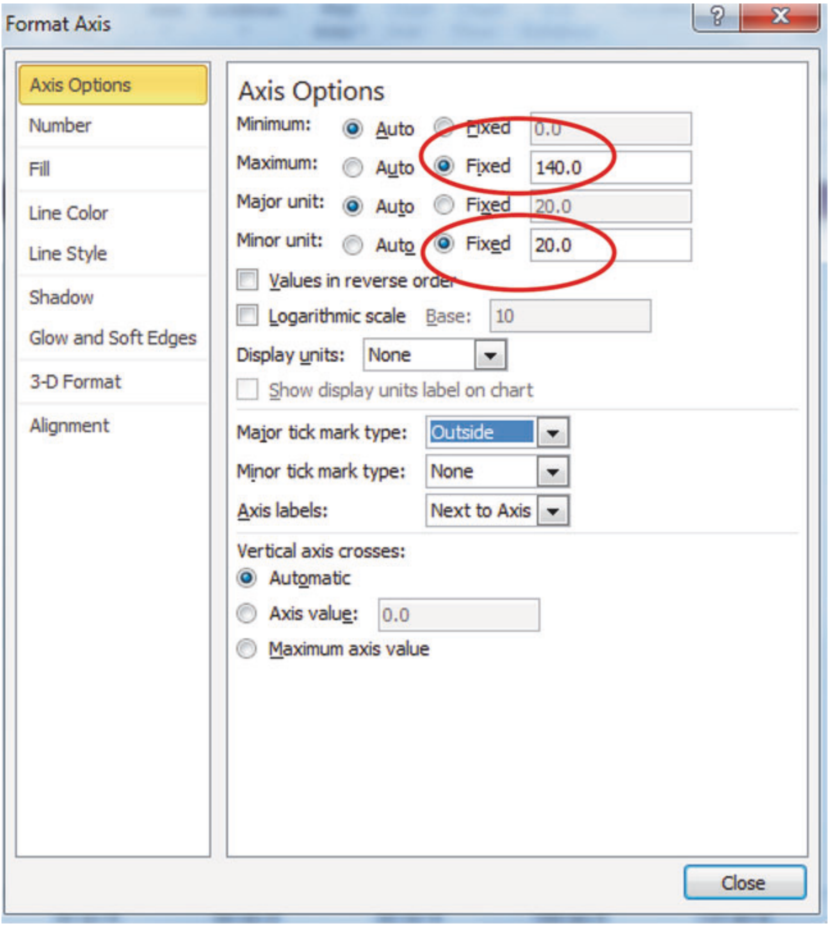

Fig. 11.58 Adjusting the horizontal axis

- **Removal of filling and legend, choice of color, suitable font and font size**

The financial modeler intends to demonstrate the range of the company valuation with the football field. The minimum and maximum bars can be interpreted as invisible supporting pillars. But they can be neglected in the final analysis. Therefore the financial modeler will now remove the filling of these bars as follows: ➲ *Right-click on the respective bar* ➲ *Format Data Point* ➲ *Fill* ➲ *No fill*. Next the legend is deleted and the required color, font and font size are determined. Figure 11.59 shows the completely modeled football field graph.

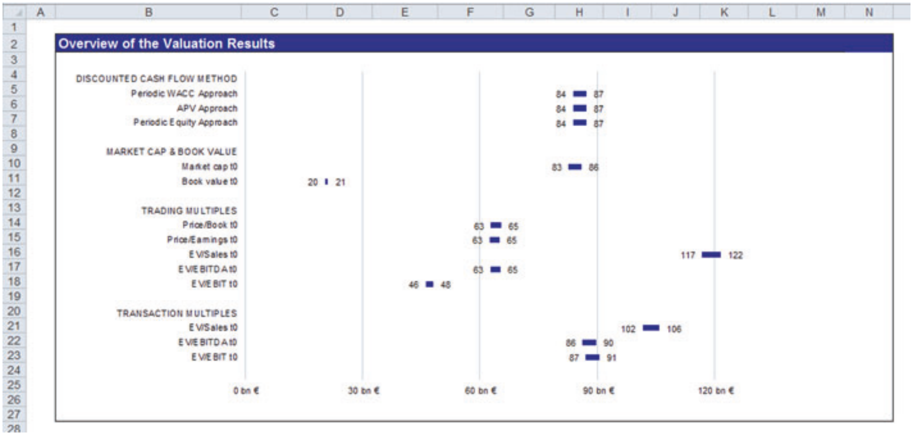

Fig. 11.59 The final version of the football field graph

6 Summary

In this corporate finance part, the financial modeler has gained insights into the following methods and approaches of company valuation:

Market capitalization:

- To value listed companies, the current market capitalization can be used as the price of a corporation.
- Under the assumption that the efficiency hypothesis of Fama holds, the price of a company (here the market capitalization) is equal to the company value as calculated with the help of the DCF method. In imperfect markets, a distinction must be made between company value (from the DCF valuation) and price of the company (from approaches using multiples).

Book value:

- The book value of equity can be considered as a long-term lower bound for the company value. The book value is backward looking and is not connected to future earning power or growth prospects of the company. For that reason, the market valuation of companies is usually higher.
- The book value is calculated by subtracting minority interest from the equity position.

Multiples:

- The valuation with the help of trading multiples is a market-oriented valuation approach.
- When using multiples, the unknown value of the valuation object is calculated with the help of multiples, which are derived from the known market values of other comparable companies.
- The valuation with multiples is based on the principle that comparable companies should have a similar company value, since they share important characteristics, such as the business model.
- Frequently used multiples are: P/E and P/B (Equity Value Multiples) as well as EV/Sales, EV/EBITDA and EV/EBIT (Enterprise Value Multiples).

Trading multiples:

- Five steps are involved in the valuation based on trading multiples: derivation of the peer group, selection of appropriate multiples, collection of the necessary data, calculation of the multiples as well as application to the target company.
- The result is a price for the company.

Transaction multiples:

- The valuation with transaction multiples is done in the same way as the valuation with trading multiples. Instead of the market capitalization of comparable listed companies, actual prices paid in M&A transactions are used.
- The result is a price for the company.

Football field graph:

- Once the complex analysis has been completed, it is important to derive a clear central message. In order to present the results derived with the various valuation methods in a comprehensive manner and to derive a valuation range, the financial modeler utilizes a so-called football field graph.
- The process of modeling follows three steps: preparing the data, creating the diagram and designing the diagram.

Notes

1. see Fama, 1970, p. 415.
2. see Damodaran, 2013, p. 2.
3. see Damodaran, 2009, p. 13.
4. see J.P. Morgan Cazenove, 2013, p. 1.
5. see SIC, 2012.
6. see Kim/Ritter, 1999, pp. 416-417.
7. see Agar, 2005, p. 32.
8. see Petitt/Ferris, 2013, p. 231.
9. see Damodaran, 2009, p. 112.
10. The data is based on an excerpt from Thompson Reuters as well as numerous individual premises introduced by the financial modeler. For example different currencies, accounting standards and business years need to be taken into consideration. The compilation is based in the following assumptions concerning the number of shares: 1.26 billion (AstraZeneca), 4.8 billion (GlaxoSmithKline), 2.398 million (Novartis), 870 million (Roche), 1.34 billion (Sanofi), 215 million (Merck) and 539 million (Novo Nordisk). These numbers were kept constant across all years considered. The planning figures were taken from Thomson Reuters I/B/E/S. These are so-called consensus estimates, which are based on a large number of analyst estimates. These consensus estimates are preferable to estimates of individual analysts, since several current assessments by analysts for an individual variable increase the precision of the forecast. Should no consensus estimates be available for a peer company (for example because the company is not covered), this company must be deleted from the list of comparable companies. The data was structured based on a holistic analysis from the perspective of the financial modeler. In order to use the exact financial figures of the peer group, the financial modeler will – in contrast to this textbook treatment – analyze each individual financial figure in the relevant annual report, consult different brokers, access different data bases if available, and calculate independently the difference between equity value and enterprise value in line with the DCF method.
11. Koller/Goedhardt/Wessels, 2010, p. 321.
12. see Koller/Goedhardt/Wessels, 2010, p. 321.
13. Herrmann/Richter, 2003, pp. 210-212.
14. see Baker, Ruback, 1999, p. 67.
15. Herrmann/Richter, 2003, pp. 2010-2012.
16. see Rosenbaum, Pearl, 2013, p. 71.
17. see Jensen/Ruback (1983); Hanouna/Sarin/Shapiro (2001).
18. see Lease/McConnell/Mikkelson (1984); McConnell/Servaes (1990).
19. see Barclay/Clifford (1989).

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12
Portfolio Management Part I

1 Executive Summary

In this chapter, the financial modeler is given the task to invest a portion of the excess liquidity of Pharma Group and to utilize the techniques of modern portfolio management. The key variables in his portfolio management decisions are the return of the assets and the structure of the corresponding risks. The financial modeler is aware of the fact that the return and risk of individual assets is determined in the financial markets, but that portfolio management, via the concrete combination of the assets, determines the return and risk attributes of the individual portfolio.

In the context of portfolio management, the financial modeler aims to obtain a desired return expectation with minimum risk or to maximize the return for a given level of risk. To reach this goal, he can either pursue active or passive portfolio management.

The aim of active portfolio management is to exceed the return of a given benchmark with the help of specific investment decisions. To accomplish this task, the financial modeler picks the appropriate securities ("selection") or the right moment ("timing").

Passive portfolio management is based on the assumption of sufficiently high market efficiency, which implies that active portfolio management cannot beat the relevant market and therefore passive portfolio management provides the appropriate solution. The implementation of passive investment strategies in portfolio management

J. Häcker and D. Ernst, *Financial Modeling*,
Global Financial Markets, DOI 10.1057/978-1-137-42658-1_12

involves the construction of a tracking portfolio, which continuously reproduces an underlying benchmark.

In order to decide between active and passive portfolio management, the financial modeler initially needs to ascertain whether the relevant methods of active or passive portfolio management can be implemented in Excel. He initially models various approaches for the calculation of returns and risks as well as the portfolio optimization in the context of active and passive portfolio management. In addition to the technical implementation of the necessary portfolio management instruments, it is also an important consideration for Pharma Group whether the personnel resources and the risk management tools needed for the task of active portfolio management are available.

2 Introduction, Structure, Learning Outcomes and Case Study

Structure

The chapter Portfolio Management Part I serves as an introduction to portfolio management and answers the following questions:

- What is meant by portfolio management?
- What types of returns exist and how are they calculated?
- Which types of risks exist and how are they measured?
- What is a random walk?
- How can return and risk figures for different time periods be calculated?

Learning outcomes

The chapter Portfolio Management Part I teaches the Excel-based application of portfolio theory and capital market theory. This enables the user and financial modeler to

- explain the term “return”, to present examples for the different types of returns and to calculate different types of returns,
- explain the term “risk”, to present examples for the different types of risks and to calculate different types of risks,

Case Study

The financial models for portfolio management are available in the download section of the Excel file Portfolio Management. Use the contents of the download offering as you work with the text. The individual steps are broken down into small units on separate worksheets:

- All calculations are done directly in Excel, in order to allow traceability of the calculations.
- All optimizations in portfolio management require the Solver. Make sure that the required add-in Solver is installed and activated in Excel. The necessary steps are explained in the text.
- A deep understanding of VBA is not needed for this chapter. It is merely demonstrated how the optimization can be conducted economically with the help of the macro recorder.
- The chapter portfolio management is structured as follows and based on the principles of financial modeling:
- The Excel file has 53 worksheets.
- All input data is marked in the color orange. These are values which are assumed and determined individually by the valuation expert.
- All calculations and output data are marked in the color gray. These are values which result from calculations.
- Mixed formulas that contain both numerical values and cell references utilize a green font.
- The worksheet marked in the color dark blue contains a summary of the chapter on portfolio management in the form of a management summary.
- The worksheets marked in the color yellow contain the data for the case study.
- Return calculations take place in the worksheets marked in the color light brown. A difference is made between discrete and continuous return.
- The worksheets marked in the color red explain how risks are calculated. A fundamental distinction is made between one-sided, two-sided and other risk measures.
- The calculations concerning active portfolio management are found in the worksheets marked in the color green. Active portfolio management utilizes absolute and relative optimization.

- The final section on passive portfolio management follows in the worksheets marked in the color light blue. A distinction is made between quadratic optimization, regression analysis with constraints and linear optimization.

3 Portfolio Management

"A good portfolio is more than a long list of good stocks and bonds. It is a balanced whole, providing the investor with protections and opportunities with respect to a wide range of contingencies."[1]

This quote from HARRY M. MARKOWITZ describes the ideal portfolio with precision.

> A portfolio is an accounting device which combines all assets of a household or an institution with the aim of collecting, presenting and controlling financial attributes such as value, liquidity, receivables and liabilities.

The portfolio serves as the basis for the calculations which determine criteria such as investment success (return) and risk. A portfolio is individually structured to be suitable for the investor, especially with regard to return and risk.

> The term portfolio management describes a specific field in finance. Portfolio management means the creation, management and adjustment of portfolios.

These activities relate to both the portfolio and the most pertinent attributes of the portfolio such as return, risk, value preservation and liquidity. Portfolio management is performed in the context of private asset management activities based on the instructions of the client and in the form of institutional fund management activities and proprietary activities of banks and financial service providers. Portfolio management can either be an advisory service or a more immediate involvement, where power of representation was granted.

The most important attributes in portfolio management are return and risk. In the context of portfolio management, investment goals and risks are defined, an investment strategy is derived and the success of this strategy is measured and analyzed. A distinction is made between active portfolio management and passive portfolio management. Portfolio management is implemented by a portfolio manager, who makes decisions about the assets and their weights. In other words, he puts together a portfolio based on risk and return considerations as well as on investment guidelines. He also monitors the portfolio and makes adjustments to the portfolio composition if needed.

Initially, the important terms risk and return will be explained in more detail. Next, the distinction between active and passive portfolio management will be thoroughly discussed.

4 Return

Portfolio management is most heavily influenced by the terms return and risk. Return is the key variable to measure the success and plays a major role in the performance analysis of the portfolio.

> The term return is defined at the ratio of revenue to invested funds over a specified time period.

Returns calculations are only possible at the end of the investment period. The return is either given as a decimal number or more frequently as a percentage.

Both discrete and continuous returns can be calculated. The term "discrete" refers to the investment horizon, which is characterized by two distinct points in time, the beginning and the end of the investment period. The investment period can also be broken down into several discrete sub-periods, for which it is also possible to calculate a discrete return.

In contrast to the discrete return, the calculation of the continuous return assumes a steady or continuous growth of the invested capital. Against the backdrop of the period length chosen, the relationship between discrete and continuous return can be captured intuitively. To derive the continuous return from the discrete return, the investment period is steadily reduced.

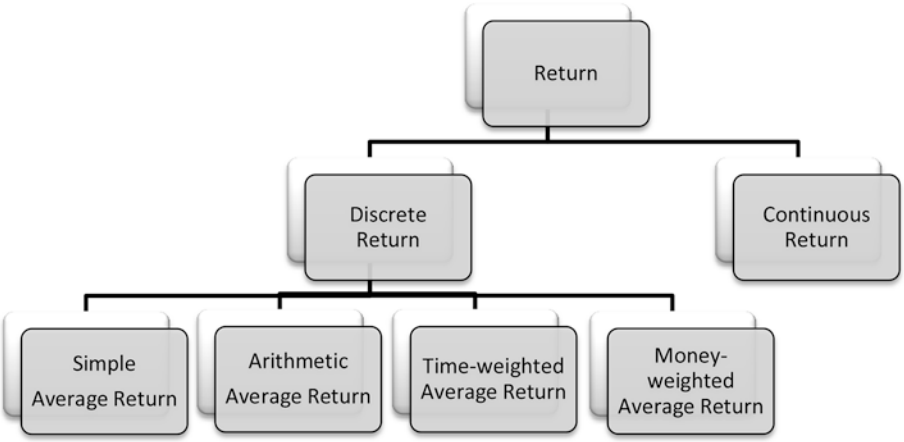


Fig. 12.1 Overview of the different types of returns

The discrete return can be broken down into the following specific ways of calculating returns:

- Simple average return,
- Arithmetic average return,
- Time-weighted average return, also called geometric average return,
- Money-weighted average return.

These different types of returns are described in more detail in the following sections. Making the appropriate selection in applied work requires the consideration of both content-related and statistical issues.

Figure 12.1 displays the various types of returns.

4.1 Discrete Return

> The discrete Return r^d considers two individual points in time (beginning and end of investment period) respectively several points in time during one investment period.

In this section we take a closer look at the various measures of discrete returns.

4.1.1 Simple Average Return

The simple average return considers only the beginning and the end of the investment period.

> For the calculation of the simple return r^s, only the points at the beginning and the end of the investment period of the portfolio are considered.

This type of return is also called "total return" or "simple rate of return" since it captures the return over the entire investment period, regardless of its length.

The following formula is used to calculate the simple return r^s:

$$r^s = \frac{P_T - P_0}{P_0} resp.\ r^s = \frac{P_T}{P_0} - 1$$

with:
r^s = simple average return
P_T = value of the portfolios at the end of the period
P_0 = value of the portfolio at time 0

Notation:
The beginning of a time period is denoted with a 0, the end of the total investment period with a capital T. The n points in time between beginning and end are numbered consecutively using the lower case t as representative: $t = 1, 2, 3, \ldots, T$.

The Excel file Portfolio Management contains the calculation of the simple average return in the worksheet `Return_(1)`. The starting values for the calculation of the simple return are taken from the Euro Stoxx from 31.08.t_{-1} to 29.02.t_0. They can be found in the worksheet `Assumptions_Data_Daily`.

The return calculation can be found in Figs. 12.2 and 12.3:

Position	Formula	Excel implementation
Simple, daily return (`=Return_(1)!D8`)	=Price 01.09.t_{-1}/Price 31.08.t_{-1}-1	`=C8/C7-1`

Fig. 12.2 Calculating the simple, daily return

	A	B	C	D
5				
6			EURO STOXX	Simple Return
7		31.08.t(-1)	2,302.08	
8		01.09.t(-1)	2,305.75	0.16%
9		02.09.t(-1)	2,220.72	-3.69%
10		05.09.t(-1)	2,107.27	-5.11%
11		06.09.t(-1)	2,080.10	-1.29%
12				

Fig. 12.3 Calculating the simple, daily return (Work File Portfolio Management, Worksheet Return_(1))

Position	Formula	Excel implementation
Simple return (`=Return_(2)!F16`)	=Price 29.02.t_0/Price 01.09.t_{-1}-1	`=C10/C9-1`

Fig. 12.4 Calculating the simple return

	A	B	C	D	E	F
4						
5		Assumptions				
6		Trading Days per Year	250			
7						
8		EURO STOXX				
9		31.08.t(-1)	2302.08	Starting Price		
10		29.02.t(0)	2512.11	Ending Price		
11		Number of Periods	130			
12						
13						
14		Calculation of the Simple Return				
15						
16		Simple Return (01.09.t(-1) to 29.02.t(0))				9.123%
17						

Fig. 12.5 Calculating the simple return (Work File Portfolio Management, Worksheet Return_(2))

The simple, daily return is calculated by dividing the current price by the price from the previous day and subtracting 1.0.

In order to calculate the simple return for the entire time period, the beginning and ending prices from the investment period are needed. These values are transferred to the cells `C10` and `C9` in the Worksheet

Return_(2) and then used for the calculation of the simple return in cell F16 (see Figs. 12.4 and 12.5).

4.1.2 Arithmetic Average Return

> The calculation of the arithmetic average return r^a is used if it can be assumed that the total return can be determined from the individual returns of the various subperiods.

The arithmetic average return is based on the assumption that the capital which was invested initially remains constant over the entire investment period. This means that the same amount is invested in each period and that profits from the investment are taken out at the end of each period and losses are similarly compensated.

The arithmetic average return r^a is calculated with the following formula:

$$r^a = \frac{(1 + r_1) + (1 + r_2) + (1 + r_3) + \ldots + (1 + r_n)}{n} - 1 = \frac{r_1 + \ldots + r_n}{n} = \frac{1}{n}\sum_{t=1}^{n} r_t$$

With:
r^a = arithmetic average return
r_t = return in period t
n = number of periods

In the worksheet Return_2) the number of periods must be specified initially in cell C11 with the help of the Excel formula COUNT. It relates to the number of daily return observations. Once the number of periods has been determined, the arithmetic average return can be calculated. Put simply, this return is equal to the sum of the daily returns during the investment period divided by the number of periods (Figs. 12.6 and 12.7).

Position	Formula	Excel implementation
Number of periods (=Return_(2)!C11)	=Number of periods 31.08.t_{-1} to 29.02.t_0	=COUNT('Return (1)'!D8:D137)
Daily arithmetic average return (=Return_(2)!F27)	=Sum (Return 01.09.t_{-1} to 29.02.t_0)/Number of periods	=SUM('Return (1)'!D8:D137)/C11

Fig. 12.6 Calculating the daily arithmetic average return

Fig. 12.7 Calculating the daily arithmetic average return (Work File Portfolio Management, Worksheet Return_(2))

In the example in the Excel file, the daily arithmetic average return is 0.08782%.

4.1.3 Geometric Average Return or Time-Weighted Return

The geometric average return, alternatively called time-weighted return r^{twr}, is also calculated as a total return, consisting of the various returns from the individual periods.

> The time-weighted return shows how an initial amount of money is transferred into a later investment result.

It is assumed that no money is added or withdrawn during the investment period. If such cash flows occur, the return is adjusted accordingly.

The formula for the time-weighted return, respectively geometric average return is:

$$r^{twr} = \sqrt[n]{\frac{P_T}{P_0}} - 1 = \sqrt[n]{(1 + r_1) \cdot (1 + r_2) \cdot (1 + r_3) \cdot \ldots \cdot (1 + r_n)} - 1$$

with:
r^{twr} = time-weighted return respectively geometric average return
r_t = return in period t
n = number of periods
P_T = value of the portfolios at the end of the period
P_0 = value of the portfolios at t=0

Die time-weighted average returns are calculated as presented in Figs. 12.8 and 12.9.

The time-weighted return is calculated by dividing the value of the investment at the end of the total time period by the value of the investment at t = 0. This value is taken to the power of 1/n, which depends on the number of periods and finally one is subtracted.

Position	Formula	Excel implementation
Daily time-weighted (geometric) return (=Return_(2)!F32)	=(Price 29.02.t_0/Price 01.09.t_{-1})^(1/Number of periods)-1	=(C10/C9)^(1/C11)-1

Fig. 12.8 Calculating the daily time-weighted (geometric) return

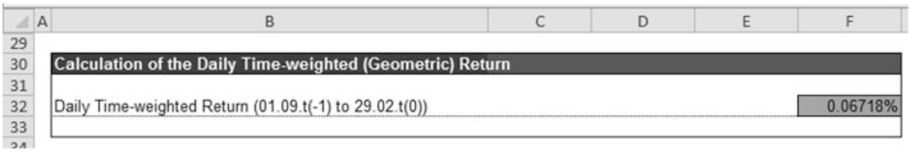


Fig. 12.9 Calculating the daily time-weighted (geometric) return (Work File Portfolio Management, Worksheet Return_(2))

Excel only provides the command SQRT for the square root. Excel calculates other roots via the power $1/n$.

The time-weighted return calculates the average percentage change of the capital per period. In the example in the Excel file this average change is equal to 0.06718% per period.

4.1.4 Comparison of Time-Weighted and Arithmetic Average Return

As was already pointed out, the use of an arithmetic average return assumes that the capital remains constant during the investment period; profits are withdrawn and losses are equalized. As a consequence, the same amount is invested in each period. For the geometric average return, meanwhile, it is assumed that no money is paid in or taken out, that means that no profits are withdrawn or losses equalized.

This difference can lead to distortions in the case of the arithmetic average return as demonstrated by the following example (see Fig. 12.10). An amount of 50 monetary units is invested at the beginning of year 1. At the end of the year, the investment amount has increased by 100% to 100 monetary units. In the second year, the amount is reduced by 50% from 100 monetary units to 50 monetary units. What is the return of this investment based on the geometric average return and the arithmetic average return?

	Starting value	Ending value	Return per period
Year 1	50	100	+100%
Year 2	100	50	-50%

Fig. 12.10 Example for the calculation of geometric average return and arithmetic average return

- Geometric average return or time-weighted return:

$$r^{twr} = \sqrt[2]{(1+1)\cdot(1-0,5)} - 1 = \sqrt[2]{2\cdot 0,5} - 1 = \sqrt[2]{1} - 1 = 0\%$$

- Arithmetic average return:

$$r^{a} = \left(\frac{(1+1)+(1-0,5)}{2}\right) - 1 = 1,25 - 1 = 0,25 \rightarrow \quad \mathbf{25\%}$$

It is apparent that the two ways of calculating the return lead to very different results. According to the geometric average return a result of 0% is obtained, while the arithmetic return is 25%.

Looking at the beginning and ending values, it becomes apparent that the starting value in year 1 and the ending value in year 2 are equal. Intuitively, the solution obtained with the geometric return appears correct, since the value of the investment capital did not change.

> The geometric average return is suitable for the determination of the historical performance of securities.

The geometric average return is preferable as a measure for determining the historical performance of securities, since it also includes compound interest. Assuming reinvestment of all gains, the geometric average return can be considered as a growth rate of the investment amount over the investment period. The geometric average return is thus more suitable for assessing historical returns.

> The arithmetic average return is used for the determination of expected future returns.

If the distribution of the returns over time is independent and identical, the arithmetic mean is an unbiased statistical estimate for the return in the next period. The arithmetic average return gives the same weight to all possible return paths, while the die geometric average return only considers the return path that was actually realized. Thus the arithmetic average return is used for the determination of returns that are expected in the future.

4.1.5 Money-Weighted Rate of Return

> The money-weighted rate of return r^m is applied when there are inflows or outflows during the investment period.

For that purpose, the return is weighted by the cash inflows and outflows during the period under consideration. The individual cash flows are compounded to get the values at the end of the investment period. These resulting values are used for the calculation of the money-weighted rate of return.

The money-weighted rate of return is equivalent to the internal rate of return (IRR).

The formula is:

$$P_T = P_0 \left(1 + r^m\right)^n + Z_1 \left(1 + r^m\right)^{n-1} + Z_2 \left(1 + r^m\right)^{n-2} + \ldots + Z_{n-1} \left(1 + r^m\right) + Z_n$$

with:
r^m = money-weighted rate of return
P_T = value of the portfolio at the end of the investment period
P_0 = value of the portfolio at t = 0
Z_t = payment in period t

For two time periods, this formula can be solved analytically. However, as soon as there are cash flows in several periods (or between periods), the money-weighted rate of return is calculated with the help of interpolation procedures.

The following must be kept in mind: the return depends on the payment date, in other words on the time the payment was made. This becomes apparent in the next example.

Position	Formula	Excel implementation
Monthly return (=Return_(3)!E9)	=Price 26.02.t$_{-2}$/Price 29.01.t$_{-2}$-1	=C9/C8-1
Time-weighted return (=Return_(3)!E22)	=(Price 31.01.t$_{-1}$/Price 29.01.t$_{-2}$)^(1/Number of observations 31.01.t$_{-1}$ to 26.02.t$_{-2}$)-1	=(C20/C8)^(1/COUNT(E9:E20))-1

Fig. 12.11 Preparing the calculation of the money-weighted return

In the worksheet Return_(3), the money-weighted rate of return is calculated using the example of three portfolios. In the first portfolio, € 100 is invested at the end of each month (see column G), in Portfolio 2, an investment of € 400 is made every four months (see column M) and in portfolio 3 a one-time investment of € 1,200 is made (see column S). In all three portfolios a total of € 1,200 is invested. The calculations are based on the monthly values of the Euro Stoxx from January t_{-2} to January t_{-1}.

Initially the individual monthly returns and the time-weighted rate of return must be calculated (see Figs. 12.11 and 12.12).

The monthly portfolio values are calculated considering the investment values and the money-weighted rates of return (see Fig. 12.13).

The cells G8:G19 contain the investment values. In the cells I8:I20, the portfolio values are calculated based on the price changes of the Euro Stoxx. The cells K8:K20 show the values of the portfolio calculated on the basis of the money-weighted rate of return, which still needs to be determined. The money-weighted rate of return is given in cell K22. It still needs to be determined and initially a value of 0% is assumed.

The money-weighted rate of return is determined using the *GOAL SEAK* in Excel (see Fig. 12.14): *Data* ➲ *Data Tools* ➲ *What if Analysis* ➲ *Goal Seek*. The money-weighted rate of return in cell M22 is determined with the help of the *GOAL SEEK* function as follows:

- "Set cell" is the last value of the money-weighted rate of return in K20.
- For "To value"; the value 1,296.97 is entered.
- Selected for "By changing cell" is the monthly money-weighted rate of return in cell K22.

	A	B	C	D	E
6		Euro Stoxx			
7			Euro Stoxx		Monthly Return
8		29.01.t(-2)	2.776,83		
9		26.02.t(-2)	2.728,47		-1,74%
10		31.03.t(-2)	2.931,16		7,43%
11		30.04.t(-2)	2.816,86		-3,90%
12		31.05.t(-2)	2.610,26		-7,33%
13		30.06.t(-2)	2.573,32		-1,42%
14		30.07.t(-2)	2.742,14		6,56%
15		31.08.t(-2)	2.622,95		-4,35%
16		30.09.t(-2)	2.747,90		4,76%
17		29.10.t(-2)	2.844,99		3,53%
18		30.11.t(-2)	2.650,99		-6,82%
19		31.12.t(-2)	2.792,82		5,35%
20		31.01.t(-1)	2.953,63		5,76%
21					
22		Time-weighted Return			0,52%
23					

Fig. 12.12 Preparing the calculation of the money-weighted return

Position	Formula	Excel implementation
Portfolio value calculated as price return (=Return_(3)!I9)	=Investment 29.01.t_{-2}*(1+Return 26.02.t_{-2})+ Investment 26.02.t_{-2}	=I8*(1+E9)+G9
Portfolio value calculated as money-weighted rate of return (=Return_(3)!K9)	=Investment 29.01.t_{-2}*(1+ Money-weighted return)+ Investment 26.02.t_{-2}	=K8*(1+$K$22)+G9

Fig. 12.13 Calculating the monthly portfolio values by considering the investment values and the money-weighted returns

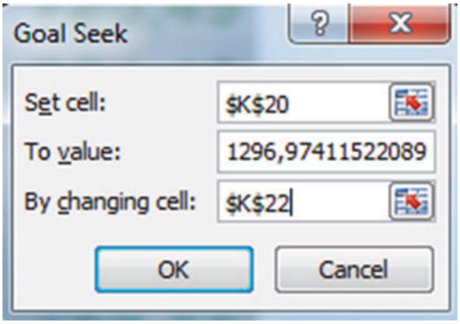


Fig. 12.14 Goal seek

Portfolio 1

Investment	Portfolio Value depending on Return	Portfolio Value based on Money-weighted Return
100	100,00	100,00
100	198,26	201,19
100	312,99	303,58
100	400,78	407,20
100	471,39	512,04
100	564,72	618,13
100	701,76	725,49
100	771,26	834,12
100	908,00	944,04
100	1.040,08	1.055,27
100	1.069,16	1.167,83
100	1.226,36	1.281,72
0	1.296,97	1.296,97
Ending Value	1.296,97	**1,19%**

Fig. 12.15 Calculating the money-weighted rate of return (Work File Portfolio Management, Worksheet Return_(3))

For Portfolio 1, a money-weighted rate of return of 1.19% is the result (see Fig. 12.15).

Rank	Portfolio	Ending Value	Money-weighted Return
1	Portfolio 1	1.296,97	1,19%
2	Portfolio 2	1.308,03	1,08%
3	Portfolio 3	1.276,40	0,52%

Fig. 12.16 Ranking of the portfolios (Work File Portfolio Management, Worksheet Return_(3))

Once all the values for the three portfolios have been determined, the portfolios can be analyzed (see Fig. 12.17) and ranked (see Fig. 12.16) to see which of the portfolios has performed best.

The example clarifies the following: even though the terminal value of Portfolio 1 (€ 1,296.97) is below the terminal value of Portfolio 2 (€ 1,308.03), an investment in Portfolio 1 is preferable to an investment in Portfolio 2. The monthly money-weighted return is 1.19% for Portfolio 1, while it is only 1.08% for Portfolio 2.

While the same overall amount was invested in both portfolios, the cash outflows occurred at different points in time. This means that depending on the price development of the Euro Stoxx, the different investment amounts participated to differing degrees in the value development of the Euro Stoxx. This feature becomes clear if, for example, the investment in Portfolio 1 is compared to the investment in Portfolio 3. The investor in Portfolio 3 is fully affected by the temporary decline of the Euro Stoxx in the months April through June. Due to the lower initial investment, the investor in Portfolio 1 is less affected in absolute terms. The appropriateness of the various investment strategies cannot be determined in advance. Their success depends entirely on the value development of the index portfolio.

With respect to portfolio management it can be concluded that the success of an investment strategy does not only depend on the selection of the appropriate assets, but also on the timing of the investment. It fundamentally holds that investments should be made at the beginning of an upswing and that positions should be liquidated ahead of a correction. The implementation of this idea is discussed in the sections on active and passive portfolio management.

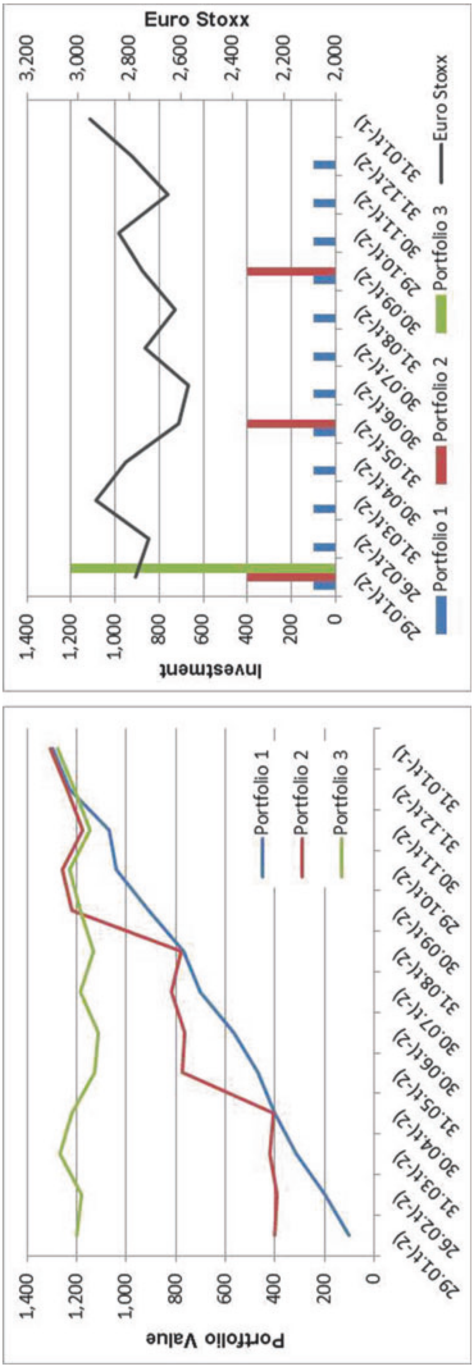


Fig. 12.17 Portfolio developments (Work File Portfolio Management, Worksheet Return_(3))

4.2 Continuous Return

The continuous return r^c assumes continuous payments of interest on the invested capital.

It differs from the discrete return in the way the time intervals between interest payments are treated. It is possible that an investment does not only receive interest payments on a monthly basis, but possibly also weekly, daily, hourly or even during shorter intervals. The shorter these periods become, the smaller is the difference between discrete and continuous return.

The continuous return is calculated by taking the logarithm of the discrete return:

$$r^c = ln\left(\frac{P_T}{P_0}\right)$$

with:
r^c = continuous return
P_T = value of the portfolio at the end of the investment period
P_0 = value of the portfolio at t = 0

If the discrete return r^d is given, the continuous return can be calculated with the following formula:

$$r^c = ln\left(1 + r^d\right)$$

with
r^c = continuous return
r^d = discrete return

At the same time, the discrete return can be derived from the continuous return as follows:

$$r^d = e^{r^c} - 1$$

with
r^c = continuous return
r^d = discrete return

The calculations for the continuous return are done in the worksheet `Return_(1)` and `Return (2)` in the Excel file. Initially the daily returns in logarithmic form are calculated in worksheet `Return_(1)` in column `E` (see Fig. 12.18).

In the worksheet `Return_(2)` the following continuous returns are calculated (see Figs. 12.19 and 12.20):

- the average, daily, continuous return based on the average continuous log-return,
- the daily, continuous return based on the daily time-weighted average return.

Position	Formula	Excel implementation
Daily continuous return (`=Return_(1)!E8`)	=Natural logarithm (Price 01.09.t_{-1}/Price 31.08.t_{-1})	`=LN(C8/C7)`

Fig. 12.18 Calculating the daily continuous return

Position	Formula	Excel implementation
Average, daily continuous return based on the average continuous log-return (`=Return_(2)!F41`)	=Sum of the returns 01.09.t_{-1} to 29.02.t_0/Number of observations	`=SUM('Return (1)'!E8:E137)/COUNT('Return (1)'!E8:E137)`
Daily continuous return based on the daily time-weighted average return (`=Return_(2)!F44`)	=Natural logarithm (1+Daily time-weighted return)	`=LN(1+F32)`

Fig. 12.19 Calculating the continuous return

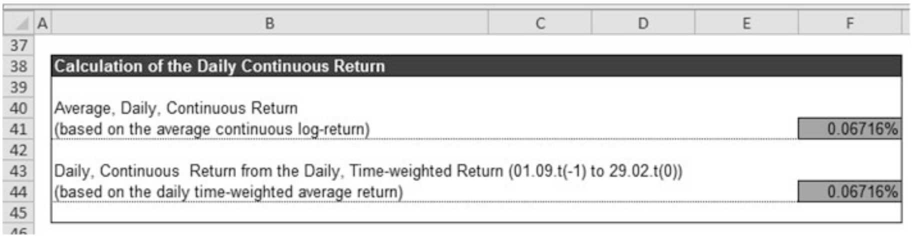


Fig. 12.20 Calculating the continuous return (Work File Portfolio Management, Worksheet Return_(2))

4.3 Comparison between Continuous and Discrete Return

The continuous return is always smaller than the discrete return.

It holds that $r^c < r^d$. The continuous return is always smaller than the discrete return, since the continuous return can be interpreted as the return for the smallest possible time interval. The continuous daily return in our example is 0.06716%, while the time-weighted daily return is 0.06718%. The difference between discrete and continuous return goes down as the time interval for the discrete return is reduced and approaches zero.

The difference between continuous and discrete return is displayed graphically in Fig. 12.21. The discrete return is the 45-degree line while the continuous return is a curved line.

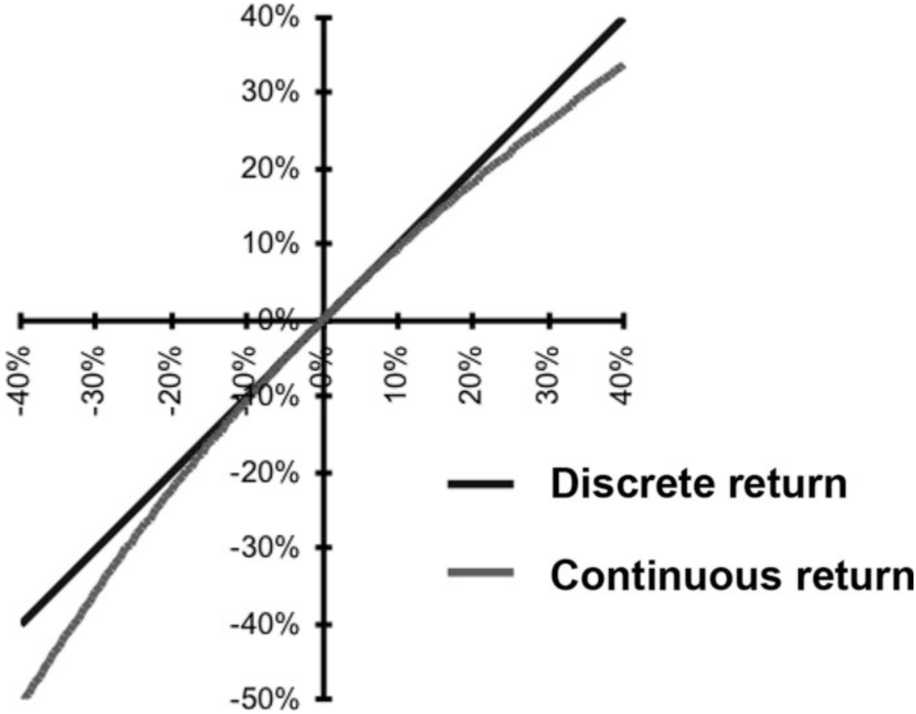


Fig. 12.21 Comparison between discrete and continuous return

The use of both types of returns has both advantages and disadvantages, which will be discussed in the following sections.

Additivity across portfolios is a feature of the discrete return.

The discrete return is frequently used when conducting a portfolio analysis, since the underlying simple additivity of the discrete returns in a portfolio allows the immediate calculation of the portfolio return as the weighted average of the individual expected returns of all securities. This feature is called portfolio additivity.

$$r_P = \sum_{i=1}^{n} w_i \cdot r_i^d$$

with
r_P = portfolio return
r_i^d = discrete return of asset i
w_i = weight of asset i in the portfolio

However, the application of discrete returns in portfolio management also has one decisive disadvantage. The discrete returns are not additive across time (see Section 4.1.4). This implies that the sum of the discrete returns across the sub-periods is not equal to the discrete return over a long period if the returns differ over time.

$$r_T^d \neq r_1^d + r_2^d + \ldots + r_{n-1}^d + r_n^d$$

with
r_T^d = discrete return at the end of the investment period
r_t^d = discrete returns of the individual periods t

The continuous return is additive across time.

In contrast to the discrete return, the continuous return is additive across time.

$$r_T^c = r_1^c + r_2^c + \ldots + r_{n-1}^c + r_n^c = n \cdot r_t^c$$

with
r_T^c = continuous return at the end of the investment period
r_t^c = continuous average returns of the individual periods t

However, the continuous returns lack the feature of additivity across portfolios. From this it results clearly that the continuous return is not suitable for the calculation of the expected return of a portfolio.

$$\sum_{i=1}^{n} w_i \cdot r_i^c \neq ln\left(1 + \sum_{i=1}^{n} w_i \cdot r_i^d\right)$$

with r_i^c = continuous return of asset i

4.4 Returns for Different Time Periods

> Returns for periods of less than one year are generally annualized to achieve comparability.

As already pointed out, returns can be calculated for different time periods. However, it is not very meaningful to compare for example annual returns with monthly or daily returns. Returns for periods of less than one year are usually annualized in order to achieve comparability.

4.4.1 Adjusting the Simple Average Return

The simple return is annualized with the following formula:

$$r_{annualized}^s = \left(1 + r_t^s\right)^{\frac{T}{n}} - 1$$

with
$r_{annualized}^s$ = simple annual average return
r_t^s = simple return for less than one year
t = individual period within one year
T = total number of periods within one year
n = number of periods within one year

Position	Formula	Excel implementation
Daily simple return (`=Return_(2)!F22`)	=(1+ Return for time period of less than one year) ^(1/Number of days)-1	`=(1+F16)^(1/C11)-1`
Annualized simple return (`=Return_(2)!K22`)	=(1+daily simple return)^(Trading days per year)-1	`=(1+F22)^C6-1`
Daily simple return (`=Return_(2)!P22`)	=(1+annualized return)^(1/ Trading days per year)-1	`=(1+K22)^(1/C6)-1`

Fig. 12.22 Simple returns for different time periods

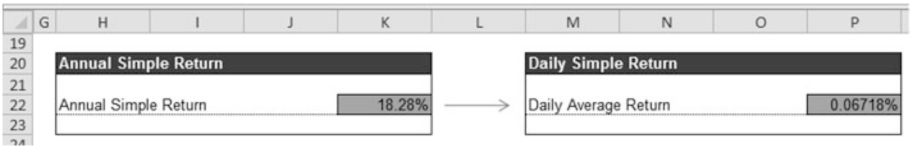


Fig. 12.23 Simple returns for different time periods (Work File Portfolio Management, Worksheet Return_(2))

The annual return can be transformed into a return for shorter time periods with the help of the following formula:

$$r_t^s = \sqrt[\frac{T}{n}]{\left(1 + r_{annualized}^s\right)} - 1$$

The adjustment of the simple return is shown in worksheet `Return_(2)` (see Figs. 12.22 and 12.23):

4.4.2 Adjusting the Arithmetic Average Return

Arithmetic average returns for time periods of less than one year are annualized as follows:

$$r_{annualized}^a = \left(1 + r_t^a\right)^{\frac{T}{n}} - 1$$

with
$r_{annualized}^a$ = arithmetic annual average return
r_t^a = arithmetic return for a period of less than one year
t = individual period within one year
T = total number of periods within one year
n = number of periods within one year

Position	Formula	Excel implementation
Annualized arithmetic average return (`=Return_(2)!K27`)	=(1+daily arithmetic average return)^(Trading days per year)-1	`=(1+F27)^C6-1`
Daily arithmetic average return (`=Return_(2)!P27`)	=(1+annualized arithmetic average return)^(1/Trading days per year)-1	`=(1+K27)^(1/C6)-1`

Fig. 12.24 Arithmetic average return for different time periods

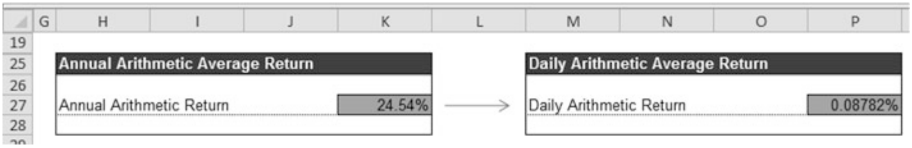


Fig. 12.25 Arithmetic average return for different time periods (Work File Portfolio Management, Worksheet_Return (2))

The formula for calculating the arithmetic average return for time periods of less than one year from the arithmetic annual return is:

$$r_t^a = \sqrt[\frac{T}{n}]{\left(1 + r_{annualized}^a\right)} - 1$$

The adjustment of the arithmetic average return is presented in the worksheet `Return_2)` (see Figs. 12.24 and 12.25):

4.4.3 Adjusting the Time-Weighted Return

Time-weighted returns for periods of less than one year are annualized as follows:

$$r_{annualized}^{twr} = \left(1 + r_t^{twr}\right)^{\frac{T}{n}} - 1$$

with
$r_{annualized}^{twr}$ = time-weighted annual return
r_t^{twr} = time-weighted return for a period of less than one year
t = individual period within one year
T = total number of periods within one year
n = number of periods within one year included in the calculation

The formula for the calculation of the time-weighted return for a period of less than one year from the time-weighted annual return is:

$$r_t^{twr} = \sqrt[\frac{T}{n}]{\left(1 + r_{annualized}^{twr}\right)} - 1$$

Position	Worksheet und Cell	Excel implementation
Annualized time-weighted return (=Return_(2)!K32)	=(1+daily time-weighted return)^(Trading days per year)-1	=(1+F32)^C6-1
Daily time-weighted return (=Return_(2)!P32)	=(1+annualized time-weighted return)^(1/Trading days per year)-1	=(1+K32)^(1/C6)-1

Fig. 12.26 Time-weighted return for different time periods

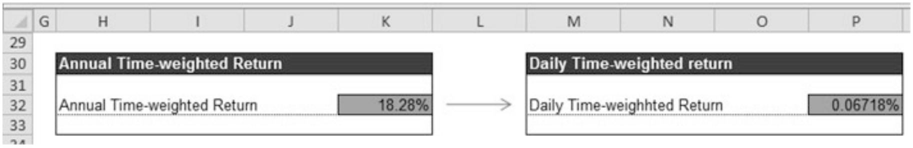


Fig. 12.27 Time-weighted return for different time periods (Work File Portfolio Management, Worksheet Return_(2))

The adjustment of the time-weighted average return is presented in the worksheet `Return_(2)` (see Figs. 12.26 and 12.27):

4.4.4 Adjusting the Continuous Return

The continuous return for a period of less than one year is annualized with the following formula:

$$r^c_{annualized} = r^c_t \cdot \frac{T}{n}$$

with
$r^c_{annualized}$ = continuous annual return
r^c_t = continuous return for a period of less than one year
t = individual period within one year
T = total number of periods within one year
n = number of periods within one year included in the calculation

The continuous annual return is calculated from the continuous returns for periods of less than one year with the following formula:

$$r^c_t = r^c_{annualized} \cdot \frac{n}{T}$$

Position	Formula	Excel implementation
Annualized continuous return (=Return_(2)!K41)	=daily continuous return*Trading days per year	=F41*C6
Daily continuous return (=Return_(2)!P41)	=annualized continuous return/Trading days per year	=K41/C6

Fig. 12.28 Continuous returns for different time periods

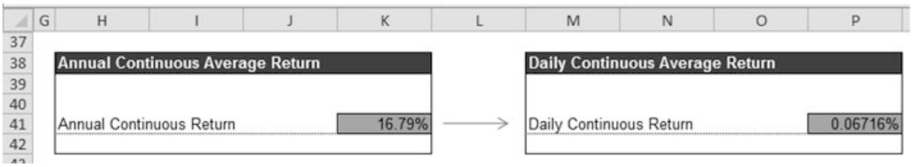


Fig. 12.29 Continuous returns for different time periods (Work File Portfolio Management, Worksheet Return_(2))

The adjustment of the continuous average return is presented in the worksheet `Return_(2)` (see Figs. 12.28 and 12.29):

4.5 Calculation of Prices based on the Different Types of Returns

In Figs. 12.30 and 12.31, the prices on 29.02.t_0 are calculated on the basis of the different types of return.

It deserves to be pointed out that all types of return – with the exception of the arithmetic average return – lead to the same ending price on 29.02.t_0.

Position	Formula	Excel implementation
Price on 29.02.t_0 based on the daily simple return (=Return_(2)!F51)	=Starting*(1+ daily simple return)^(Number of days)	=C9*(1+F22)^C11
Price on 29.02.t_0 based on the daily time-weighted return (=Return_(2)!F53)	=Starting price*(1+daily time-weighted return)^(Number of days)	=C9*(1+F32)^C11
Price on 29.02.t_0 based on the daily continuous return (=Return_(2)!F55)	=Starting price*EXP(daily continuous return*Number of days)	=C9*EXP(F44*C11)

Fig. 12.30 Calculation of the ending prices based on the different types of return

	A	B	C	D	E	F
48						
49		**Calculating the Ending Price using Different Types of Return**				
50						
51		Price on 29.02.t(0) based on the Daily, Simple Return				2512.11
52						
53		Price on 29.02.t(0) based on the Daily, Time-weighted Return				2512.11
54						
55		Price on 29.02.t(0) based on the Daily, Continuous Return				2512.11
56						

Fig. 12.31 Calculation of the ending prices based on the different types of return (Work File Portfolio Management, Worksheet Return_(2))

5 Risk

5.1 The Term Risk

> Risk refers to the possibility of price fluctuations and significant losses.

Risk is the second important decision variable that portfolio management relies on. Broadly, risk can be defined as the failure to achieve a target. Since this definition is too broad for the purposes of portfolio management, the definition of risk is narrowed down: risk is the possibility of price fluctuations of financial instruments and the likelihood that investors may suffer substantial losses. The larger the fluctuations, the larger the likelihood of losses.

Risk can be separated into qualitative and quantitative risks. Portfolio management deals mostly with quantitative risks. As risk is quantified, it can be used in portfolio and risk models as an input variable. Risk is an integral component in the technique of portfolio optimization.

In addition to quantitative risks, qualitative risks, such as the credit standing of a company, also exist. However, these risks are harder to quantify and are included in the risk management process via subjective assessments.

5.2 How to Estimate Risk

5.2.1 Return as a Random Number

The precise forecasting of returns is impossible.

A key aspect of every investment is the (un)certainty surrounding future period returns at the time the investments are made. Future returns can normally only be estimated or expected in the case of equity investments. The value that will ultimately be realized is more or less uncertain. In such as case, the future returns are random numbers.

This does not mean that the sequence of the actual returns is purely coincidental, as is the case in games of chance, but that the return can be expected to fall within a forecast range with a given probability. However, an exact forecast is not possible.

A random number can be generated in Excel with the function *RAND*. The random number can take on values between 0 and 1. By hitting the F9 key a new random number is generated from a random number generator. Since the random numbers are uniformly generated over the interval [0; 1], a mean value of 0.5 can be expected. If 0.5 is subtracted from the random number that was generated and the resulting value is multiplied by 10, all results fall within the interval [–5, 5] with a mean of 0 (see Fig. 12.32).

If this calculation is done for 250 days (trading days), the following values are obtained, which are displayed in the following diagram (see Fig. 12.33):

Position	Formula	Excel implementation
Random number interval [-5;5] (=Random_Numbers!B6)	=10*(Random number-0.5)	=10*(RAND()-0.5)

Fig. 12.32 Generation of random numbers in the interval [(5), 5]

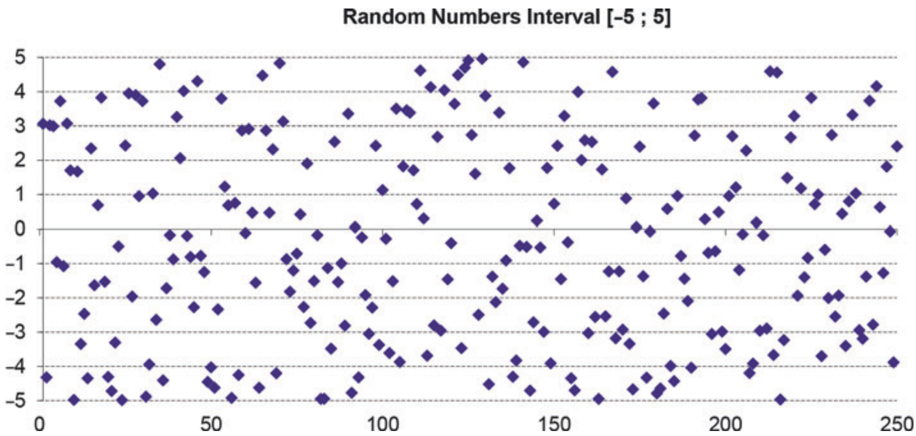


Fig. 12.33 Diagram of the random numbers (Work File Portfolio Management, Worksheet Random_Numbers)

5.2.2 Random Walk

> A random walk assumes that any development cannot be predicted on the basis of past patterns.

A very simple and well known statistical model to describe random influences and return deviations from expectations is the random walk. A random walk is any development where future changes or the future direction cannot be predicted on the basis of past patterns. If the term is used in the context of capital markets, it implies that short-term movements of asset prices cannot be predicted reliably. Alternatively, it can be said that share prices have no memory.

The following equation for the price movement can be used as a starting point for the description of the random walk:

$$P_t = P_{t-1}\left(1 + r_t^d\right) = P_{t-1}e^{r_t^c}$$

A mathematically equivalent linear form is given by taking the logarithm on both sides of the equation.

$$lnP_t = lnP_{t-1} + ln\left(1 + r_t^d\right)$$

If q_t is used in place of the logarithm of the return factors $(1 + r_t^d)$, it follows that:

$$lnP_t - lnP_{t-1} = ln\left(\frac{P_t}{P_{t-1}}\right) = ln\left(1 + r_t^d\right) = q_t$$

The logarithm of the return factors is equal to the logarithm of the ratio of prices $\frac{P_t}{P_{t-1}}$. q_t is also called log-return and is a continuous period return.

If the description of the return is replaced by an estimate, the variable r_t^d is replaced by the estimated return $\overline{q}$ and a forecast error ε_t needs to be added. The continuous return, in other words the average log-return $\overline{q}$, is used for the return estimate on the basis of a historical data series. The continuous return (and not the discrete return) is chosen, because time-additivity is relevant (please review again Section 4.3, where the distinction between discrete and continuous return was introduced.) The mean log-return $\overline{q}$ is calculated as the arithmetic average (and not geometric average) of the logarithm of the price rations q_t. The arithmetic average return is selected in this case, since it is preferred for the determination of future expected returns (review the application of arithmetic average return and geometric average return in Section 4.1.4).

Thus the future log-return is given by the following formula:

$$q_t = \overline{q} + \varepsilon_t$$

with
q_t = log-return
$\overline{q}$ = mean log-return
ε_t = random forecast error in period t.

Based on these considerations, the random walk model in its simplest version can be defined as follows:

$$ln\left(\frac{P_t}{P_{t-1}}\right) = \overline{q} + \varepsilon_t$$

> A random walk is characterized by fluctuations of the return around a (long-term) mean.

In the financial model of the random walk, the return fluctuates around a (long-term) mean with random deviations ε_t. Depending on the size of the fluctuations of the random deviations, the realized price development can deviate significantly over time from the expected growth path, which is given by the mean. The (logarithm of) the development of price, respectively value, of the investment reflects this growth rate equal to the mean return, which is subject to random fluctuations.

This process can be described as a successive development

$$
\begin{aligned}
&lnP_0 = lnP_0 \\
&lnP_1 = lnP_0 + \overline{q} + \varepsilon_1 \\
&lnP_2 = lnP_1 + \overline{q} + \varepsilon_2 = (lnP_0 + \overline{q} + \varepsilon_1) + \overline{q} + \varepsilon_2 = lnP_0 + 2 \cdot \overline{q} + \varepsilon_1 + \varepsilon_2 \\
&\vdots \\
&lnP_T = lnP_0 + n \cdot \overline{q} + \textstyle\sum_{t=1}^{n} \varepsilon \text{ with t} = 1, 2, 3, \ldots, n
\end{aligned}
$$

The long-term value development consists of a steady growth rate of the return $n \cdot \overline{q}$ (for a positive return) and the sum of the random residual ε_t which is impossible to forecast. For these residuals it is merely assumed that they are independent, in other words that past observations cannot be used to derive information for forecasting future realizations of ε_t. Put differently, knowledge of the past development of prices does not allow a precise forecast of future developments. The prices have no memory and no preference for a specific path, to put it figuratively. This attribute is called Markov process in statistics (named after the Russian mathematician Andrei Markov). The expected mean return $\overline{q}$ is also called drift or trend in the random walk model. Depending on the volatility of the residual ε_t, very different price movements can result, which in their appearance resemble the paths taken by securities prices.

$$
ln\left(1 + r_t^d\right) = ln\left(\frac{P_T}{P_0}\right) = n \cdot \overline{q} + \sum_{t=1}^{n} \varepsilon_t
$$

$$
1 + r_t^d = \frac{P_T}{P_0} = e^{n \cdot \overline{q} + \sum\limits_{t=1}^{n} \varepsilon_t}
$$

Underlying the development of the asset values is a growth path, which is determined by the drift. Due to the development of the residuals ε_t which are unpredictable, significant deviations can be observed over time, so that the actually observed time-weighted or geometric average period return r_t^{twr} at the end of the n periods deviates significantly from the expected value (the time-weighted respectively geometric average return is used in this case, since it is suitable for the determination of the historical performance of securities. Please once again review the application of the arithmetic average return and the geometric average return in section 4.1.4). Such deviations can already be caused by a few strong or even extreme values for the random variable ε_t, usually called shocks. Depending on the magnitude of the shocks, the expectations of the investor are either significantly surpassed or massively disappointed.

In the Excel file in the worksheet `Risk_(2)`, the random walk is calculated. This is done with the help of this formula:

$$P_t = P_{t-1} \cdot e^{\overline{q}+\varepsilon_t}$$

with
P_{t-1} = ending value from the previous period
$\overline{q}$ = constant trend factor or drift
ε_t = random influence

The necessary input data for the calculation of the random walk can be found in Fig. 12.34. Needed are:

- Starting price,
- Constant return $\overline{q}$ (trend factor = drift);
- Volatility of the random numbers as well as
- Period length (here 12 month per year).

	A	B	C
4			
5		Assumptions Random Walk	
6		Starting price	100
7		Trend factor = drift p.a.	0.05
8		Volatility p.a.	0.25
9		Period length	12

Fig. 12.34 Assumptions for the calculation of the random walk (Work File Portfolio Management, Worksheet Random_Walk)

Position	Formula	Excel implementation
Monthly drift (=Random_Walk!C13)	=Natural logarithm*(1+Drift p.a.)/Factor to annualize data	=LN(1+C7)/C9
Scaled volatility (=Random_Walk!E13)	Volatility p.a./Square root(Factor to annualize data)	=C8/SQRT(C9)

Fig. 12.35 Transforming the annual values into monthly observations

	A	B	C	D	E
12					
13		Monthly drift	0.004066	Scaled volatility	0.072168784

Fig. 12.36 Calculating scaled drift and scaled volatility (Work File Portfolio Management, Worksheet Random_Walk)

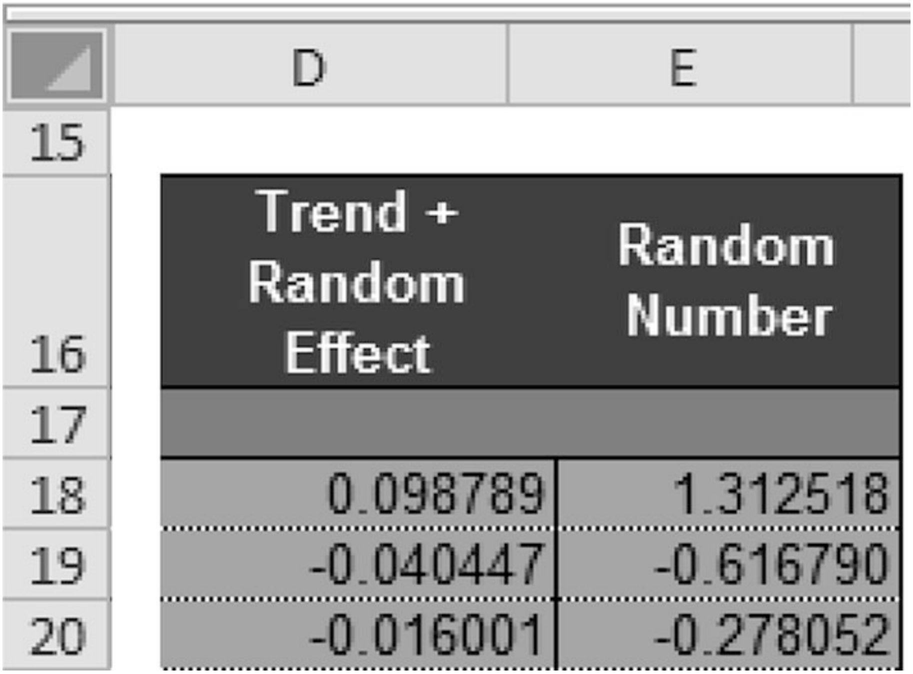
Position	Formula	Excel implementation
Excel formula percentile of normal distribution (=Random_Walk!E18)	=NORM.INV(Probability; Mean; Standard deviation)	=NORM.INV(RAND();0;1)
Sum of trend and random parameter (=Random_Walk!D18)	=Scaled drift + Scaled volatility * Random number	=$C$13+$E$13*E18

Fig. 12.37 Calculating the random number as well as trend plus random number

Since return and volatility are stated as annual values in Fig. 12.34, they initially need to be transformed into monthly values. The monthly drift is calculated in cell C13 and the scaled volatility in cell E13 (see Figs. 12.35 and 12.36). Additional information concerning volatility, annual values and adjustment of the standard deviation for periods of less than one year are found in the sections 5.4.1, 5.6 and 5.7.2.

The random number ε_t is determined next (see Figs. 12.37 and 12.38). Initially the percentiles are determined in column E on the basis of a normal distribution with mean of 0 and standard deviation of 1. Percentiles divide an ordered dataset into one hundred segments which all consist of an identical number of measured values. Additionally, the sum of trend $\overline{q}$ and random parameter ε_t is calculated in column D.

To calculate the percentiles of the normal distribution, the function *NORM.INV* is used. Needed as arguments for the formula are the probability, the mean and the standard deviation. When calculating the sum



	D	E
15		
16	Trend + Random Effect	Random Number
17		
18	0.098789	1.312518
19	-0.040447	-0.616790
20	-0.016001	-0.278052

Fig. 12.38 Calculating the random number as well as trend plus random (Work File Portfolio Management, Worksheet Random_Walk)

of trend and random effect, the scaled drift in cell E13 is used as the trend and the value from the normal distribution (from the relevant period) multiplied by the scaled volatility in cell C13 is used for the random effect (see Fig. 12.39).

The sum of the components of the random walk which were specified in this manner results in the logarithm of the price during a period. In order to obtain the absolute price instead of the logarithm of the price, the excel function *EXP* must be applied in a final step. This is done for example in cell C18. The random walk for the price is thus determined as follows:

$$P_t = P_{t-1} \cdot e^{\overline{q}+\varepsilon_t}$$

Figure 12.40 shows the results of the random walk.

In addition, a diagram of the random walk during the specified time period is created (see Fig. 12.41).

By hitting the *F9*-key it is possible to repeatedly generate new random price patterns. As the simulations make clear, the high volatility

Period	Random Walk
0	100.00
1	91.44
2	96.21
3	101.31

Fig. 12.39 Calculating the random walk (Work File Portfolio Management, Worksheet Random_Walk)

Monthly drift	0.004066	Scaled volatility	0.072168784

Period	Random Walk	Trend + Random Effect	Random Number
0	100.00		
1	102.54	0.025093	0.291359
2	105.38	0.027315	0.322154
3	103.89	-0.014219	-0.253362
4	92.79	-0.113026	-1.622470

Fig. 12.40 Results of the random walk (Work File Portfolio Management, Worksheet Random_Walk)

of the random price developments relative to the constant return can lead to massive deviations from the underlying trend. The resulting price patterns can be very different and illustrate the manifold effects of random influences.

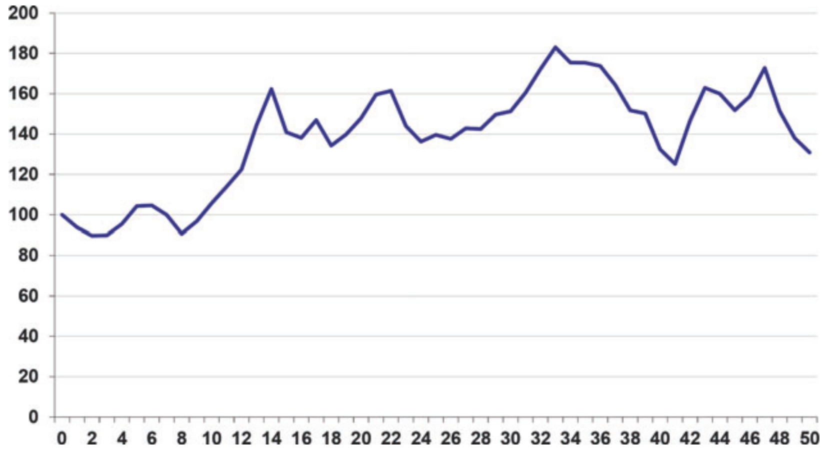


Fig. 12.41 Graphical representation of the random walk (Work File Portfolio Management, Worksheet Random_Walk)

5.3 Categories of Risk

A distinction is made between one-sided, two-sided and other risk measures.

The quantitative risk measures fall into three categories (see Fig. 12.42):

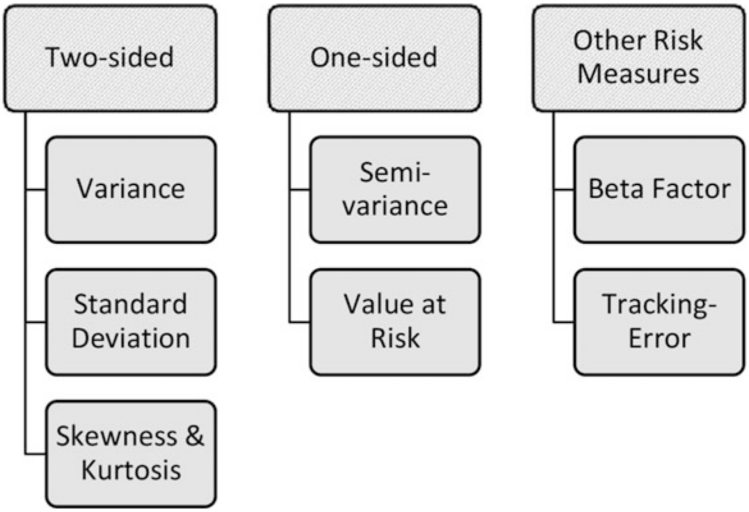


Fig. 12.42 Risk categories

- One-sided,
- Two-sided,
- and other risk measures.

5.3.1 Two-Sided Risk Measures

> Two-sided risk measures consider both positive and negative deviations from the expected value.

As the name already indicates, two-sided risk measures consider both sides of the return distribution when determining risk. Two-sided risk measures incorporate both the positive deviations to the right of the expected value (upside risk) as well as the negative deviations to the left of the expected value (downside risk). Under the assumption of normally distributed returns, variance and standard deviation are frequently used risk measures.

Since capital markets are frequently characterized by larger deviations compared to the standard normal distribution in the lower end of the distribution (fat tails), the distribution of the observed returns is frequently leptokurtic. For that reason, the use of alternative measures of risk, which incorporate skewness and kurtosis of a distribution seems appropriate.

5.3.2 One-Sided Risk Measures

> One-sided risk measures only consider the left side of the return distribution.

In contrast, one-sided risk measures only consider the left side of the return distribution. Their focus is exclusively on possible losses in capital markets which leads to more restrictive risk management and a significantly more realistic description of the potential losses of an investment or portfolio. Important representatives of the one-sided risk measures are semi-variance and value-at-risk.

5.3.3 Other Risk Measures

Additional risk measures exist, which cannot be assigned unambiguously to the previously discussed categories due to differences in the underlying statistical concepts:

- The tracking error is a symmetrical measure which quantifies the actual deviations between the price development of a portfolio and a market index;
- The beta factor of a portfolio measures the average sensitivity of a portfolio with respect to market fluctuations.

5.4 Volatility

5.4.1 Calculation

> Volatility describes the dispersion of security price changes.

Volatility is defined as the dispersion of price changes of securities or portfolios and is calculated as the annualized standard deviation.

To calculate volatility and other risk measures as well as for their use in portfolio management, we exclusively work with simple (discrete) returns, since the following models require the attribute of portfolio additivity (see Section 4.3). In option price theory, in contrast, the volatility is calculated on the basis of the log-returns, following the random walk model presented. As a basic rule, it is important for correct financial modeling to always select the return definition which is suitable for the model used.

The volatility calculation is contained in the worksheets `Volatility_(1)` and `Volatility_(2)`. First, the returns are calculated

Position	Formula	Excel implementation
Mean return with the Excel function *AVERAGE* (=Volatility_(2)!C8)	=Average(Return 02.01.t_{-9} to 29.02.t_0)	=AVERAGE('Volatility (1)'!D8:D2363)
Manual calculation of the mean return (=Volatility_(2)!C8)	=Sum (Return 02.01.t_{-9} to 29.02.t_0)/Number of observations	=SUM('Volatility (1)'!D8:D2363)/COUNT('Volatility (1)'!D8:D2363)

Fig. 12.43 Calculating the mean

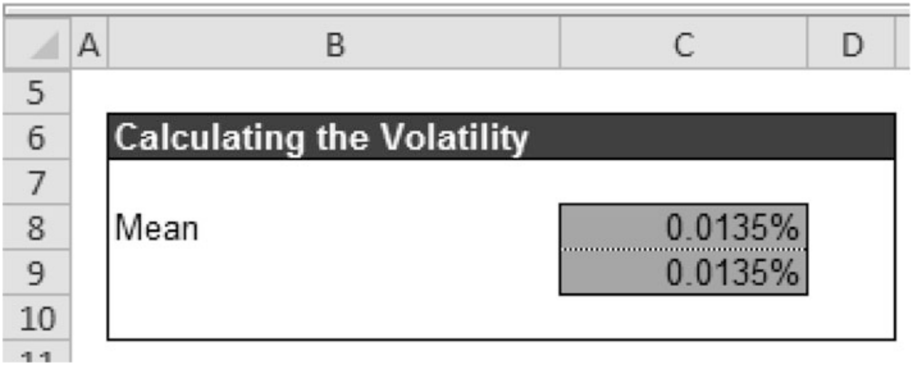


Fig. 12.44 Calculating the mean (Work File Portfolio Management, Worksheet Volatility_(2))

in the worksheet `Volatility_(1)`. The calculation was already described in the section "Return."

Once the returns have been determined, the volatility can be calculated. In the worksheet `Volatility_(2)` the mean value of the returns is calculated with two different methods. First with the Excel function *AVERAGE* and second manually by dividing the sum of the returns by the number of observations. The two values must be identical (see Figs. 12.43 and 12.44).

- Excel formula for the calculation of the mean return with the Excel function *AVERAGE*
- Manual calculation of the mean return

The standard deviation of a population is calculated in Column C in three different ways (see Figs. 12.45 and 12.46):

- Using the function for the standard deviation *STDEV.P*[2]

Position	Formula	Excel implementation
Function for the standard deviation *STDEVP* (=Volatility_(2)!C14)	=Standard deviation of the population of returns 02.01.t_9 to 29.02.t_0	=STDEV.P('Volatility (1)'!D8:D2363)
Standard deviation as the square root of the variance (=Volatility_(2)!C15)	=Square root of the variance of the population of returns 02.01.t_9 to 29.02.t_0	=SQRT(VAR.P('Volatility (1)'!D8:D2363))
Formula for the standard deviation from the manual formula (=Volatility_(2)!C16)	=Square root of the sum product	=SQRT((SUMPRODUCT(('Volatility (1)'!D8:D2363)-C$8;('Volatility (1)'!D8:D2363)-C$8))/(COUNT('Volatility (1)'!D8:D2363)))

Fig. 12.45 Calculating the standard deviation of the population

	A	B	C	D	E
11					
12					Method of
13			Population		Calculation
14		Standard Deviation a	0.0150405		Standard Dev.
15		Standard Deviation b	0.0150405		from Variance
16		Standard Deviationc	0.0150405		Formula

Fig. 12.46 Calculating the standard deviation of the population (Work File Portfolio Management, Worksheet Volatility_(2))

Position	Formula	Excel implementation
Annualized standard deviation (=Volatility_(2)!C20)	=Standard deviation * Square root(Trading days per year)	=C14*SQRT(Assumptions General!C207)

Fig. 12.47 Calculating the annualized standard deviation respectively volatility

- As the square root of the variance
- From the manual formula

Additionally the annualized standard deviation needs to be calculated (also see Section 5.7.2) in order to determine the annual volatility (see Figs. 12.47 and 12.48). The factor used to annualize the data is 250 days (cell C20).

The results for the various volatilities are presented in Fig. 12.49.

	A	B	C
18			
19		Annualised based on 250 Days	
20		Ann. Standard Deviation	0.2378
21			

Fig. 12.48 Calculating the annualized standard deviation respectively volatility (Work File Portfolio Management, Worksheet Volatility_(2))

	A	B	C	D	E	F
5						
6		**Calculating the Volatility**				
7						
8		Mean	0.0135%			
9			0.0135%			
10						
11						
12					Method of	
13			Population		Calculation	
14		Standard Deviation a	0.0150405		Standard Dev.	
15		Standard Deviation b	0.0150405		from Variance	
16		Standard Deviationc	0.0150405		Formula	
17						
18						
19		Annualised based on 250 Days				
20		Ann. Standard Deviation	0.2378			
21						

Fig. 12.49 Calculating the volatility (Work File Portfolio Management, Worksheet Volatility_(2))

5.4.2 Histogram, Density Function and Distribution Function

> A histogram is used to display volatility.

A histogram is used to graphically display the volatility.

A histogram is a graphical display of the discrete frequency distribution of statistical data. It is s specific type of bar diagram. The attributes are on the X-axis and the frequency is on the Y-axis. The frequency of a value is represented by a bar above the value – this can be either in relative (in percent) or in absolute terms.

The creation of a histogram and the steps needed are described in the worksheet `Histogram` in the Excel file. The relative frequency of the returns (in percent) is calculated for predefined return intervals. In statistics, this concept is called frequency distribution.

Initially,

- minimum,
- maximum,
- mean and
- number of observations

are calculated in the worksheet Histogram with the relevant Excel functions (see Figs. 12.50 and 12.51).

To create the graph, the bin range must be set in cells `C18:C50`. In the Excel example, the bin range starts at -8% and increases in steps of 0.5% to 8%. With the help of the analysis function *HISTOGRAM* it is very easy to determine the distribution. The function is accessed in Excel via *Data* ➲ *Analysis* ➲ *Data Analysis* ➲ *Histogram* (see Fig. 12.52).

For the input range, the returns from worksheet `Volatility_(1)` in the cells `D8:D2363` are entered. The bin range is equal to the previously determined upper and lower bounds in the cells `C18:C50` and the output range starts with the cell `D17`. Additionally, the box "Chart Output" is activated in order to immediately obtain a graph from the data. The columns for category and frequency are automatically inserted and calculated.

Position	Formula	Excel implementation
Minimum (`=Histogram!E8`)	=Minimum of the returns 02.01.t_{-9} to 29.02.t_0	`=MIN('Volatility (1)'!D8:D2363)`
Maximum (`=Histogram!E10`)	=Maximum of the returns 02.01.t_{-9} to 29.02.t_0	`=MAX('Volatility (1)'!D8:D2363)`
Mean value of the returns (`=Histogram!E12`)	=Mean value of the returns 02.01.t_{-9} to 29.02.t_0	`=AVERAGE('Volatility (1)'!D8:D2363)`
Number of observations (`=Histogram!E14`)	=Number of observations 02.01.t_{-9} to 29.02.t_0	`=COUNT('Volatility (1)'!D8:D2363)`

Fig. 12.50 Calculations required for the histogram

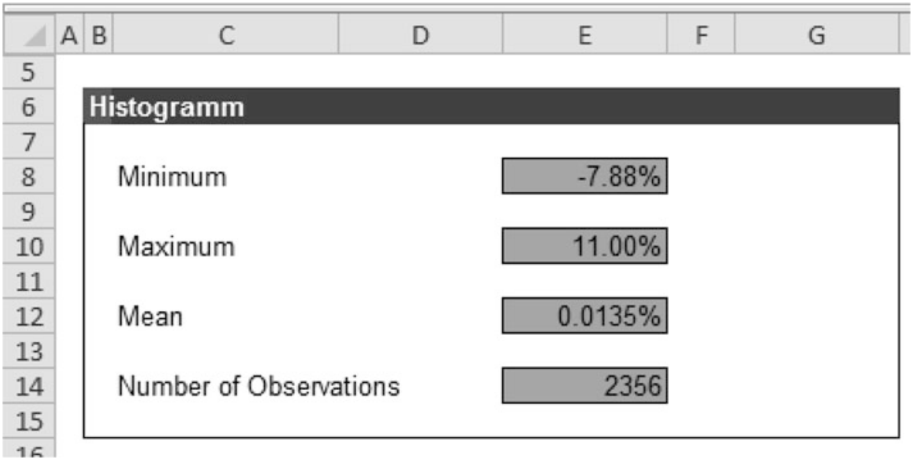


Fig. 12.51 Calculations required for the histogram (Work File Portfolio Management, Worksheet Histogram)

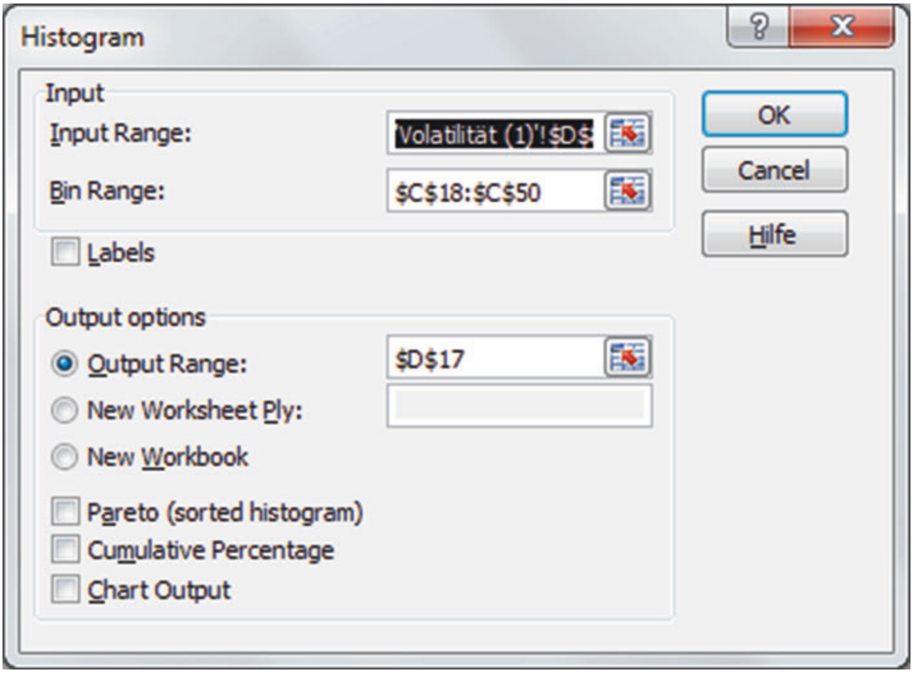


Fig. 12.52 Creating a histogram

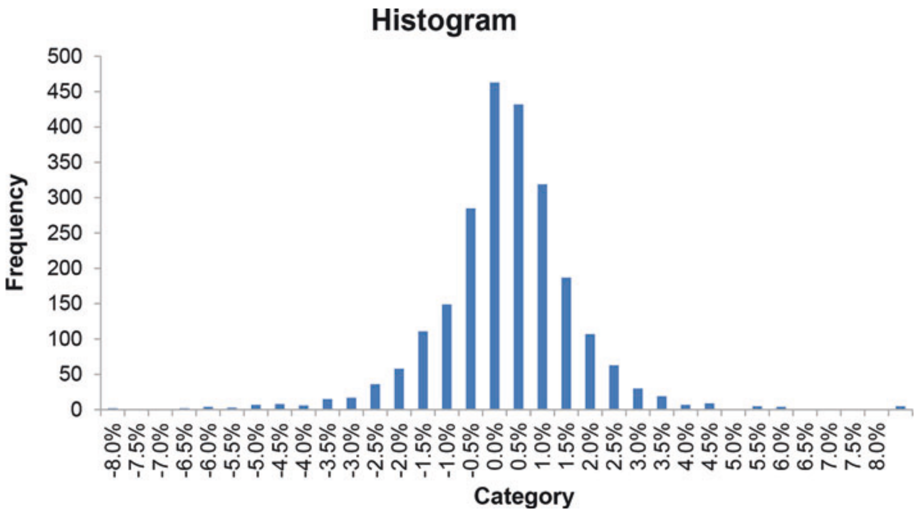


Fig. 12.53 Display of the histogram (Work File Portfolio Management, Worksheet Histogram)

The completed histogram looks as follows (see Fig. 12.53):

> The standard normal distribution is a special case of the normal distribution with expected value of 0 und standard deviation of 1.

In probability theory, the density function is used to describe a continuous probability distribution. It describes the probability that a random variable falls into a specific category. The density function replaces the previously discussed discrete histogram. A typical form of a density function is shown in Fig. 12.56.

A distribution function describes the relationship between a random variable and its probability, in other words it describes the probability that a random variable has at most a specified range of values. The probability function specifies a cumulative probability.

In the worksheet `Density_and_Distribution_Funct.` a density function and a distribution function of the standard normal distribution are created. In cell `C6` the value 0.0 is entered for the expected value and in cell `C7` the value 1.0 is entered for the standard deviation. In cells `D10:D144` the values of the standard normal distribution for a specific probability are calculated with the help of the

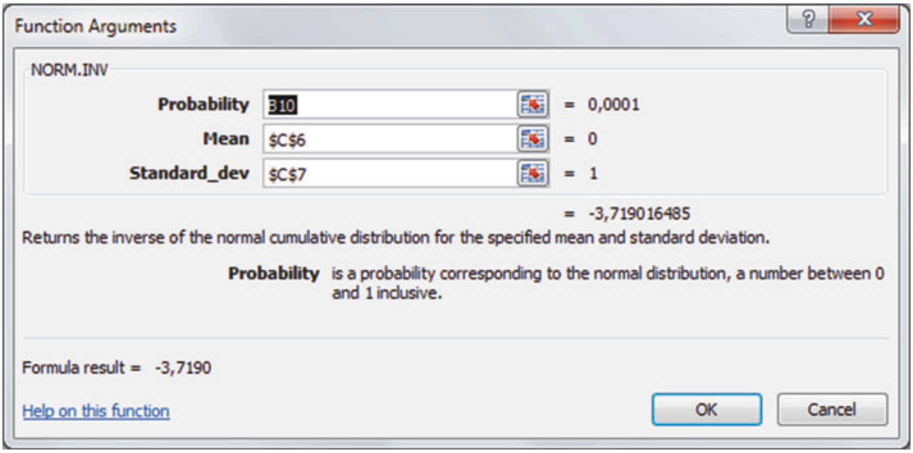


Fig. 12.54 Calculating the values of the standard normal distribution

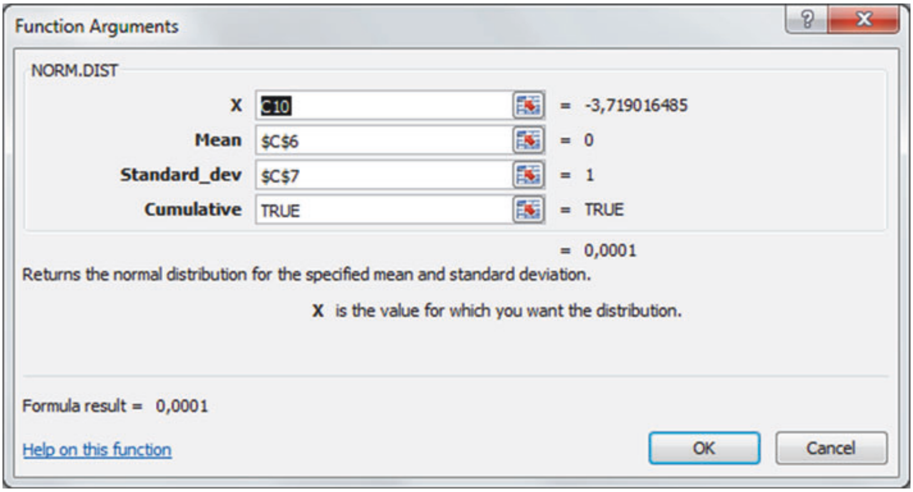


Fig. 12.55 Calculating the relative frequency

function *NORM.INV*. The function *NORM.INV* returns percentiles for the normal distribution (see Fig. 12.54).

In addition, the probability for a specific value of the standard normal distribution is calculated in cells `E10:E144`. This is done with the help of the function *NORM.DIST* (analogous to the previous calculation) (see Fig. 12.55).

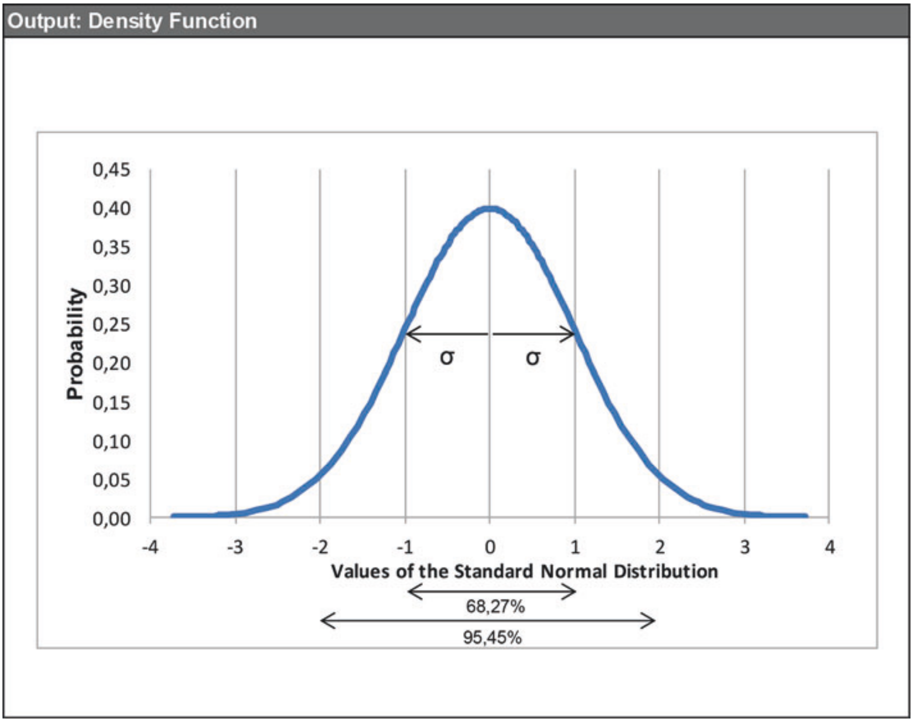


Fig. 12.56 Density function (Work File Portfolio Management, Worksheet Histogram)

- As X value the given value of the standard normal distribution from Column `C` is entered,
- for the mean value cell `C6` is entered,
- for the standard deviation cell `C7` is entered and
- for the argument cumulative, false is entered.

It is possible that the function *NORM.DIST* returns a cumulative probability. For the density function in cells `D10:D144` this is not intended. Therefore the fourth parameter is FALSE. Alternatively the distribution function can be calculated via the cumulative probability in cells `E10:E144`. In this case, the parameter TRUE is entered for the argument cumulative.

Once all values have been calculated, the density function is displayed in graphical form (see Fig. 12.56).

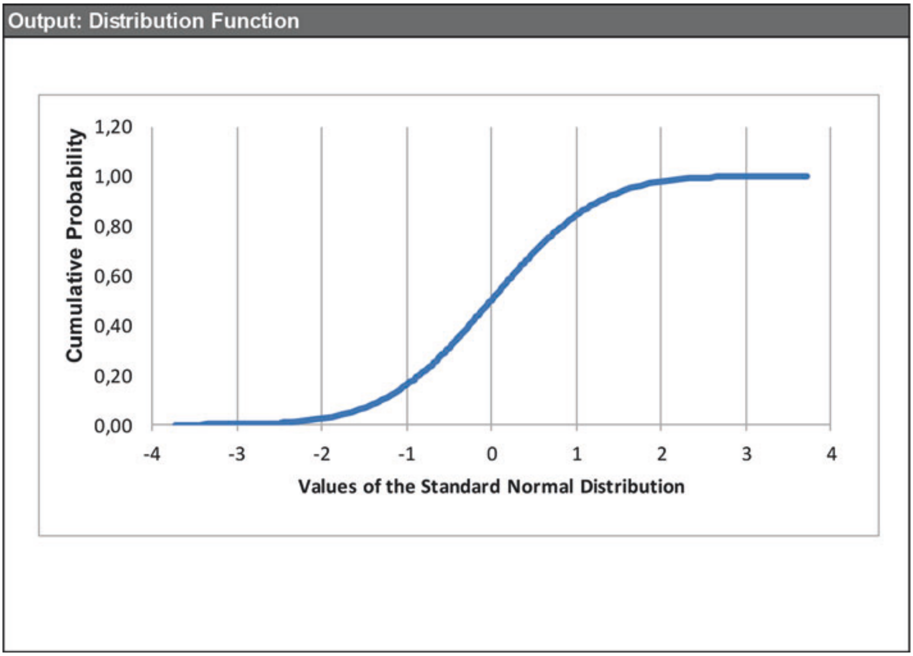


Fig. 12.57 Distribution function (Work File Portfolio Management, Worksheet Histogram)

The density function shows the dispersion of returns around the expected value. Depending on the inputs used for the expected value or the standard deviation, the curve moves, respectively becomes narrower or wider.

Similar to the density function, the distribution function can be calculated as well (see Fig. 12.57).

5.4.3 The Limit Theorem in Statistics

The limit theorem provides the foundation for traditional risk measures

The sum of n log-returns q_t describes the growth of the underlying asset. If the previous ideas about random variables and the random walk are pursued further and the n log-returns are replaced by the return estimates, the return equation of the random walk model follows:

$$ln\,(1 + r_T) = (\overline{q} + \varepsilon_1) + (\overline{q} + \varepsilon_2) + \ldots + (\overline{q}\varepsilon_{n-1}) + (\overline{q} + \varepsilon_n) = n \cdot \overline{q} + \sum_{t=1}^{n} \varepsilon_t$$

A hypothesis about the distribution function of the log-returns for such a return process can be derived from the central limit theorem:

The distribution of a sum of random numbers converges approximately towards the normal distribution.

A main advantage of the normal distribution is its straightforward functional form with only two defining parameters, the expected value and the variance, respectively standard deviation. This allows precise statements about probabilities for the realization of specific value ranges of the random variable ε_t.

Despite the solid statistical foundation for the normal distribution, its relevance can be questioned due to the frequency of extreme realizations of the random variable ε_t, a so-called crash. In the reality of capital markets, such crash scenarios appear more frequently than implied by the normal distribution. Thus the assumption of a normal distribution can be questioned. Especially in the field of risk management, significantly more complex distribution models are implemented in order to better capture the larger probability of crash situations. An alternative possibility to model extreme price movements is to assume changes of volatility over time (so-called heteroscedasticity, see section 5.8).

5.5 Variance

> Variance is a measure of dispersion, which describes the distribution of observations around the mean

As in the case of volatility, a distinction is made between population and sample when calculating the variance. If the population is assumed, division by n is used (total number of observations):

$$\mathrm{Var}\,[\mathrm{r}] = \sigma^2 = \frac{1}{n} \sum_{t=1}^{n} (r_t - \mu)^2$$

with
σ^2 = variance of returns
n = number of observations

Position	Worksheet und Cell	Excel implementation
Variance of the population (=Variance_and-Standard_Dev._(2)!D10)	=Variance of the population of returns 01.01.t_1 to 29.02.t_0	=VAR.P('Variance and Standard Dev. (1)'!C7:C136)

Fig. 12.58 Calculating the variance

	A	B	C	D	E	F
8						
9				Euro Stoxx 50	Danone	Alianz
10			VAR.P	0.0004	0.0002	0.0010

Fig. 12.59 Calculating the variance (Work File Portfolio Management, Worksheet Variance_and_Standard_Dev._(2))

r_t = return at time t
μ = expected value of the return

VAR.P is the corresponding function in Excel to calculate the variance of the population. In the case of a sample, division by $n-1$ is required. The corresponding Excel function is *VAR.S*.

In the worksheet `Variance_and_Standard_Dev._(1)` the daily values of the Euro Stoxx50 from the worksheet `Assumptions_Data_daily` are used. The daily returns for Danone (Column `D`) and Allianz (Column `E`) are also calculated. For these three data series, the variance of the population is calculated in the worksheet `Variance_and_Standard_Dev._(2)` with the help of the function *VAR.P* (cells `D10:F10`) (see Fig. 12.58 and 12.59).

5.6 Standard Deviation

Standard deviation is the square root of the average squared distance of all observations from the mean.

Instead of the variance, a squared measure, the use of the standard deviation σ is customary since return and standard deviation share the same (linear) dimension. The standard deviation can either be calculated with Excel directly or as the square root of the variance:

$$S[r] = \sigma = \sqrt{\sigma^2} = \sqrt{Var[r]}$$

Just as the variance, the standard deviation can either be derived from the population or from a sample.

If the standard deviation is calculated based on the population, division by $n$is required, where n is the number of data points in the population.

$$S[r] = \sigma = \sqrt{\frac{1}{n}\sum_{t=1}^{n}(r_t - \mu)^2}$$

with
$S[r]$ resp. σ = standard deviation of returns
n = number of observations
r_t = return at time t
μ = expected value of the return

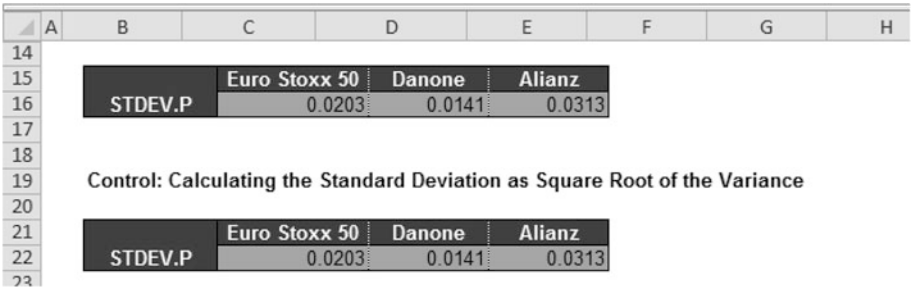
The Excel function for the standard deviation based on the population is *STDEV.P*. In case of a sample, division by n–1 is required. The corresponding Excel function is *STDEV.S*.

For the data series that were already used in Section 5.5, the standard deviation of the population is calculated in the worksheet `Variance_and_Standard_Dev._(2)` using the function *STDEV.P* (see Fig. 12.60). To check the Excel function, the standard deviation of the population is also calculated manually using the *SQRT* function.

The calculation of the standard deviation and the results obtained are presented in Fig. 12.61.

Position	Worksheet und Cell	Excel implementation
Standard deviation of the population (`=Variance_and_Standard_Dev._(2)!D16`)	=Standard deviation of the population of returns 01.01.t_{-1} to 29.02.t_0	`=STDEV.P('Variance and Standard Dev. (1)'!C7:C136)`
Standard deviation of the population (`=Variance_and_Standard_Dev._(2)!D22`)	=Square root of the variance of the population of returns 01.01.t_{-1} to 29.02.t_0	`=SQRT(D10)`

Fig. 12.60 Calculating the standard deviation



	Euro Stoxx 50	Danone	Alianz
STDEV.P	0.0203	0.0141	0.0313

Control: Calculating the Standard Deviation as Square Root of the Variance

	Euro Stoxx 50	Danone	Alianz
STDEV.P	0.0203	0.0141	0.0313

Fig. 12.61 Calculating the standard deviation (Work File Portfolio Management, Worksheet Variance_and_Standard_Dev._(2))

5.7 Risk Measures for Different Time Periods

Risk measures for periods of less than one year are usually annualized to achieve comparability.

Any comparison of risk is only meaningful for identical time periods. It makes no sense, for example, to compare monthly variances with annual variances. For that reason comparability needs to be assured for risks measured over different time periods.

5.7.1 Adjusting the Variance

The variance can be annualized as follows:

$$\sigma^2_{annual} = \sigma^2_t \cdot \frac{T}{n}$$

with
σ^2_{annual} = annualized variance of returns
σ^2_t = variance of returns for less than one year
t = single period of less than one year
T = total number of periods of less than one year in one year
n = number of periods of less than one year used in the calculation

The transformation of the variance of returns from an annualized base to a period of less than one year is achieved as follows:

$$\sigma_t^2 = \sigma_{annual}^2 \cdot \frac{n}{T}$$

5.7.2 Adjusting the Standard Deviation

The adjustment of the standard deviation follows a similar process. The standard deviation of returns is annualized as follows:

$$\sigma_{annual} = \sigma_t \cdot \sqrt{\frac{T}{n}}$$

with
σ_{annual} = annualized standard deviation of returns
σ_t = standard deviation of a period of less than one year
t = single period of less than one year
T = total number of periods of less than one year in one year
n = number of periods of less than one year used in the calculation

The transformation of the standard deviation from an annualized base to a period of less than one year is achieved as follows:

$$\sigma_t = \sigma_{annual} \cdot \sqrt{\frac{n}{T}} = \frac{\sigma_{annual}}{\sqrt{\frac{T}{n}}}$$

5.8 Moving Volatility

> Risk measures are not stable and can change over time.

The estimates of volatility can vary strongly depending on the time period chosen. In order to improve the precision of the estimate of variance respectively standard deviation, large amounts of data are usually preferred in statistical work. However, this assumes at the same time a constant dispersion, in other words volatility that is constant over time. Thus volatilities calculated over such long time periods reflect the typical long-term market movements. In order to capture current variability, it is customary to shorten the time period under consideration and to calculate rolling standard deviations for intervals of fixed length. This shortened historical data basis is rolled towards the current time period. This results in a time series with individual elements that have been calculated as moving averages. This is called moving volatility.

The historical volatility in financial markets and of individual assets over short periods of time can exceed the long-term volatility. During periods of strong market movements, the short-term volatility can be above the long-term historical volatility, while periods of calmer market developments are characterized by short-term volatility below the historic average. Short-term volatility is characterized by a positive correlation. However, this violates the fundamental assumption of an identical distribution of returns. Extreme deviations thus occur more frequently than the assumption of a constant volatility would suggest. Modern estimation techniques for volatility take these effects in consideration, for example GARCH models. However, for our purpose these considerations are outside the scope of our analysis.

The most frequently used volatilities are the 30-day and 250-day volatility. It is calculated by taking the standard deviation of the past 29 returns (30 trading days) or the past 249 returns (250 trading days).

Formally the moving historical volatility is defined as:

$$\sigma_t = \sqrt{\frac{1}{m-1} \cdot \sum_{i=0}^{m-1} (q_{t-i} - \overline{q_t})^2}$$

with

m = length of the time interval

$\overline{q_t}$ = mean return for the interval, also calculated on a rolling basis

In the Excel example in the worksheet `Moving_Volatility_(1)` it is initially required to calculate the daily returns in Column `C`. In Column `D`, the 30-day volatility is determined and in Column `E` the 250-day volatility. Both 30-day volatility and 250-day volatility are daily volatilities that are annualized (see Fig. 12.62).

A diagram of the two moving volatilities is constructed in the worksheet `Moving_Volatility_(2)` (see Fig. 12.63).

Position	Formula	Excel implementation
30-day volatility (=Moving_Volatility_(1)!D38)	=Standard deviation for the last 30 days* Square root (Trading days per year)	=STDEV.P(C10:C38)*SQRT(Assumptions General!$C$207)
250-day volatility (=Moving_Volatility_(1)!E258)	=Standard deviation for the last 250 days* Square root days* Square root (Trading days per year)	=STDEV.P(C10:C258)*SQRT(Assumptions General!$C$207)

Fig. 12.62 Calculating the moving volatility

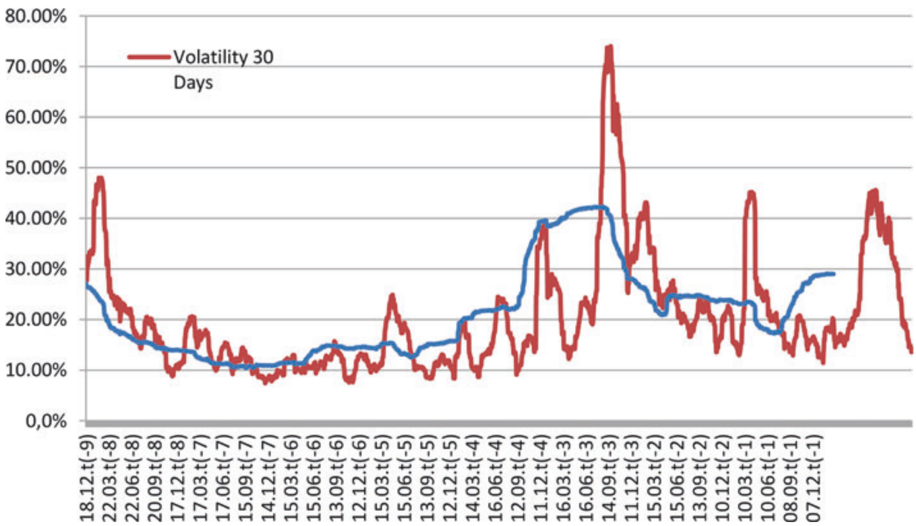


Fig. 12.63 30-day and 250-day volatility (Work File Portfolio Management, Worksheet Moving_Volatility_(2))

5.9 Covariance

Covariance is needed to determine the portfolio variance.

In addition to the separate estimates of the volatility of single investments or markets, many issues in financial market analysis also require an understanding of the co-movement of the fluctuations. Do the investments fluctuate in the same direction, are they moving in opposite directions or is there no discernible relationship? A fundamental measure to assess the linear relationship between two data series is the covariance.

The covariance is calculated as the average of the products of the deviations of two variables from their expected values. It describes the degree of parallel movement of two variables around their individual expected value.

The formula for the covariance of a population is:

$$Cov\left[r_{i,j}\right] = \sigma_{i,j} = \frac{1}{n}\sum_{t=1}^{n}\left(r_{i,t} - \mu_i\right) \cdot \left(r_{j,t} - \mu_j\right)$$

with $Cov\left[r_{i,j}\right] = \sigma_{i,j}$ = covariance

The Excel function for the covariance of the population is *COVARIANCE.P*.

This expression resembles the calculation of the variance. The only difference is the fact that the deviations from the mean are not squared, but instead multiplied with the deviation from the mean of another investment.

With the help of the covariance, the formula for the portfolio variance can be defined as follows:

$$\sigma_P^2 = \sum_{i=1}^{n} w_i \cdot \sigma_{i,P}$$

Since the portfolio variance is made up of the individual variance contributions of the assets, the portfolio risk can be described succinctly as the weighted sum of the covariances between the individual portfolio components and the portfolio itself. The portfolio variance can thus also be described as the weighted sum of all covariances of the individual portfolio components with the portfolio itself.

In the Excel example the daily returns are again calculated in the worksheet `Covariance_Matrix_(1)`. A covariance matrix is used to determine the covariances of Allianz and Danone in the worksheet `Covariance_Matrix_(2)`. The covariance for the population is calculated with the help of the Excel function *COVARIANCE.P* in cells `D10:E11` (see Figs. 12.64 and 12.65).

Position	Formula	Excel implementation
Covariance between the returns of Allianz and Danone (=Covariance_Matrix_(2)!D11)	=Covariance (Return Danone 01.09.t_1 to 20.02.t_0 and return Allianz 01.09.t_1 to 20.02.t_0)	=COVARIANCE.P('Covariance Matrix (1)'!D7:D136;'Covariance Matrix (1)'!E7:E136)

Fig. 12.64 Calculating the covariance

	Danone	Alianz
Danone	0.00019981	0.00028371
Alianz	0.00028371	0.00098282

Fig. 12.65 Calculating the covariance (Work File Portfolio Management, Worksheet Covariance_Matrix_(2))

There are two possible ways to determine the covariance matrix:

- with the Excel function *COVARIANCE;*
- with the analysis function *COVARIANCE*.

For the Excel function *COVARIANCE.P* (Population) a table is constructed where the headers of both the columns and the rows are the names of the individual assets. Then the Excel function *COVARIANCE.P* (Population) is used to calculate the values of the covariance matrix.

The second choice involves the use of the analysis function *COVARIANCE.* It is accessed in Excel via *Data* ➲ *Analysis* ➲ *Data Analysis* ➲ *Covariance*. This function only displays the lower triangle of the matrix. The upper half must be added manually. This can be accomplished very easily by first copying the entire matrix and placing it elsewhere in the spreadsheet. Then the upper half is inserted via *Home* ➲ *Clipboard* ➲ *Paste* ➲ *Paste Special* ➲ *Insert contents* and then marking *Skip blanks* and *Transpose*. In this way the upper half of the matrix is obtained (see Fig. 12.66).

It must be noted that the analysis function *COVARIANCE* calculates the covariance on the basis of the population. If a calculation on the basis of a sample is required, the analysis function *COVARIANCE* is not suitable. A further disadvantage is the fact that changes in the input

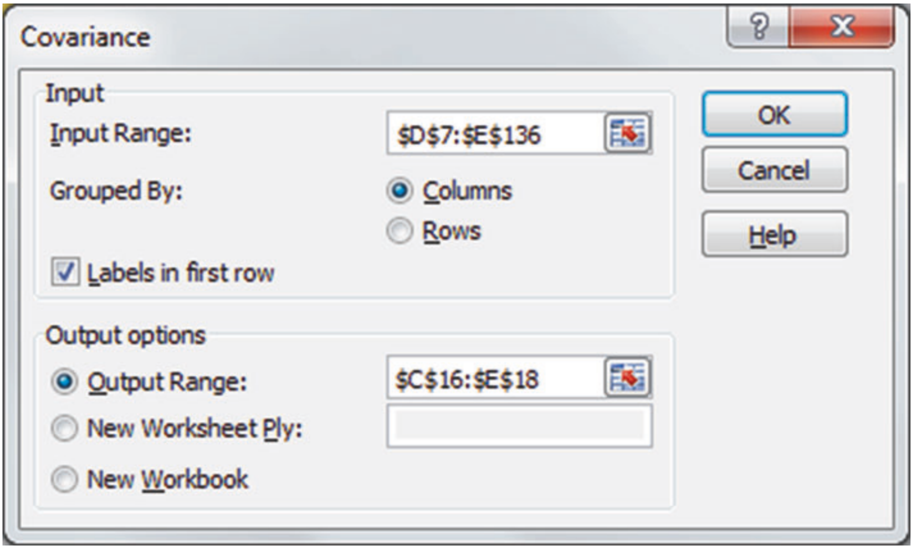


Fig. 12.66 Calculation of covariance with the analysis function

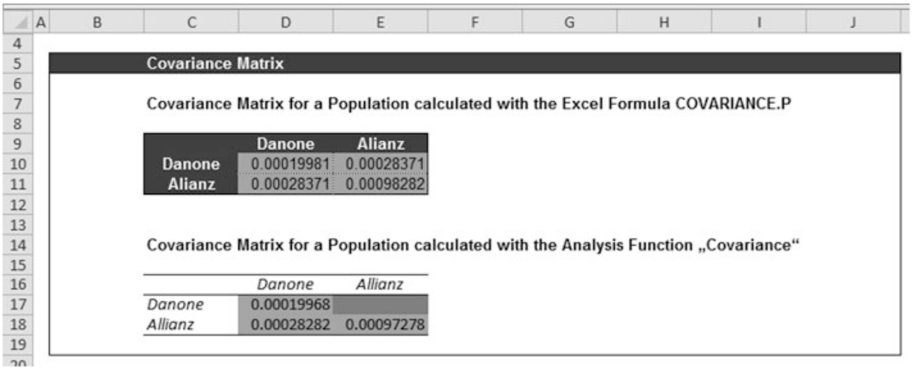


Fig. 12.67 Covariance matrix (Work File Portfolio Management, Worksheet Covariance_Matrix_(2))

data (prices or returns) do not automatically lead to an adjustment of the results of the covariance matrix.

The two covariance matrixes are displayed in Fig. 12.67.

5.10 Coefficient of Correlation

The coefficient of correlation measures the “strength” of a positive or negative linear relationship between two variables.

Due to differences in the return variation of the assets under consideration, the empirically observable covariances can take on very different dimensions. The covariance is therefore standardized with the help of the standard deviation – the measurement of individual variation – to arrive at the coefficient of correlation.

The coefficient of correlation is a standardized and dimensionless variable that can fall between –1 and +1. Positive values are indicative of a linear interrelationship that points in the same direction, while negative values indicate an opposing linear relationship. The closer the coefficient of correlation is to the value of one (minus one), the more direct (more opposing) is the relationship. As the coefficient of correlation approaches zero, the linear relationship becomes weaker.

It is calculated by dividing the covariance $_{i,j}$ between the returns of security i and the return of security j by the product of the standard deviation of Security return i and the standard deviation of security return j.

$$Corr\left[r_{i,j}\right] = \frac{Cov\left[r_{i,j}\right]}{S\left[r_i\right] \cdot S\left[r_j\right]} = \rho_{i,j} = \frac{\sigma_{i,j}}{\sigma_i \cdot \sigma_j}$$

with
$Corr\left[r_{i,j}\right]$ resp. $\rho_{i,j}$ = coefficient of correlation
$_{i,j}$ = covariance
$_i$ = standard deviation of the security return i
$_j$ = standard deviation of the security return j

> The lower the coefficient of correlation, the lower the portfolio risk.

The coefficient of correlation can either be applied to two securities or to an entire portfolio. The following statement holds: the lower the correlation of the different securities in a portfolio, the stronger is the diversification effect concerning the portfolio risk. A low coefficient of correlation thus increases the diversification effect in the portfolio.

The influence of various coefficients of correlation on portfolio risk is displayed in Fig. 12.68.

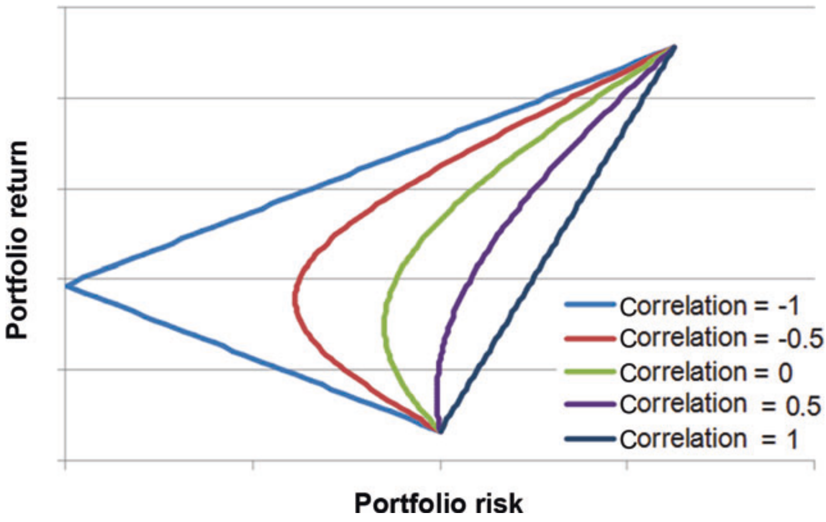


Fig. 12.68 Effects of different coefficients of correlation

Position	Formula	Excel implementation
Correlation Danone and Euro Stoxx 50 (=Correlation_Coeff._and_Beta_(2)!D8)	=Correlation(Return Danone 01.09.t_{-1} to 20.02.t_0 and return Euro Stoxx 50 01.09.t_{-1} to 20.02.t_0)	=CORREL('Correlation Co-eff. and Beta (1)'!C8:C137;'Correlation Coeff. and Beta (1)'!D8:D137)

Fig. 12.69 Calculating the coefficient of correlation

> The portfolio risk is zero in the case of a perfectly negative correlation of –1.

It can be seen in the figure that the portfolio risk can be reduced to zero in the case of a perfectly negative correlation of –1. If the correlation is 1, the combination of two securities does not yield any benefit. However, in the usual case of a correlation of less than one, spreading the invested capital among several investments reduces the portfolio risk (diversification effect).

In the Excel file, the coefficient of correlation is calculated in the worksheet `Correlation_Coeff._and_Beta_(2)` (see Figs. 12.69 and 12.70). In cell `D8`, the correlation between Danone and the Euro Stoxx 50 is calculated and in cell `D11` the correlation between Allianz and the Euro Stoxx 50 is determined (the lreturns,

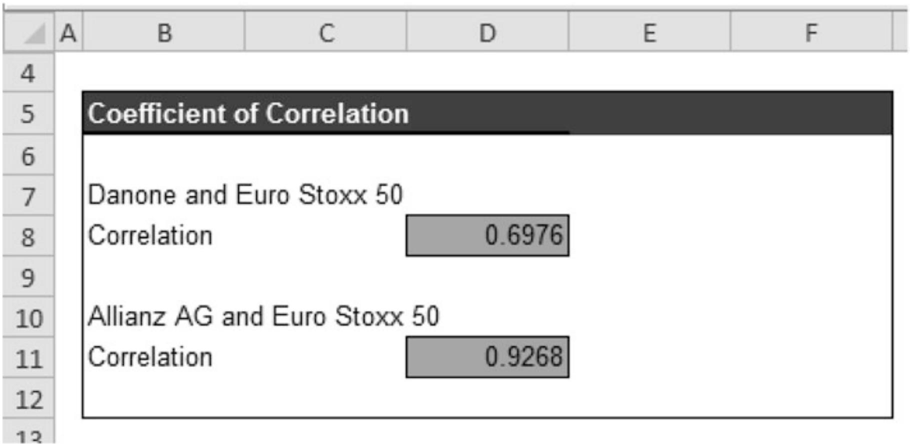


Fig. 12.70 Calculating the coefficient of correlation (Work File Portfolio Management, Worksheet Correlation_Coeff._and_Beta_(2))

which serve as the basis of the calculation, are calculated in the worksheet `Correlation_Coeff._and_Beta_(1)`.

5.11 Semi-variance

> Unlike measures of overall risk, semi-variance focuses only on the lower half of the distribution.

Since both variance and standard deviation are two-dimensional, respectively symmetrical risk measures, which consider both positive and negative deviations from the mean, they are not necessarily aligned with the interests of the providers of capital. For that reason, additional key figures for the assessment of risk need to be considered, which have an exclusive focus on negative deviations from the observed mean. Since this method only focuses on the left part of the probability distribution, these risk measures, which include semi-variance and value-at-risk are frequently called one-dimensional or downside risk measures. Under the assumption of the normal distribution, the semi-variance $\mathrm{SemiVar}[r]$ is equivalent to half of the variance of the underlying returns.

The formal definition of the semi-variance is as follows:

$$\mathrm{SemiVar}\,[r] = \frac{1}{n}\sum_{i=1}^{n}\left(r_i^{<m} - \mu\right)^2$$

with
SemiVar $[r]$ = semi-variance of returns
n = number of observations
$r_i^{<m}$ = returns that are lower than the mean
μ = expected value of the returns

Similar to the standard deviation, the semi-standard deviation SemiS $[r]$ is given as:

$$\mathrm{SemiS} = \sqrt{\frac{1}{\mathrm{n}}\sum_{\mathrm{i}=1}^{\mathrm{n}}\left(r_i^{<m} - \mu\right)^2}$$

with
SemiS $[r]$ = semi-standard deviation of returns

Even though the semi-variance has attributes which make it preferable to the variance, variance or standard deviation are frequently used as unified risk measures in applied work due to their easy implementation. In a symmetrical distribution (skewness = 0) an equivalent result is obtained.

In the Excel file both semi-variance and semi-standard deviation are calculated in the worksheets `Semi-Variance_(1) - (3)`. First the mean values of the daily returns of Euro Stoxx 50, Danone and Allianz are calculated with the Excel function *AVERAGE* in the worksheet `Semi-Variance_(1)` in cells `C138:E138`. Then the deviations of the daily returns from the mean are calculated in the worksheet `Semi-Variance_(2)`. Since only negative deviations are to be selected, the Excel function *IF* is used, which inserts "" for all positive values while keeping all negative values (see Figs. 12.71 and 12.72).

The formulas for the Euro Stoxx 50 are again used for Danone and Allianz. Once the deviations have been calculated, the negative values are squared (see Figs. 12.73 and 12.74).

The semi-variance of the population is calculated for the three investments in the cells `D10:F10` and the semi-standard deviation

Position	Formula	Excel implementation
Selection of the negative deviations of the daily returns from their mean value (`=Semi-Variance_(2)!B7`)	=If(Return 01.09.t$_1$-Mean>0; No entry; Return 01.09.t$_1$-Mean)	`=IF('Semi-Variance (1)'!C7-'Semi-Variance (1)'!$C$138>0;"";'Semi-Variance (1)'!C7-'Semi-Variance (1)'!$C$138)`

Fig. 12.71 Deviations of the log-returns from the mean

	A	B	C	D
4				
5		$(r_i^{<m}-\mu)$		
6		Euro Stoxx 50	Danone	Allianz
7			-0.0006	-0.0027
8		-0.0378	-0.0006	-0.0027
9		-0.0520	-0.0378	-0.0638
10		-0.0138		-0.0178

Fig. 12.72 Deviations of the returns from the mean (Work File Portfolio Management, Worksheet Semi-Variance_(2))

Position	Formula	Excel implementation
Squared negative deviations of the daily returns from their mean value (`=Semi-Variance_(2)!F7`)	=If(Return 01.09.t$_1$-Mean<0; (Return 01.09.t$_1$-Mean)^2; No entry)	`=IF(B7<0;B7^2;"")`

Fig. 12.73 Squared deviations of the returns from the mean

	E	F	G	H
4				
5	$(r_i^{<m}-\mu)^2$			
6	Euro Stoxx 50	Danone	Allianz	
7		0.0000%	0.0007%	
8	0.1425%	0.0000%	0.0007%	
9	0.2700%	0.1427%	0.4066%	
10	0.0190%		0.0316%	

Fig. 12.74 Squared deviations of the returns from the mean (Work File Portfolio Management, Worksheet Semi-Variance_(2))

Position	Formula	Excel implementation
Semi-variance Euro Stoxx 50 (`=Semi-Variance_(3)!D10`)	=Sum (squared negative deviations of the daily returns of the investments from their mean /number of observations)	`=SUM('Semi-Variance (2)'!F7:F136)/COUNT('Semi-Variance (2)'!F7:F136)`
Semi-standard deviation Euro Stoxx 50 (`=Semi-Variance_(3)!D18`)	=Square root (Sum (squared negative deviations of the daily returns of the investments from their mean /number of observations))	`=SQRT(SUM('Semi-Variance (2)'!F7:F136)/COUNT('Semi-Variance (2)'!F7:F136))`

Fig. 12.75 Calculating the semi-variance and the semi-standard deviation (Work File Portfolio Management, Worksheet Semi-Variance_(3))

Semi-variance

Calculating the Semi-Variance

	Euro Stoxx 50	Danone	Alianz
Based on the Population	0.000387	0.000195	0.000817

Semi-Standard Deviation

Calculating the Semi-Standard Deviation

	Euro Stoxx 50	Danone	Alianz
Based on the Population	0.019674	0.013966	0.028575

Fig. 12.76 Calculating semi-variance and semi-standard deviation

of the population is calculated in cells `D18:F18` in the worksheet `Semi-Variance_(3)` (see Figs. 12.75 and 12.76).

The results of the calculation of semi-variance and semi-standard deviation are:

5.12 Value at Risk

> Value at Risk (VaR) is a frequently utilized risk measure in applied work.

An additional and prominent one-sided risk measure is Value at Risk (VaR). This risk measure, just like probability of default, is among the downside risk measures. Value at Risk describes the possible loss of an investment within a predefined time period and for a given confidence level $(1-\alpha])$. Since this measure is expressed in monetary units, it can be interpreted quickly and is easily understood.

For a VaR of 5,000 €, a probability of 99% and a time period of one month, the loss threshold which cannot be crossed is 5,000 €. Put differently, in one percent of all cases, the loss threshold can exceed 5,000 €.

The formula for VaR is:

$$VaR = k \cdot \sigma_P \cdot \sqrt{T} \cdot \mathrm{P_T}$$

with
k = factor for the confidence level, k times the standard deviation
σ_P = standard deviation of the portfolio
T = time period for which the Value at Risk is to be calculated
P_T = portfolio value

An additional reason for the popularity of this number is the fact that it can be used to determine the risk capital which is required to hold the position. In addition, it is possible to make specific statements about the VaR as the variables *holding period* and *confidence level* are considered. The longer the holding period, in other words the period during which no purchases and sales take place, the more likely it is that there are major fluctuations and that a higher Value at Risk results. Enlarging the confidence level $(1-\alpha)$ automatically results in an increase in VaR and lower probability of error α. As can be seen in Fig. 12.77, an increase in the confidence level moves the Value at Risk further to the left. In other words, the Value at Risk becomes larger and this implies a reduction of the area α.

In the Excel example, the Value at Risk is calculated in the worksheet `Value_at_Risk` for four cases. Two cases have a confidence level of 99% and a time period of 20, respectively 30 days, while two cases have a confidence level of 95% and again a time period of 20, respectively 30 days.

The factor for the confidence level is calculated with the help of the formula *NORM.INV*. For a given probability it determines the

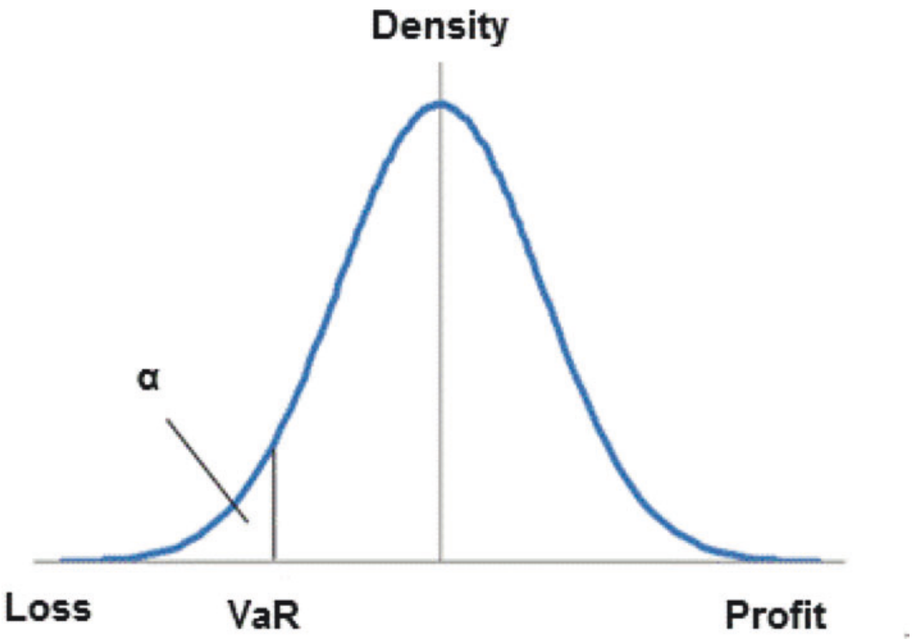


Fig. 12.77 Value at Risk

corresponding value of the standard normal distribution. The time factor is calculated in cell `F11`. The time factor scales the volatility to the given time period. When annualizing this figure, 250 working days at the stock exchange are used. For a chosen time period of 20 days, $T = 0.28$. The standard deviation for 20 days is equal to 0.28 times the annual standard deviation. In all four cases the portfolio value is 100,000.

The following Excel formulas are used (see Fig. 12.78):

The result of the calculation of the VaR with a confidence level of 95% and a period of 20 days is presented in Fig. 12.79:

With a probability of 95%, the maximum loss is € 14,939. Alternatively, the loss exceeds that value with a probability of 5%.

Position	Formula	Excel implementation
Factor for the confidence level (=Value_at_Risk!B12)	=NORM.INV(Probability ; Mean; Standard deviation)	=NORM.INV(B11;0;1)
Annualized volatility (=Value_at_Risk!C12)	=Daily volatility*Trading days per year	='Variance and Standard Dev. (2)'!D16*SQRT(Assumptions General!C207)
Time factor (=Value_at_Risk!D12)	=Square root(Given time period/ Trading days per year)	=SQRT(D11/Assumptions General!C207)
Value at Risk (=Value_at_Risk!F12)	= Factor for the confidence level *Annualized volatility *Time factor *Portfolio value	=B12*C12*D12*E12

Fig. 12.78 Value at Risk calculation

	A	B	C	D	E	F
7						
8		Value at Risk with Confidence Level of 95% and				
9		20 Day Calculation Period				
10		Confidence Level	Volatility	Time Factor in Days	Portfolio Value in Euro	Value at Risk in Euro
11		0.95	0.02032752	20		
12		1.64	32.14%	0.28	100,000	14,953

Fig. 12.79 Results of the Value at Risk calculation (Work File Portfolio Management, Worksheet Value_at_Risk)

5.13 Beta Factor

The beta factor describes the systematic risk associated with the investment (more general: market risk).

Among the risk measures that are neither one-sided nor two-sided are beta factor and tracking error. We will discuss these two measures in detail in the context of portfolio management.

The derivation of the beta factor is based on the Capital Asset Pricing Model (CAPM). It expresses the sensitivity of a security return relative to changes in the broad market return.

It can be estimated as follows:

$$\beta_i = \frac{Cov\left[r_i, r_m\right]}{Var\left[r_m\right]} = \frac{\sigma_{i,m}}{\sigma_m^2} = Corr\left[r_i, r_m\right] \cdot \frac{S_i}{S_m} = \rho_{i,m} \cdot \frac{\sigma_i}{\sigma_m}$$

with
β_i = beta factor
$\sigma_{i,m}$ = covariance
σ_m^2 = variance of the market
$\rho_{i,m}$ = coefficient of correlation
$S_{i,i}$ = standard deviation of the security
$S_{i,m}$ = standard deviation of the market

The covariance $\sigma_{i,m}$ is divided by the variance of the market σ_m^2 in order to determine the beta factor β_i. In addition, it is also possible to calculate the beta factor by dividing the standard deviation of security σ_i by the standard deviation of the market σ_m and multiplying with the coefficient of correlation $\rho_{i,m}$.

If the beta factor is greater than 1, the systematic risk exceeds that of the broad market. If the factor is less than 1, the systematic risk is lower than that of the broad market.

The beta factor can also be used for to assess the risk of the entire portfolio. In order to obtain the beta factor β_p of a portfolio, the beta factors of the individual securities β_i are weighted by their portfolio shares w_i and summed up.

$$\beta_p = \sum_{i=1}^{n} w_i \beta_i \; with \; \sum_{i=1}^{n} w_i = 1$$

with
w_i = share, respectively weight of the asset i in the portfolio
β_i = beta factor of the individual security

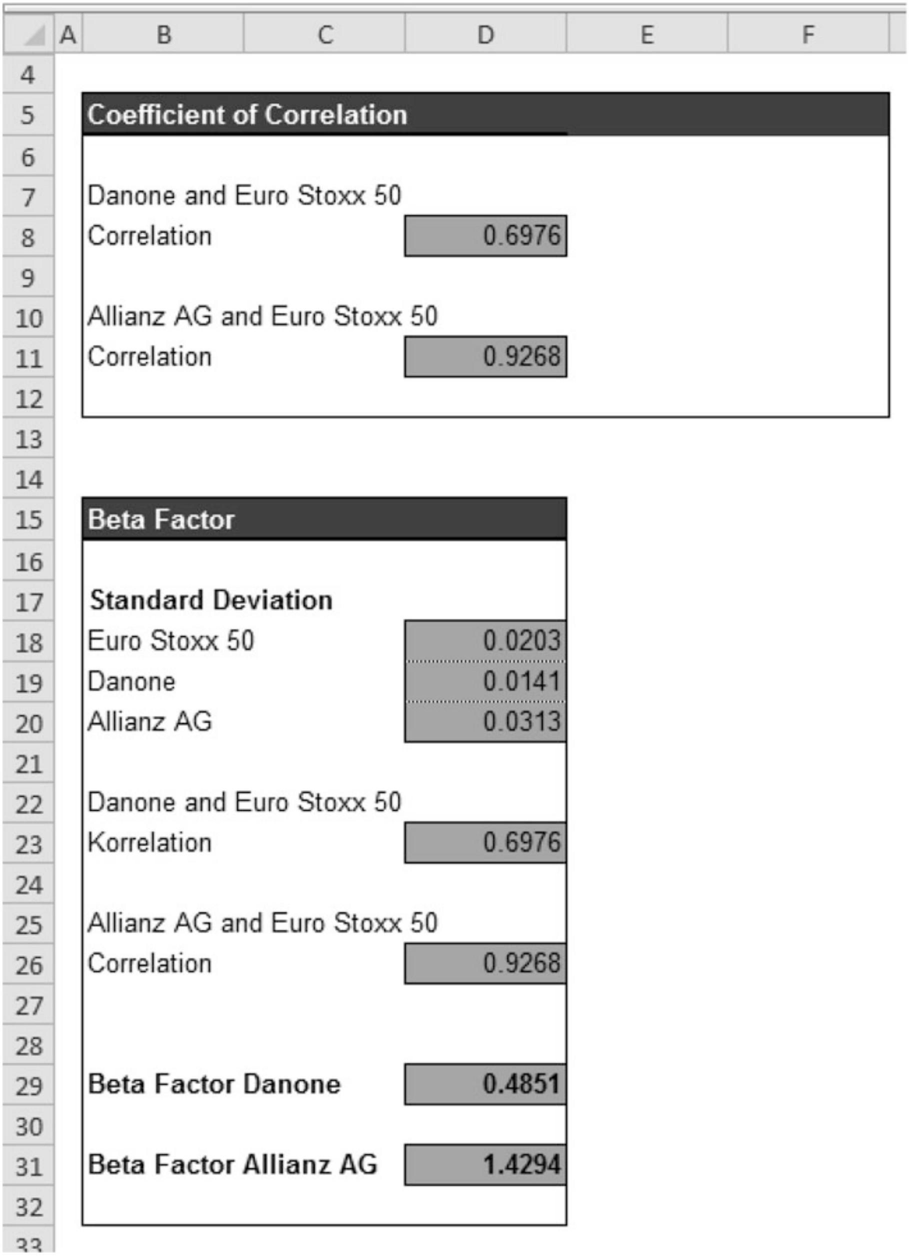
Position	Formula	Excel implementation
Standard deviation of Euro Stoxx 50 (=Correlation_Coeff._and_Beta_(2)!D18)	=Standard deviation of the population of returns 01.01.t_1 to 29.02.t_0	=STDEV.P('Correlation Coeff. and Beta (1)'!C8:C137)
Correlation Danone and Euro Stoxx 50 (=Correlation_Coeff._and_Beta_(2)!D8)	=Coefficient of correlation of the population of returns 01.01.t_1 to 29.02.t_0	=CORREL('Correlation Coeff. and Beta (1)'!C8:C137;'Correlation Coeff. and Beta (1)'!D8:D137)
Beta factor Danone (=Correlation_Coeff._and_Beta_(2)!D29)	=Coefficient of correlation *Standard deviation of return (Danone)/ Standard deviation of return (Euro Stoxx 50)	=D8*D19/D18

Fig. 12.80 Determining the beta factor

To determine the beta factor in the Excel example, it is initially required to calculate the standard deviation for the Euro Stoxx 50, Danone and Allianz in the cells D18:D20 as well as the correlation of Danone with the Euro Stoxx (in cells D23 respectively D8) and of Allianz with the Euro Stoxx (in cells D26 respectively D11) in the worksheet Correlation_Coeff._and_Beta_(2). Using these values, it is now possible to calculate the beta factor for Danone in cell D29 and the beta factor for Allianz in cell D31 (see Figs. 12.80 and 12.81).

Displayed in the two graphs in Fig. 12.82 are the daily returns of the investments as well as a trend line. As can be seen, the relationship between Allianz shares and Euro Stoxx is closer than the relationship between Danone shares and Euro Stoxx. This is also revealed by the coefficient of correlation (for Allianz 0.9278 and for Danone 0.6980). When looking at the beta factor, it becomes clear that the systematic risk of Allianz shares exceeds that of the Euro Stoxx (β = 1.4249), while the systematic risk of Danone shares is lower (β = 0.4856).

The trend line can be added with the help of the following function: ➲ *Chart Tools* ➲ *Layout* ➲ *Analysis* ➲ *Trend Line* ➲ *Linear Trend Line*. The functional form of this line can also be added via additional trend line options (*Show formula in diagram*).



Coefficient of Correlation		
Danone and Euro Stoxx 50		
Correlation		0.6976
Allianz AG and Euro Stoxx 50		
Correlation		0.9268

Beta Factor		
Standard Deviation		
Euro Stoxx 50		0.0203
Danone		0.0141
Allianz AG		0.0313
Danone and Euro Stoxx 50		
Korrelation		0.6976
Allianz AG and Euro Stoxx 50		
Correlation		0.9268
Beta Factor Danone		**0.4851**
Beta Factor Allianz AG		**1.4294**

Fig. 12.81 Determining the beta factor (Work File Portfolio Management, Worksheet Correlation_Coeff._and_Beta_(2))

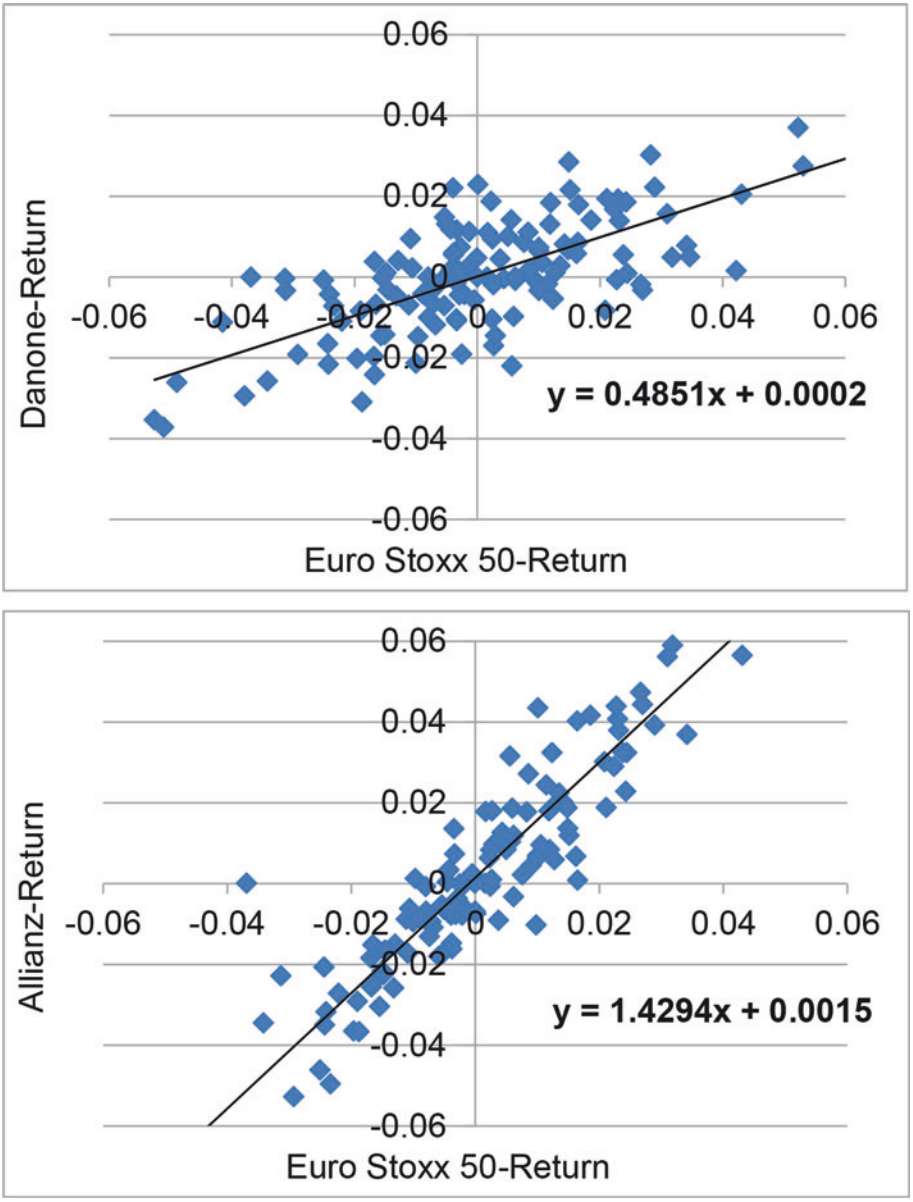


Fig. 12.82 Relationship of two securities with the market (Work File Portfolio Management, Worksheet Correlation_Coeff._and_Beta_(2))

6 Summary

In this chapter the financial modeler gained the following insights:

Portfolio Management

- A portfolio is an accounting device which collects capital investments or assets of a person, a household or an institution with the aim of compiling, presenting and controlling financial portfolio attributes such as value, liquidity, receivables and liabilities.
- The portfolio serves as the foundation for the calculations which determine criteria such as return and investment risk.
- Portfolio management means assembling, controlling and adjusting portfolios. These activities refer both to portfolios as well as the most important portfolio characteristics such as return, value preservation and liquidity.
- Portfolio management takes place in the context of asset management for private customers, as institutional fund management and as proprietary business of banks and financial service providers.
- Portfolio management can be separated into active and passive portfolio management.

Return

- The term return describes the income relative to the invested capital received over a specified time period. It is either stated as a decimal number or more frequently as a percentage value.
- Returns can be calculated either as discrete or as continuous returns.
- The discrete return considers two specific points in time (time the investment was made and end of the investment period) respectively several specific points in time within an investment period.
- Among the discrete returns are the simple average return, the arithmetic average return, the time-weighted average return and the money-weighted average return.
- For the calculation of the simple average return, only the points in time at the beginning and the end of the specified term of the portfolio are considered.

- The calculation of the arithmetic average return is used if it can be assumed that the overall return can be determined from the returns in the individual sub-periods.
- The time-weighted average return, also called geometric average period return, is also calculated as an overall return from the returns in the various sub-periods. It can be considered as a growth rate of the investment amount over the investment period.
- The money-weighted return is used in cases when money flows into or out of the portfolio during the investment period. For this method, the return is weighted with the capital inflows and outflows during the periods under review.
- In the case of a continuous return it is assumed that the investment capital receives interest continuously.
- Returns for time periods of less than one year are usually annualized in order to achieve comparability.

Risk

- The term risk in portfolio management describes the danger that prices of investment vehicles fluctuate and the possibility that an investor will suffer losses, which can be substantial.
- Portfolio management mostly deals with quantitative risks.
- A distinction is made between one-sided, two-sided and other risk measures.
- As the name implies, two-sided risk measures consider both sides of the return distribution when determining risk. Two-sided risk measures consider both deviations to the right of the expected value (upside risk), as well as deviations to the left of the expected value (downside risk).
- One-sided risk measures only look at the left side of the return distribution in their assessment of risk. Thus the one-sided risk measures only deal with possible losses in capital markets.
- In addition to the one-sided and two-sided risk measures, other measures also exist, which due to the underlying statistical concepts cannot be clearly assigned to one of the previously discussed categories.
- A random walk is a price movement where future changes or directions cannot be forecasted on the basis of past information. If the

expression is used in the context of capital markets, it means that short-term price changes of assets cannot be predicted reliably.

- A random walk can be simulated with the help of a random number generator in Excel.
- Volatility means the dispersion of price changes of securities and portfolios.
- The total return of an investment is based on three components: the length of the investment period, the estimated or expected return and a sum of random effects captured by the residuals ε_t, which show the deviations from the expected value over time.
- The distribution of a sum of random numbers converges approximately towards the normal distribution.
- Volatility describes the dispersion of price changes of securities or portfolios and is calculated as annualized standard deviation.
- Variance is defined as the mean of the sum of squared deviations from the expected value.
- The standard deviation is the average distance of all measured observations from the mean and is equal to the square root of the variance.
- Risks for periods of less than one year are normally annualized to achieve comparability.
- Covariance is calculated as the average of the products of the deviations of two series from their expected value. It describes the degree of co-movement of two series around their individual expected value.
- The coefficient of correlation is a standardized and dimensionless measure, which is limited to a value range between –1 and +1.
- The portfolio risk is equal to a weighted sum of the individual risks plus the risks that are attributable to the mutual correlations.
- Unlike the measures of overall risk, semi-variance only focuses on the lower half of a distribution.
- The beta factor describes the systematic risk (called market risk) of the investment.

Another very popular one-sided risk measure is Value at Risk (VaR). This risk measure, just like the probability of default, is among the downside risks. Value at Risk describes the possible loss from an investment during a defined period of time for a given confidence level *(1–α)*. Since this figure is expressed in monetary units, it is easily interpreted and understood.

Notes

1. Markowitz 2008, p. 2.
2. The calculations for the following expositions are always based on the population, since a number of Excel analysis functions refer exclusively to the population. If smaller data sets are used, which are frequently found in applied work, we recommend that you base your calculations on samples.

Literature and Suggestions for Further Reading

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13
Portfolio Management

1 Executive Summary

In this chapter, the financial modeler is given the task to invest a portion of the excess liquidity of Pharma Group and to utilize the techniques of modern portfolio management. The key variables in his portfolio management decisions are the return of the assets and the structure of the corresponding risks. The financial modeler is aware of the fact that the return and risk of individual assets is determined in the financial markets, but that portfolio management, via the concrete combination of the assets, determines the return and risk attributes of the individual portfolio.

In the context of portfolio management, the financial modeler aims to obtain a desired return expectation with minimum risk or to maximize the return for a given level of risk. To reach this goal, he can either pursue active or passive portfolio management.

The aim of active portfolio management is to exceed the return of a given benchmark with the help of specific investment decisions. To accomplish this task, the financial modeler picks the appropriate securities ("selection") or the right moment ("timing").

Passive portfolio management is based on the assumption of sufficiently high market efficiency, which implies that active portfolio management cannot beat the relevant market and therefore passive

J. Häcker and D. Ernst, *Financial Modeling*,
Global Financial Markets, DOI 10.1057/978-1-137-42658-1_13

portfolio management provides the appropriate solution. The implementation of passive investment strategies in portfolio management involves the construction of a tracking portfolio, which continuously reproduces an underlying benchmark.

In order to decide between active and passive portfolio management, the financial modeler initially needs to ascertain whether the relevant methods of active or passive portfolio management can be implemented in Excel. He initially models various approaches for the calculation of returns and risks as well as the portfolio optimization in the context of active and passive portfolio management. In addition to the technical implementation of the necessary portfolio management instruments, it is also an important consideration for Pharma Group whether the personnel resources and the risk management tools needed for the task of active portfolio management are available.

2 Introduction, Structure, Learning Outcomes and Case Study

Structure

The chapter Portfolio Management Part II serves as an introduction to portfolio management and answers the following questions:

- What is meant by active and passive portfolio management?
- How are portfolios optimized in active and passive portfolio management?
- What methods are used in active and passive portfolio management and how are they implemented in Excel?
- Which mathematical and statistical basics are needed for portfolio optimization?
- How can the Solver be used efficiently in the portfolio optimization process?

Learning outcomes

The chapter Portfolio Management Part II teaches the Excel-based application of portfolio theory and capital market theory. This enables the user and financial modeler to

- describe differences between active and passive portfolio management and to relate them to the assumption of complete capital markets,
- conduct portfolio optimization with the help of the Solver,
- conduct complex optimizations in such a way that they conform to the principles of professional financial modeling.

Case Study

The financial models for portfolio management are available in the download section of the Excel file Portfolio Management. Use the contents of the download offering as you work with the text. The individual steps are broken down into small units on separate worksheets:

- All calculations are done directly in Excel, in order to allow traceability of the calculations.
- All optimizations in portfolio management require the Solver. Make sure that the required add-in Solver is installed and activated in Excel. The necessary steps are explained in the text.
- A deep understanding of VBA is not needed for this chapter. It is merely demonstrated how the optimization can be conducted economically with the help of the macro recorder.

The chapter portfolio management is structured as follows and based on the principles of financial modeling:

- The Excel file has 53 worksheets.
- All input data is marked in the color orange. These are values which are assumed and determined individually by the valuation expert.
- All calculations and output data are marked in the color gray. These are values which result from calculations.
- Mixed formulas that contain both numerical values and cell references utilize a green font.
- The worksheet marked in the color dark blue contains a summary of the chapter on portfolio management in the form of a management summary.

- The worksheets marked in the color yellow contain the data for the case study.
- Return calculations take place in the worksheets marked in the color light brown. A difference is made between discrete and continuous return.
- The worksheets marked in the color red explain how risks are calculated. A fundamental distinction is made between one-sided, two-sided and other risk measures.
- The calculations concerning active portfolio management are found in the worksheets marked in the color green. Active portfolio management utilizes absolute and relative optimization.
- The final section on passive portfolio management follows in the worksheets marked in the color light blue. A distinction is made between quadratic optimization, regression analysis with constraints and linear optimization.

3 Overview of Active and Passive Portfolio Management

3.1 Introduction to the Topic

Active and passive management are the two possibilities to optimize portfolios. Among these two fundamental choices, different approaches can be distinguished.

> The aim of active portfolio managements is the generation of an optimal allocation of wealth or to achieve an outperformance relative to a benchmark index.

It is the fundamental aim of portfolio management to generate an optimal allocation of wealth (absolute optimization). Important factors to consider include the time horizon as well as the forecasts of return and risk parameters.

If an index serves as approximation for a typical allocation, active portfolio management aims at beating that benchmark. This requires an ability to forecast returns and risks over shorter time periods with a precision that is sufficient to cover the costs of information generation. The aim of active portfolio management is the systematic selection and weighting of securities (stock picking) in order to achieve an outperformance relative to the previously defined benchmark portfolio (relative optimization).

> The aim of a passive portfolio is the replication of a reference index.

Passive portfolio management assumes that short-term forecasting concerning future returns and risks is not possible or is of insufficient quality to compensate for the corresponding costs. This is based on the premise of efficient capital markets, which cannot be beat. The aim of passive portfolio management is therefore the precise and cost-effective replication of a previously defined benchmark. In most cases, the benchmark index is formed based on the current market weight of the securities, since efficient markets imply efficient prices.

However, it is frequently not possible for cost reasons to precisely replicate comprehensive market indexes. An additional problem follows from the fact that securities are not divisible, which rules out an exact index replication. Therefore it is attempted in applied work to replicate the benchmark index as closely as possible or to invest in only a part of the securities in such a way that the overall portfolio has a similar development and identical key figures as the benchmark. A frequently made error is to think that this is equivalent to a pure buy-and-hold strategy. However, due to the fact that the composition of the benchmark can change or that dividends need to be reinvested, passive management also involves buying and selling of securities.

The relationship between active and passive portfolio management can be described with the following equation in line with the Capital Asset Pricing Model (CAPM):

$$\begin{aligned}\text{Overall return} &= (\text{Expected return}) + \text{Alpha}\\ &= \underbrace{\underbrace{(\text{Risk-free rate} + \text{Risk premium})}_{\text{passive}} + \text{Alpha}}_{\text{active}}\end{aligned}$$

The aim of passive portfolio managers is to obtain the risk-free rate plus a risk premium, where the return should be equal to the return of the benchmark.x Active managers attempt to outperform the market return and to achieve a return that exceeds the risk-adjusted expected return of the market or of the benchmark used as comparison. The difference between active portfolio management and passive portfolio management is called "alpha." Alpha can be used both ex-post and ex-ante. Alpha ex-ante is of uncertain magnitude (random variable). Alpha ex-post shows the (positive or negative) realization over a historic time period. In this case, the risk that is necessarily associated with the attempt of outperforming the market must be considered as well.

Before getting started with the approaches of active and passive portfolio management, we need a few Excel skills which facilitate the optimization of portfolios. The following topics will be considered in more detail:

- Solving of optimization problems with the Excel Solver
- Matrix calculations in Excel

3.2 Solving Optimization Problems with the Excel Solver

> The Excel Solver is the most important instrument to solve optimization problems.

The Excel Solver is an add-in for Microsoft Excel. It can be installed separately and provides several algorithms which help to solve complex mathematical optimization problems in Microsoft Excel. The add-in Solver basically belongs to a set of commands which can generally be considered as "What-If-Analysis-Tools". Portfolio management is only one possible practical application for the Solver. Optimization problems are also common in other issues in finance, in corporate production planning, or to solve complex logistical distribution issues.

In general, optimization can be described as a process where among a large volume of computed numbers, always those numbers are chosen which reach a previously defined goal, either as a minimum or a maximum. This process initially requires the identification and formulation of the optimization problem, which then needs to be written down in the form of a model. This is frequently called modeling an optimization problem.

In order to achieve a solution for the optimization problem with the help of various standardized algorithms, every optimization model always has a unified structure. For that reason, the optimization model consists of three components:

- The objective cell,
- The variable cells and
- The binding constraints.

3.2.1 Installing the Solver

An add-in is needed to activate the Excel Solver.

Initially it must be assured that the required add-in Solver is installed in Excel and activated. The following steps are required:

1. Click on ➲ *File* in the upper left corner of the screen and go to ➲ *Options*.
2. Click on the left side of the screen on the tab with the item ➲ *Add-Ins* and next choose ➲ *Manage* and select the item ➲ *Excel Add-Ins*. Confirm by clicking ➲ *Go*.
3. An overview with the currently available add-ins is opening up. To install the Solver, place a checkmark next to ➲ *Solver* and confirm with ➲ *OK*.

SUGGESTION: If you have activated the tab ➲ *Developer* in the ribbon, you can also access the developer tools by following ➲ *Add-Ins* ➲ *Add-Ins.* This will also take you to the list of available and installed add-ins. Figure 13.1 gives a detailed overview on how to install the Solver.

For other product versions of Microsoft Office, the basic steps for installing the Solver are similar.

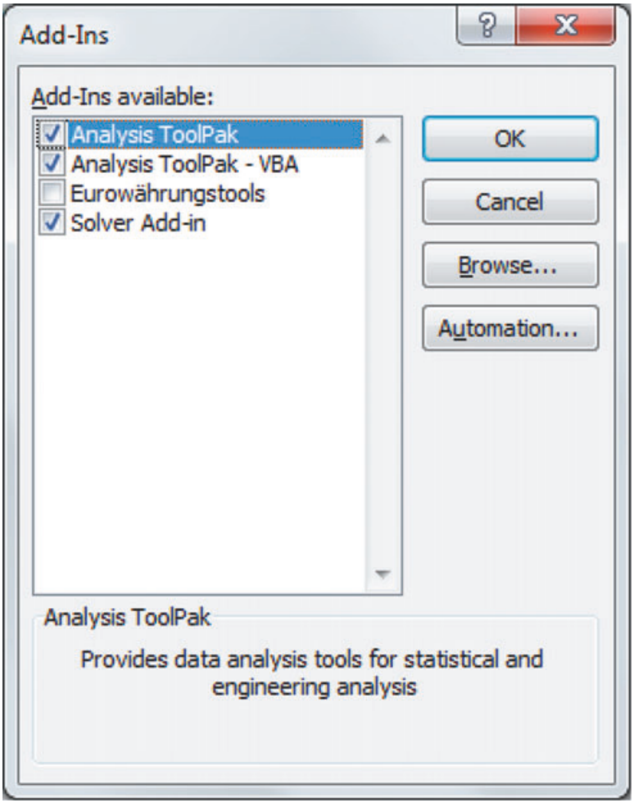


Fig. 13.1 Installing the Excel add-in Solver

3.2.2 Activating and Using the Solver

Before the Solver is used, it is preferable if the optimization problem has already been formulated in the form of a mathematical optimization which defines and clearly distinguishes all necessary decision variables, constraints and objective functions. Using all underlying formal criteria, this optimization model is then implemented in Excel. As a rule of thumb it is advisable that the Excel model should be completed prior to utilizing the Excel add-in.

The Solver can be opened in the ribbon via the tab ➲ *Data* in the area ➲ *Analysis* and the button ➲ *Solver*. Once the Excel add-in Solver has been opened successfully, an overview appears, which shows the Solver parameters that still need to be defined. The setup of the dialogue box of the Excel add-in Solver in Fig. 13.2 is mainly based on the

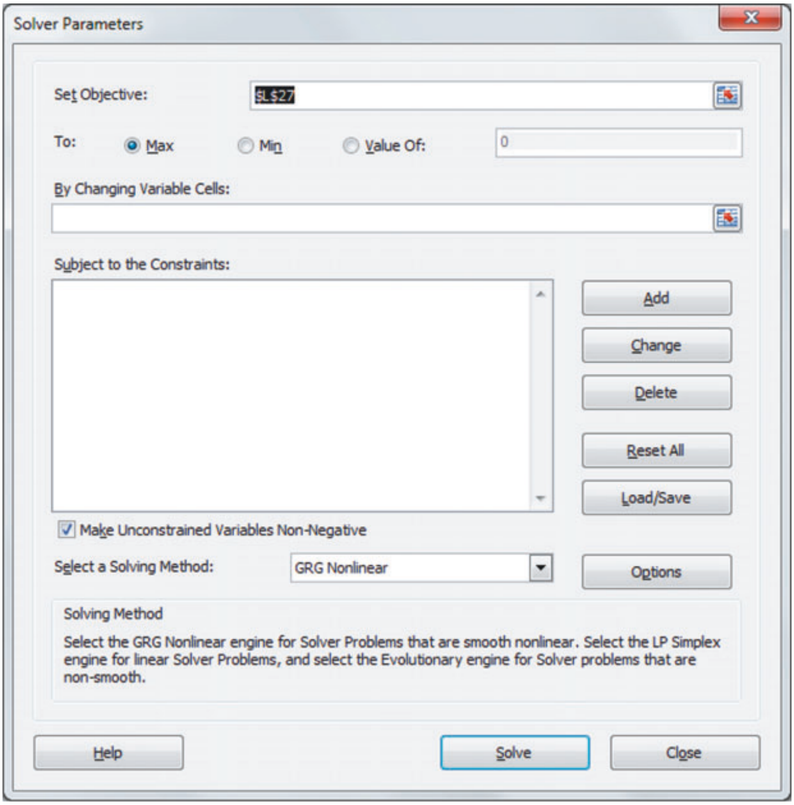


Fig. 13.2 The Excel add-in Solver

three previously defined components of the optimization exercise: the objective function, the variable cells and the consideration of possible constraints.

Once the dialogue box for the Solver parameters has been opened, all necessary inputs can be determined manually step by step.

1. In the input field *"Set Objective"* the objective function to be optimized is entered. This references a previously defined objective function in a single cell of the Excel model.
2. In the field *"To"* the required criterion for the optimization can be selected. Depending on the type of optimization, maximize, minimize or a precise value for the objective function can be selected.
3. Next the variable cells that can be changed are selected and an unambiguous cell reference to one or more cells is specified.

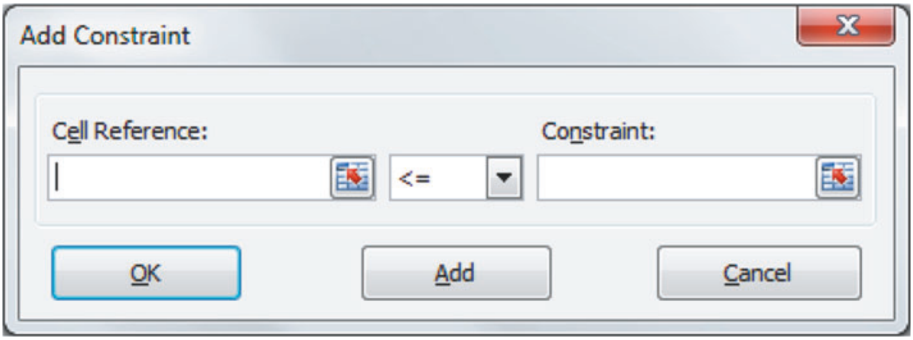


Fig. 13.3 Adding a constraint

4. If the optimization is subject to one or more constraints, these can be included in the form of logical equalities or inequalities via the button ➲ *Add*. A new window opens up (see Fig. 13.3), which allows the logical link of cell references.
5. Depending on the type of the underlying optimization, a suitable algorithm should be selected in the field ➲ *Solving Method*. To solve linear optimization problems, the ➲ *Simplex Procedure* is available. If instead a quadratic optimization problem needs to be solved, the suggested solution involves the use of the gradient method ➲ *GRG Nonlinear*.
6. Clicking the button ➲ *Solve* starts the Excel add-in Solver.

The menu of available options for the Excel add-in Solver can be activated by clicking ➲ *Options* and allows for additional individual settings concerning the algorithm used to solve the problem. This includes the setting of an appropriate termination criterion, the maximum time allowed, number of iterations, precision, tolerance and rate of convergence of the algorithm selected. Depending on the complexity of the optimization problem that needs to be solved, an adjustment of these parameters appears warranted, even though the standard settings should be sufficient for most portfolio management applications.

3.3 Matrix Operations in Excel

Matrix operations are the most important mathematical tool in portfolio management.

Since some of you may not have worked with vectors and matrix operations for a while, we want to briefly review basics of vector and matrix operations as far as they are relevant for an understanding of the calculations in this volume. Here is the good news: Excel provides superb support concerning vector and matrix operations so that the topic is completely manageable.

Even though Microsoft Excel offers the simple processing of vector and matrix operations, in the following sections the users are provided with a few detailed and specific points of reference to guarantee the efficiency of their work with vectors and matrices.

The use of so-called array formulas in Excel is an absolute necessity when implementing portfolio management processes. The term array originates from the field of programming and in general stands for a collection of elements. Thus an array in its various forms can best be compared to a vector or a matrix. A one-dimensional horizontal array corresponds to a row vector, a one-dimensional vertical array corresponds to a column vector and a two-dimensional array corresponds to a matrix. Depending on the size and dimension of the rows and columns, two basic types of arrays can be distinguished:

- the single cell array formula and
- the multi-cell array formula.

When processing vectors and matrices it should be kept in mind that an array formula can provide more than one result as an output. In addition to the continuous and consistent processing of the data, working with array formulas offers the advantage that the number of steps needed in a calculation can be reduced drastically.

The user already needs to select and mark the target area prior to the processing of vectors and matrices. This requires advance knowledge of the size of the output field. In case of an insufficient selection of the target area, Excel does not provide an error, but an incomplete result.

The array formula is entered by pressing CTRL + SHIFT + Enter.

Once an array formula has been entered by using the combination CTRL + SHIFT + Enter, the contents of this array formula cannot be changed immediately. Instead the command needs to be completely using the DEL key and the changed version must be reentered afterwards. Excel automatically adds unique curly braces {} to the formula and thus assures that array formulas can be distinguished from standard Excel formulas.

The following examples can be found in the worksheet `Matrix_Operations`.

3.3.1 General Display in Excel

As can be seen in Fig. 13.4, each cell represents a single element of a vector or a matrix. Depending on the ordering of the elements within a row or column a row or column vector is created. If the elements are ordered in a rectangle or in a square, an M x N matrix is created.

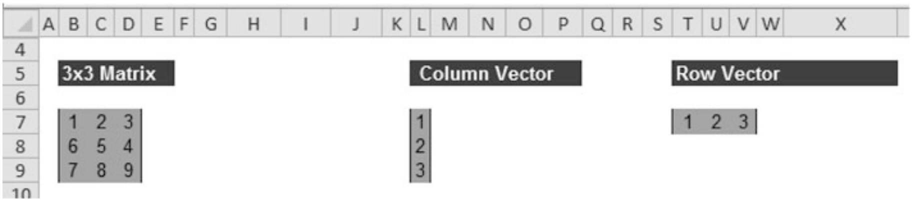


Fig. 13.4 Display and use of matrices in Excel (Work File Portfolio Management, Worksheet Matrix_Operations)

3.3.2 Transposing Vectors and Matrices in Excel

When transposing a vector or matrix, the function *TRANSPOSE()* is used. Since this is an array formula, the following rules for the data input must be followed. If, for example, a column vector is to be transposed, the following steps are needed (see Figs 13.5 and 13.6).

1. Determining the size of the target vector or matrix and marking the cell range.
2. Entering the formula: =*TRANSPOSE*(original vector)
3. Completing the data entry with CTRL + SHIFT + Enter.

The structure represents the general approach for transposing vectors and matrices, but it needs to be kept in mind that the initially

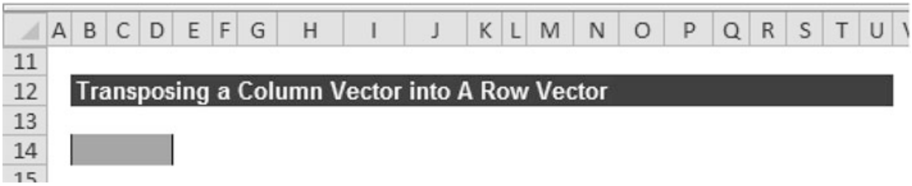


Fig. 13.5 Selecting the results cell (Work File Portfolio Management, Worksheet Matrix_Operations)

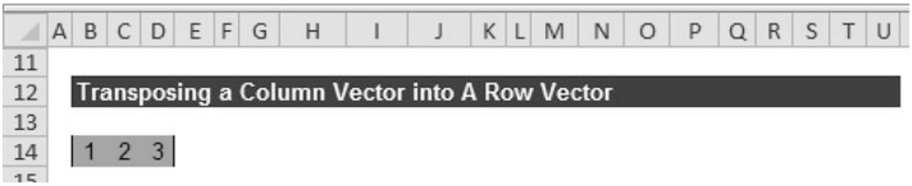


Fig. 13.6 Result (Work File Portfolio Management, Worksheet Matrix_Operations)

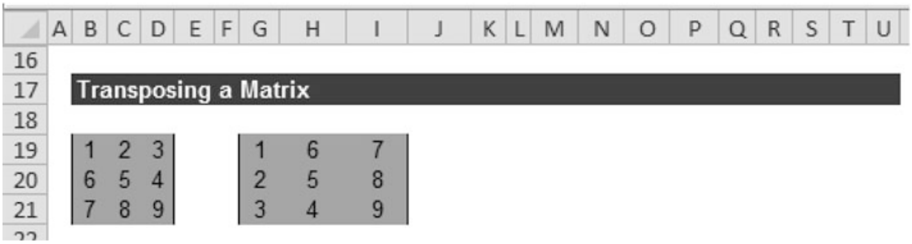


Fig. 13.7 Transposing matrices (Work File Portfolio Management, Worksheet Matrix_Operations)

selected and marked area is now equivalent to that of a column vector or a matrix. Figure 13.7 shows the result of a transposed matrix.

3.3.3 Multiplying Matrices and Vectors in Excel

> The multiplication of matrices and vectors is easily accomplished in Excel.

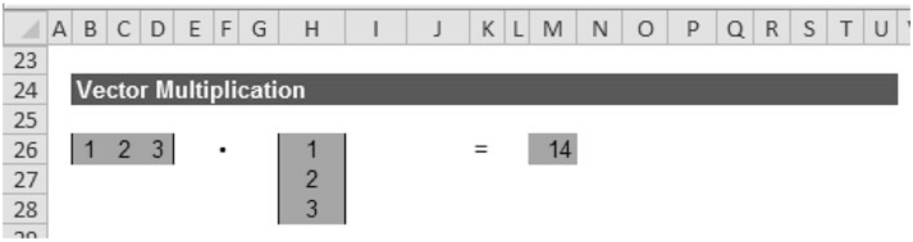


Fig. 13.8 Multiplication of vectors (Work File Portfolio Management, Worksheet Matrix_Operations)

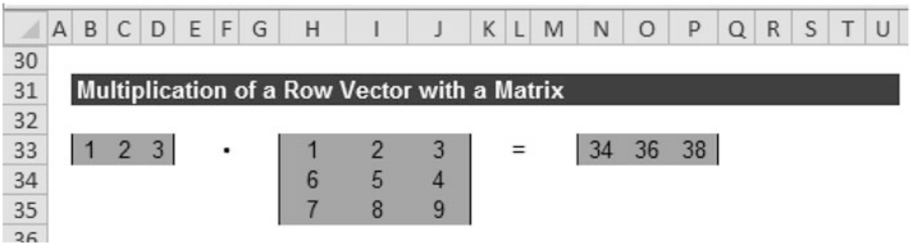


Fig. 13.9 Multiplication of a row vector with a matrix (Work File Portfolio Management, Worksheet Matrix_Operations)

The multiplication of matrices and vectors is an important foundation for an understanding of portfolio models. In the following, the multiplication of vectors is described in order to discuss the various possibilities of matrix multiplication. Here we will again utilize the array formulas mentioned in the previous section.

For the multiplication of a matrix or a vector we use the formula

- *MMULT ()*.

Methodology: (see Fig. 13.8)

1. Determination of the size of the resulting vector or matrix. The attributes of a vector or matrix need to be considered in this step.
2. Selection and marking of the resulting matrix.
3. Entry of the formula such as *MMULT* (Matrix/Vector 1; Matrix/Vector 2)
4. Confirming the input of the formula with CTRL + SHIFT + Enter.

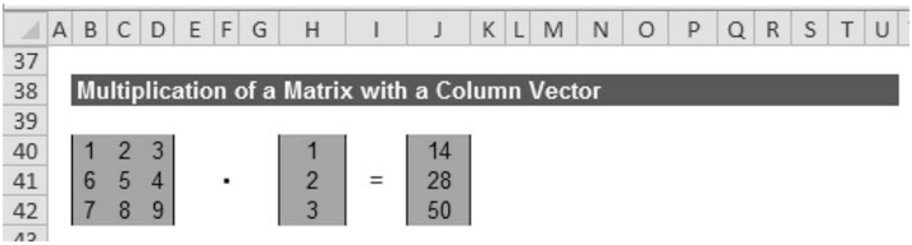


Fig. 13.10 Multiplication of a matrix with a column vector (Work File Portfolio Management, Worksheet Matrix_Operations)

This task would be solved as follows with a calculator: $1 * 1 + 2 * 2 + 3 * 3 = 14$

Both the multiplication of a matrix with a column vector and the multiplication of a row vector with a matrix are done in similar fashion. Figures 13.9 and 13.10 show the practical implementation in Microsoft Excel.

This task would be solved as follows with a calculator: $1 * 1 + 2 * 6 + 3 * 7 = 34; 1 * 2 + 2 * 5 + 3 * 8 = 36; 1 * 3 + 2 * 4 + 3 * 9 = 38$

This task would be solved as follows with a calculator: $1 * 1 + 2 * 2 + 3 * 3 = 14; 6 * 1 + 5 * 2 + 4 * 3 = 28; 7 * 1 + 8 * 2 + 9 * 3 = 50$

4 Active Portfolio Management

> Absolute optimization aims at generating an optimal asset allocation.

Two approaches can be distinguished in active portfolio management:

- absolute optimization and
- relative optimization.

In the context of absolute optimization, an optimal asset allocation is targeted for a predetermined set of potentially investable assets. The aim of absolute optimization is to obtain the best possible return for a given portfolio risk. A comparison with the reference market can be used to assess the investment success.

Relative optimization aims at exceeding a concrete benchmark.

Relative Optimization directly considers the allocation of the benchmark in the objective function. The aim of beating the benchmark is made more difficult by the fact that compared to a passive strategy, higher management and transaction costs are accumulated. It is also possible that the portfolio manager selects securities or sectors with high individual risk. This higher risk also needs to be compensated.

4.1 Absolute Optimization

There are several ways of absolute optimization of a portfolio. In preparation, the input data, namely the monthly returns of the various securities (in cells `C8:J117`) and the monthly returns of the benchmark in Column `K` (in cells `K8:K117`) are calculated in the Excel file in the worksheet `Absolute_Opt._(1).`

The monthly returns of the benchmark World are calculated from the monthly returns of the eight different investments. It is assumed that all securities are equally weighted (input of the weights in cells `C221:C228` in the worksheet `Assumptions_General`). It would also be possible to choose any other weight.

The monthly return of the benchmark World is calculated using matrix multiplication (*MMULT*) (see Fig. 13.11). The monthly returns are multiplied by the weights of the individual assets. This is an array formula and Excel automatically adds curly braces once the command is completed via the key combination CTRL + SHIFT + Enter.

Next, the following variables are calculated in the worksheet `Absolute_Opt._2):`

- The mean values of the historic returns (arithmetic average return) of the assets (cells `D12-L12`);
- The historic standard deviation (cell `D13-L13`);

Position	Formula	Excel implementation
Monthly returns of the benchmark World (`=Absolute_Opt._(1)!K8`)	=MMULT(Monthly returns; Initial weights)	`{=MMULT(C8:J8;Assumptions_General!$C$221:$C$228)}`

Fig. 13.11 Calculating the monthly returns of the benchmark World

Position	Formula	Excel implementation
Expected returns of the individual assets (=Absolute_Opt._(2)!D45:D52)	=TRANSPOSE(historic return)	{=TRANSPOSE(D12:K12)}

Fig. 13.12 Calculating the expected returns of the individual assets

- The covariance matrix both with the Excel function *COVARIANCE.P* (cells D19:K26) as well as with the analysis function "Covariance" (cells D32:K39);
- The expected returns of the individual assets (cells D45:52).

The expected return is calculated with the Excel function *TRANSPOSE* (see Fig. 13.12). This function returns the horizontal cell area as a vertical area. Since this is also an array formula, curly braces are automatically added once the command is completed via the key combination CTRL + SHIFT + Enter.

Now all preparatory steps have been completed and the absolute optimization in the context of active management can begin. The following approaches will be analyzed in more detail:

- Minimum variance portfolio
- Minimum variance portfolio without restrictions on short selling
- Minimum variance portfolio with lower and upper bounds
- Tangency portfolio
- Maximum return portfolio
- Efficient portfolio for given return
- Optimum portfolio without risk-free investment opportunity
- Optimum portfolio with risk-free investment opportunity

4.1.1 Minimum Variance Portfolio

> The portfolio risk is minimized in the minimum variance portfolio.

The minimum variance approach follows from the portfolio theory of MARKOWITZ. It utilizes the fact that the portfolio risk can be lower than, and not equal to the sum of the individual values. In portfolio theory, a portfolio is considered efficient if it produces the lowest risk for an expected portfolio return. The future risk, which needs to be calculated, is derived from the fluctuations of the historic return from which the expected variance is obtained.

The objective function for the minimum variance portfolio is[1]:

$$f(w_1, \ldots, w_n) = \sigma_P^2 = \sum_{i=1}^{n} \sum_{j=1}^{n} w_i \cdot w_j \cdot \sigma_{i,j} \rightarrow min!$$

In matrix notation:

$$f(w) = \sigma_P^2 = w^T \cdot V \cdot w \rightarrow min!$$

The following binding constraints are assumed for the determination of the minimum variance portfolio:

- Budget restriction: $\sum_{i=1}^{n} w = 1$ resp. $1^T \cdot w = 1$
- Non-negativity constraint, no short selling:

$$w_i \geq 0, \text{for all } \mathrm{i} = 1, \ldots \mathrm{n}$$

Initially the weights of the assets in the starting portfolio are entered in the worksheet `Absolute_Opt._(3)` in cells `E12:E19`. The values which appear in the worksheet `Absolute_Opt._(3)` in the cells `F12:F19` are the values after the portfolio has been optimized. Prior to the optimization, the weights of the starting portfolio are used, which are replaced with the optimum weights during the process of portfolio optimization.

Additional calculations yield the portfolio return in cell `F22`, the portfolio variance in cell `F23` and the portfolio standard deviation in cell `F24`. The portfolio variance is the objective function which is calculated in cell `F26`. These are the formulas (see Fig. 13.13):

The portfolio return and the variance are calculated with the matrix multiplication *MMULT*. For the return, the transposed weights are multiplied with the expected returns. Since the formula *MMULT* only works for two arrays, the calculation of the variance requires the nesting of that command, so that two matrix multiplications are conducted. Also the ordering must be kept. Therefore the initial multiplication involves the transposed weights and the variance-covariance matrix (inner multiplication). This result is multiplied in turn with the matrix of weights (outer multiplication). Array formulas are put in curly braces ({}) and the command is entered via the key combination CTRL + SHIFT + Enter.

Position	Formula	Excel implementation
Objective function (=Absolute_Opt._(3)!F26)	{=MMULT(MMULT(TRANSPOSE(Colum vector of the portfolio weights); Covariances; Column vector of the portfolio weights)	{=MMULT(MMULT(TRANSPOSE($F$12:$F$19);'Absolute Opt. (2)'!$D$19:$K$26);$F$12:$F$19)}
Portfolio return (=Absolute_Opt._(3)!F22)	{=MMULT(TRANSPOSE(Column vector of the portfolio weights); Expected return}	{=MMULT(TRANSPOSE(F12:F19);'Absolute Opt. (2)'!D45:D52)}
Portfolio variance (=Absolute_Opt._(3)!F23)	{=MMULT(MMULT(TRANSPOSE(Column vector of the portfolio weights); covariances; Column vector of the portfolio weights)	{=MMULT(MMULT(TRANSPOSE(F12:F19);'Absolute Opt. (2)'!D19:K26);F12:F19)}
Standard deviation of the Portfolio (=Absolute_Opt._(3)!F24)	=Square root(Portfolio variance)	=SQRTR(F23)

Fig. 13.13 Calculating the minimum variance portfolio

The optimization of the objective function with the constraints can be achieved in Excel with the help of the Solver. Once the Solver has been opened, the cell which contains the objective function is determined. In our case this is the cell F26. Since the objective function needs to be minimized when determining the minimum variance portfolio, the Solver parameter *"Min"* needs to be selected for the optimization. The optimization relies on changing the portfolio weights of the risky securities. This requires the transfer of the variable portfolio weights to the Solver. These weights of the individual assets are stored in cells F12:F19. In the following, all binding constraints are added manually. These are the budget constraint and the prohibition on short selling. In our example, the budget restriction means that the budget is limited to 100% of the available investment amount. The manual input of the budget restriction in the Solver is accomplished by pressing the key ➲ *Add*. A value of 1 is assigned to the cell F20. The second constraint rules out short selling. Short selling involves the sale of securities which are not in the possession of the seller at the time of sale. In order to fulfill his obligation to deliver the securities at a later point in time, he eventually needs to buy the financial instruments. It is possible that short selling is prohibited by law. This prohibition of short sales can be modeled in Excel by ticking the box *Make Unconstrained Variables Non-negative* (see Fig. 13.14).

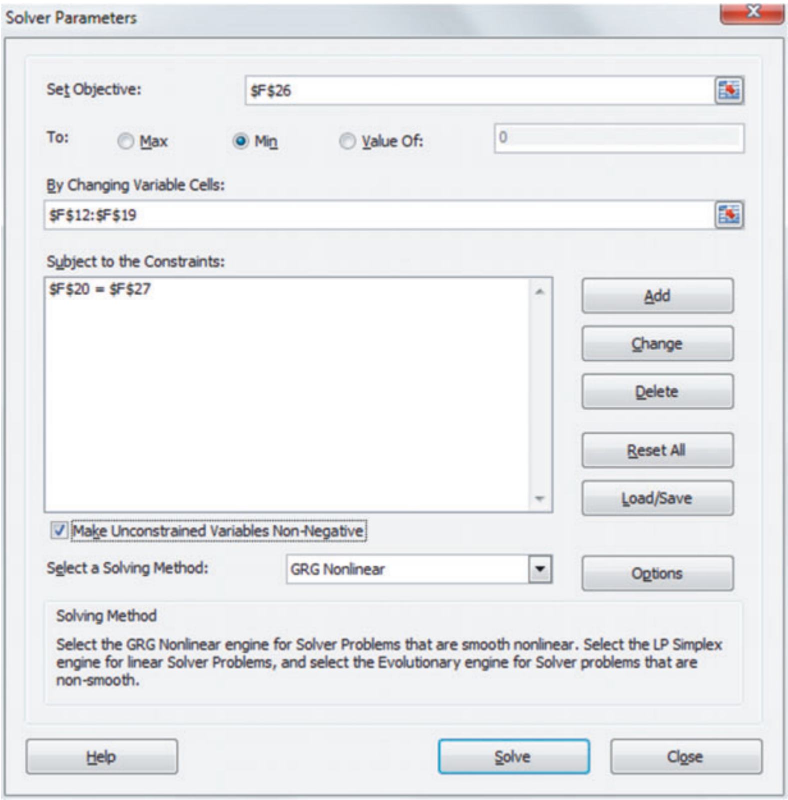


Fig. 13.14 Solver input for the minimum variance portfolio

The optimization yields a minimum variance portfolio with a portfolio variance (objective function) of 0.00006, which is equivalent to a standard deviation of 0.00792. An additional calculation - which is however, not related to the optimization – leads to the expected portfolio return of 0.12%. Figure 13.15 shows the results of the portfolio optimization. The composition of the minimum variance portfolio is 80.95% German bonds, 8.56% Japanese bonds, 7.24% European equities, 2.45% Japanese equities and 0.08% US equities. The results reveal that the minimum variance portfolio contains only 5 of the 8 securities initially considered and does not use all possible inputs. The result depends largely on the representativeness of the underlying dataset.

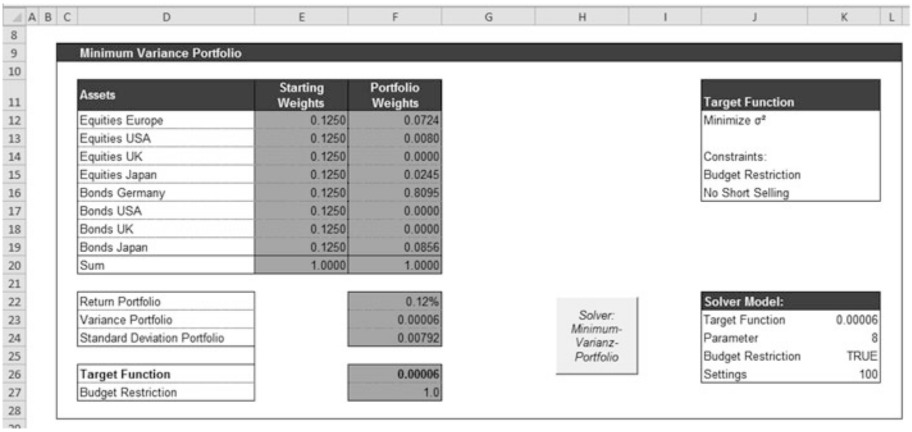


Fig. 13.15 Determining the minimum variance portfolio (Work File Portfolio Management, Worksheet Absolute_Opt._(3))

> The *Solver* functions *Save Model* and *Load Model* facilitate work in portfolio management.

An additional important function of the Solver is the ability to save and load the models (*Save model or Load model*). This is advantageous especially in the case of complex optimization problems, since the repetitive input of parameters in the case of model variations is avoided. The model can be placed in the worksheet at a location selected by the user. In the optimization problem presented, the saved results are in cells `K23:K26`. If the result cells are uploaded via the Solver, the values for the optimization problem are again available.

> For tasks in portfolio management, the macro recorder can be used effectively.

For use of the Solver it is also possible to develop a macro with the macro recorder (see Fig. 13.16). The path is *Developer* ➲ *Code* ➲ *Record Macro*. A window opens up in which the macro can be named. Once this window has been confirmed with *OK*, the individual

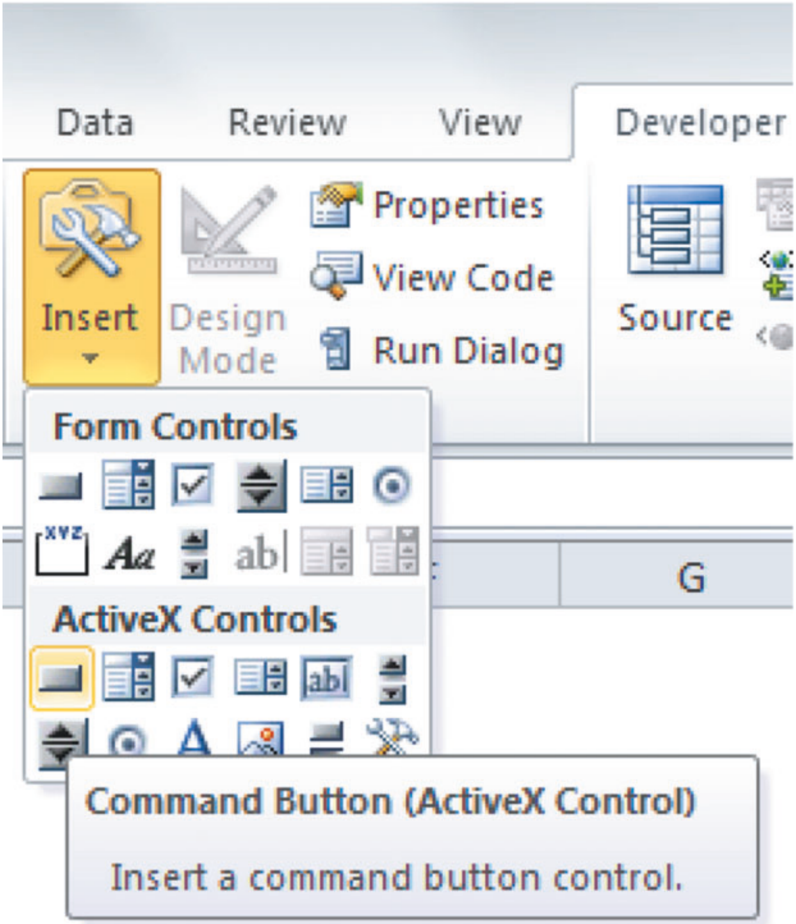


Fig. 13.16 Inserting controls for macros

input steps are programmed as usual. First of all, the Solver is accessed and ➲ *Reset All* is checked in order to set all inputs to zero. Next, the objective function, cells to be changed, constraints and options are added. ➲ *Solve* can be clicked and the solution is confirmed. Now ➲ *End Recording* is clicked in the developer tool and the macro is thus created. To connect it with a button, go to *Developer* ➲ *Controls* ➲ *Insert* ➲ *Form Controls* ➲ *Button.* The field for button is in the upper left corner.

4.1.2 Minimum Variance Portfolio without Restrictions on Short Selling

> Short selling involves the sale of securities that the seller does not possess at the time of sale.

If the restriction on short selling is lifted, it is possible to use the sale of assets that are not in the possession of the seller at the time of sale in order to invest in other assets in the portfolio. The aim is to further reduce the portfolio risk.

Lifting the restriction on short selling is very easy in the Solver. Only the checkmark in the box ⊃ *Make Unconstrained Variables Non-negative* must be removed. All other inputs are unchanged compared to the previous analysis.

Figure 13.17 shows the results of the optimization of the minimum variance portfolio when short selling is permitted. It can be noted that the portfolio risk, as measured by portfolio variance, can be reduced from 0.00006 to 0.00005 because of short selling. To achieve this aim, US and UK bonds as well as UK shares are sold short. All following optimizations will again assume that no short sales are allowed.

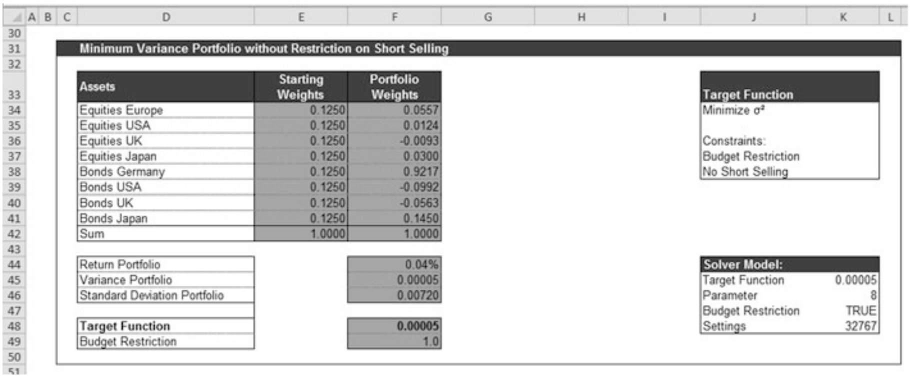


Fig. 13.17 Determining the minimum variance portfolios without prohibition on short selling (Work File Portfolio Management, Worksheet Absolute_Opt._(3))

4.1.3 Minimum Variance Portfolio with Lower and Upper Bound

Lower and upper bounds frequently result from strategic portfolio management or legal requirements.

In order to achieve additional portfolio diversification, it is possible to add a further constraint and to limit the weights of the individual assets in the portfolio. In this example, the minimum weight per asset was set at 5% (cells `G56:G63`) and the maximum weight per asset at 30% (cells `H56:H63`). This means that every asset is represented in the portfolio with at least 5% and at most 30%. The constraints can also be entered as a vector in the Solver. One example for a constraint would be to set the vector of weights greater than or equal to the vector for the lower bounds (`F56:F63` $\geq$ `G56:G63`) and smaller than or equal to the vector of the upper bound (`F56:F63` $\leq$ `H56:H63`). Here, as well as in the following optimizations, the prohibition on short selling is again used.

The objective function for the minimum variance portfolio is again:

$$f(w_1, \ldots, w_n) = \sigma_P^2 = \sum_{i=1}^{n} \sum_{j=1}^{n} w_i \cdot w_j \cdot \sigma_{i,j} \rightarrow min!$$

In matrix notation:

$$f(w) = \sigma_P^2 = w^T \cdot V \cdot w \rightarrow min!$$

Constraints:

- Budget restriction: $\sum_{i=1}^{n} w = 1$ resp. $1^T \cdot w = 1$
- Non-negativity constraint,

$$\text{no short selling}: w_i \geq 0, \text{for all } i = 1, \ldots, n$$

- Lower/upper bound: $w_i \geq 0.05$ for all $i = 1, \ldots, n$
  $w_i \leq 0.3$ for all $i = 1, \ldots, n$

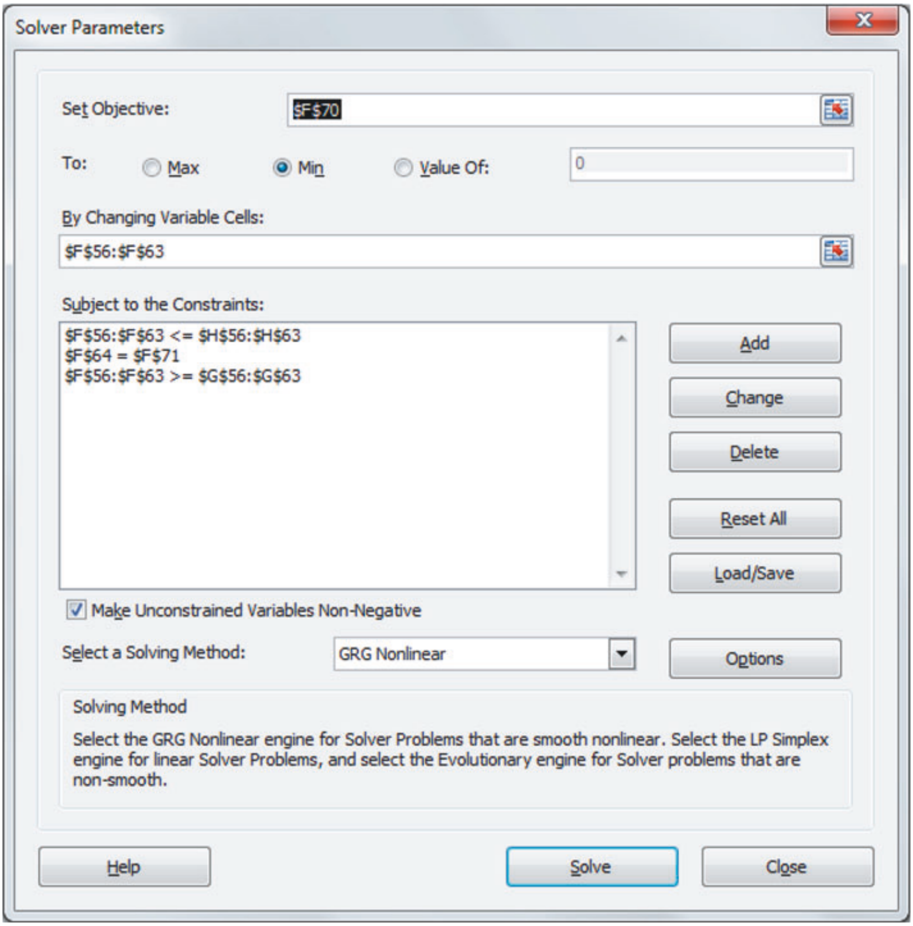


Fig. 13.18 Solver input for the minimum variance portfolio with lower and upper bounds

The starting weights, which add up to one, are again set equal to the weights of a naive portfolio with 12.5% per asset. The portfolio is then optimized with the help of the Solver. Two additional binding constraints are introduced in the form of minimum and maximum weights.

Figure 13.18 shows the Solver input:

The following solution for the minimum variance portfolio with lower and upper bounds is obtained (see Fig. 13.19):

Minimum Variance Portfolio with Minimum and Maximum Weight

Assets	Starting Weights	Portfolio Weights	Min. Weight	Max. Weight
Equities Europe	0.1250	0.0500	0.05	0.30
Equities USA	0.1250	0.0500	0.05	0.30
Equities UK	0.1250	0.0500	0.05	0.30
Equities Japan	0.1250	0.0500	0.05	0.30
Bonds Germany	0.1250	0.3000	0.05	0.30
Bonds USA	0.1250	0.0500	0.05	0.30
Bonds UK	0.1250	0.1500	0.05	0.30
Bonds Japan	0.1250	0.3000	0.05	0.30
Sum	1.0000	1.0000		

Return Portfolio	0.27%
Variance Portfolio	0.0001
Standard Deviation Portfolio	0.0117

Target Function	**0.0001**
Budget Restriction	1.0

Target Function
Minimize σ²
Constraints:
Budget Restriction
No Short Selling
Min. and Max. Weights

Solver Model:	
Target Function	0.0001
Parameter	8
Budget Restriction	TRUE
Min. Weights	TRUE
Max. Weights	TRUE
Settings	100

Fig. 13.19 Minimum Variance Portfolio with lower and upper bounds (Work File Portfolio Management, Worksheet Absolute_Opt._(3))

4.1.4 Efficient Portfolio for Given Return

> An efficient portfolio is characterized by minimum portfolio risk for a predetermined level of return.

The aim of determining an efficient portfolio is the minimization of the portfolio risk for a given target return. This is a realistic demand in applied portfolio management.

The optimization problem when determining an efficient portfolio in principle requires minimizing portfolio risk for a given target return. This leads to the following objective function in the Excel model:

$$f(w) = \sigma_P^2 = w^T \cdot V \cdot w \rightarrow min!$$

and the primary constraint:

$$w^T \mu = r_G$$

with r_G : *variable target return, where* $\mu_{MVP} \leq r_G \leq \mu_{MEP}$

as well as the secondary constraints of an existing budget restriction and the prohibition of short sales.

In this example, a return of 0.35% per month is required (cell `F136`). The objective function specifies to minimize the variance while achieving the required return. This fundamental relationship is the basic idea behind the portfolio optimization of Markowitz.

The continued variation of the required return leads to the efficient frontier. The required return falls between the return of the minimum variance portfolio and the return of the maximum return portfolio. Starting with a return of 0.3%, the Solver was utilized in steps of 0.025% and the values were copied into a new table (cells P126-Q136). This data, plus the minimum variance portfolio and the maximum return portfolio, allows the derivation of the efficient frontier. It is displayed in Figs. 13.20 and 13.21.

The objective function is:

$$f(w_1, \ldots, w_n) = \sigma_P^2 = \sum_{i=1}^{n} \sum_{j=1}^{n} w_i \cdot w_j \cdot \sigma_{ij} \rightarrow \min!$$

In matrix notation:

$$f(w) = \sigma_P^2 = w^T \cdot V \cdot w \rightarrow \min!$$

The constraints are:

- Required return of the portfolio: $r^{req} = 0.035$
- Budget restriction: $\sum_{i=1}^{n} w = 1$ resp. $1^T \cdot w = 1$

Position	Formula	Excel implementation
Objective function (=Absolute_Opt._(3)!F142)	{=MMULT(MMULT(TRANSPOSE(Column vector of the portfolio weights); Covariances; Column vector of the portfolio weights)	{=MMULT(MMULT(TRANSPOSE(F126:F133);'Absolute Opt. (2)'!D19:K26);F126:F133)}
Portfolio return (=Absolute_Opt._(3)!F138)	{=MMULT(TRANSPOSE(Column vector of the portfolio weights); Expected return}	{=MMULT(TRANSPOSE(F126:F133);'Absolute Opt. (2)'!D45:D52)}
Portfolio variance (=Absolute_Opt._(3)!F139)	{=MMULT(MMULT(TRANSPOSE(Column vector of the portfolio weights); Covariances; Column vector of the portfolio weights)	{=MMULT(MMULT(TRANSPOSE(F126:F133);'Absolute Opt. (2)'!D19:K26);F126:F133)}
Standard deviation of the portfolio (=Absolute Opt. (3)!F140)	=Square root (Portfolio variance)	=SQRT(F139)

Fig. 13.20 Calculating the efficient portfolio

Efficient Frontier

	Return	Standard Deviation
Min. Variance Portfolio	0.275%	0.0117
Required Return	0.300%	0.0121
Required Return	0.325%	0.0127
Required Return	0.350%	0.0134
Required Return	0.375%	0.0141
Required Return	0.400%	0.0149
Required Return	0.425%	0.0157
Required Return	0.450%	0.0165
Required Return	0.475%	0.0174
Required Return	0.500%	0.0182
Utility Max. Portfolio	0.509%	0.0186

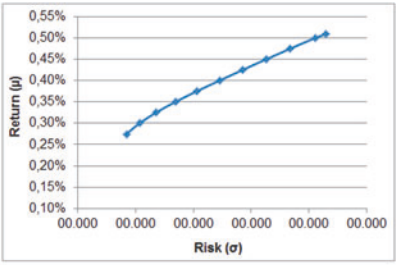


Fig. 13.21 Efficient frontier (Work File Portfolio Management, Worksheet Absolute_Opt._(3))

Efficient Portfolio

Assets	Starting Weights	Portfolio Weights	Min. Weight	Max. Weight
Equities Europe	0.1250	0.0500	0.05	0.30
Equities USA	0.1250	0.0535	0.05	0.30
Equities UK	0.1250	0.0500	0.05	0.30
Equities Japan	0.1250	0.0500	0.05	0.30
Bonds Germany	0.1250	0.3000	0.05	0.30
Bonds USA	0.1250	0.1237	0.05	0.30
Bonds UK	0.1250	0.2436	0.05	0.30
Bonds Japan	0.1250	0.1292	0.05	0.30
Sum	1.0000	1.0000		

Required Return	0.35%
Return Portfolio	0.35%
Variance Portfolio	0.0002
Standard Deviation Portfolio	0.0134
Target Function	**0.0002**
Budget Restriction	1.0

Target Function
Minimize σ²
Constraints:
Required Return
Budget Restriction
No Short Selling
Min. and Max. Weights

Solver Model:	
Target Function	0.0002
Parameter	8
Budget Restriction	TRUE
Required return	TRUE
Min. Weight	TRUE
Max. Weight	TRUE
Settings	100

Fig. 13.22 Efficient portfolio (Work File Portfolio Management, Worksheet Absolute_Opt._(3))

- Non-negativity constraint, no short selling: $w_i \geq 0$, for all i = 1, . . . , n
- Lower/upper bound: $w_i \geq 0.05$ for all i = 1, . . . , n
  $w_i \leq 0.3$ for all i = 1, . . . , n

The formula for the determination of an efficient portfolio are shown in figures 102 and 103:

The overall result for the efficient portfolio is presented in Fig. 13.22:

4.1.5 Tangency Portfolio

> The tangency portfolio assumes a risk-free investment opportunity in addition to the risky assets of the portfolio.

The determination of the tangency portfolio is based on the separation theorem developed by TOBIN, which assumes the existence of a risk-free investment opportunity in addition to the risky assets. This makes it possible for the investor to combine risk-free and risky securities. He can also take out a loan at the risk-free rate and invest in risky assets with the aim of obtaining an excess return. The efficient portfolio is located on the line which connects the risk-free rate with the efficient frontier. The line is called capital market line. The point where the two lines meet is the tangency portfolio (see Figs. 13.23 and 13.24).

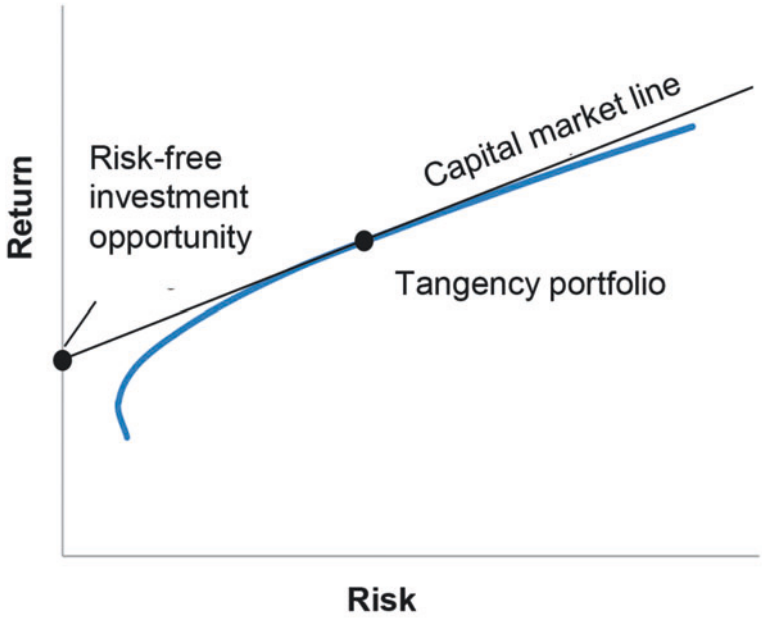


Fig. 13.23 Tangency portfolio

The tangency portfolio is obtained by determining the steepest capital market line that still touches the efficient frontier. This can be done with the help of the Sharpe ratio, which relates the difference between portfolio return μ_P and risk-free return r_f to the risk taken (standard deviation of the portfolio return σ_p).

For the determination of the tangency portfolio it holds that:

$$SR = \frac{\mu_P - r_f}{\sigma_P} \rightarrow max!$$

Thus the objective function is:

$$f = \frac{\mu_P - r_f}{\sigma_P} \rightarrow \max!$$

In matrix notation:

$$f = \frac{w^T \cdot r - r_f}{\sqrt{w^T \cdot V \cdot w}} \rightarrow \max!$$

The following binding constraints are implemented for the determination of the tangency portfolio:

Position	Formula	Excel implementation
Objective function (=Absolute_Opt._(3)!F92)	=(Portfolio return- monthly risk-free rate)/Standard deviation of the portfolio	=(F88-Assumptions General!C213)/F90
Portfolio return (=Absolute_Opt._(3)!F88)	{=MMULT(TRANSPOSE(Column vector of the portfolio weights);Expected return}	{=MMULT(TRANSPOSE(F78:F85);'Absolute Opt. (2)'!D45:D52)}
Portfolio variance (=Absolute_Opt._(3)!F89)	{=MMULT(MMULT(TRANSPOSE(Column vector of the portfolio weights); Covariances; Column vectors of the portfolio weights)	{=MMULT(MMULT(TRANSPOSE(F78:F85);'Absolute Opt. (2)'!D19:K26);F78:F85)}
Standard deviation of the portfolio (=Absolute_Opt._(3)!F90)	=Square root (Portfolio variance)	=SQRT(F89)

Fig. 13.24 Calculating the tangency portfolio

Tangency Portfolio

Assets	Starting Weights	Portfolio Weights	Min. Weight	Max. Weight
Equities Europe	0.1250	0.0500	0.05	0.30
Equities USA	0.1250	0.1500	0.05	0.30
Equities UK	0.1250	0.0500	0.05	0.30
Equities Japan	0.1250	0.0500	0.05	0.30
Bonds Germany	0.1250	0.0500	0.05	0.30
Bonds USA	0.1250	0.3000	0.05	0.30
Bonds UK	0.1250	0.3000	0.05	0.30
Bonds Japan	0.1250	0.0500	0.05	0.30
Sum	1.0000	1.0000		

Return Portfolio	0.51%
Variance Portfolio	0.0003
Standard Deviation Portfolio	0.0186

Target Function	**0.1411**
Budget Restriction	1.0

Target Function
Maximize (μ-rf)/σ
Constraints:
Budget Restriction
No Short Selling
Min. and Max. Weights

Solver Model:	
Target Function	0.1411
Parameter	8
Budget Restriction	TRUE
Min. Weight	TRUE
Max. Weight	TRUE
Settings	100

Fig. 13.25 Tangency portfolio (Work File Portfolio Management, Worksheet Absolute_Opt._(3))

- Budget restriction: $\sum_{i=1}^{n} w = 1^{T} \cdot w = 1$
- Non-negativity constraint, no short selling: $w_i \geq 0$, for all i = 1, . . . , n
- Lower/upper bound: $w_i \geq 0.3$ for all i = 1, . . . , n
  $w_i \leq 0.5$ for all i = 1, . . . , n

The portfolio is again optimized using the Solver. It needs to be kept in mind that the objective function is maximized in the case of the tangency portfolio. Also needed is the risk-free rate, which is calculated in the worksheet `Assumptions_General` in cell `C213` based on the annual risk-free rate (cell `C212`).

The formulas for the determination of the tangency are shown in Fig. 13.24:

The next steps of the optimization follow the examples presented before.

The result is displayed in Fig. 13.25:

4.1.6 Maximum Return Portfolio

The portfolio return is maximized for the maximum return portfolio.

In addition to the maximum return portfolio, the minimum variance portfolio is the other extreme case in portfolio optimization. While the risk is minimized for the minimum variance portfolio, the return is maximized for the maximum return portfolio. The maximum return portfolio is a portfolio which contains 100% of the asset with the maximum return. In the case of several existing investment options, the dominant one is selected.

The optimization of the maximum return portfolio with binding constraints concerning the weights can be presented as follows:

$$\mu_{(r_P)} = \sum_{i=1}^{n} w_i \cdot \mu_i \rightarrow \max!$$

The objective function is: $f = \mu_P = \sum_{i=1}^{n} w_i \cdot \mu_i \rightarrow \max!$

In matrix notation: $f(w) = \mu_P = w^T \cdot r \rightarrow \max!$

The binding constraints are identical to the ones listed above:

Position	Formula	Excel implementation
Objective function (=Absolute_Opt._(3)!F116)	{=MMULT(TRANSPOSE(Column vector of the portfolio weights); Expected return}	{=MMULT(TRANSPOSE(F102:F109);'Absolute Opt. (2)'!D45:D52)}
Portfolio return (=Absolute_Opt._(3)!F112)	{=MMULT(TRANSPOSE(Column vector of the portfolio weights); Expected return}	{=MMULT(TRANSPOSE(F102:F109);'Absolute Opt. (2)'!D45:D52)}
Portfolio variance (=Absolute_Opt._(3)!F113)	{=MMULT(MMULT(TRANSPOSE(Column vector of the portfolio weights); Covariances; Column vector of the portfolio weights)	{=MMULT(MMULT(TRANSPOSE(F102:F109);'Absolute Opt. (2)'!D19:K26);F102:F109)}
Standard deviation of the portfolio (=Absolute_Opt._(3)!F114)	=Square root (Portfolio variance)	=SQRT(F113)

Fig. 13.26 Calculating the maximum return portfolio

Maximum Return Portfolio

Assets	Starting Weights	Portfolio Weights	Min. Weight	Max. Weight
Equities Europe	0.1250	0.0500	0.05	0.30
Equities USA	0.1250	0.1500	0.05	0.30
Equities UK	0.1250	0.0500	0.05	0.30
Equities Japan	0.1250	0.0500	0.05	0.30
Bonds Germany	0.1250	0.0500	0.05	0.30
Bonds USA	0.1250	0.3000	0.05	0.30
Bonds UK	0.1250	0.3000	0.05	0.30
Bonds Japan	0.1250	0.0500	0.05	0.30
Sum	1.0000	1.0000		

Return Portfolio	0.51%
Variance Portfolio	0.000
Standard Deviation Portfolio	0.019
Target Function	**0.0051**
Budget Restriction	1.0

Target Function
Maximize μ
Constraints:
Budget Restriction
No Short Selling
Min. and Max. Weights

Solver Model:	
Target Function	0.0051
Parameter	8
Budget Restriction	TRUE
Min. Weight	TRUE
Max. Weight	TRUE
Settings	100

Fig. 13.27 Maximum return portfolio (Work File Portfolio Management, Worksheet Absolute_Opt._(3))

- Budget restriction: $1^T \cdot w = 1$
- Non-negativity constraint,
  no short selling: $w_i \geq 0$, for all i = 1, . . . , n
- Lower/upper bound: $w_i \geq 0.05$ for all i = 1, . . . , n

$$w_i \leq 0.3 \text{ for all i} = 1, \ldots, \text{n}$$

The formulas for the determination of the maximum return portfolio are shown in Fig. 13.26:

The results for the optimization of the maximum return portfolio are presented in Fig. 13.27:

The asset with the strongest return is selected in the optimization until the maximum investment weight of 30% has been reached, followed by the asset with the second highest return and so forth. The assets with a weak return are considered with the minimum share of 5%.

4.1.7 Optimum Portfolio without Risk-Free Investment Opportunity

The optimum portfolio takes the utility function of the investor into consideration.

While we have constructed efficient portfolios in line with the portfolio theory of MARKOWITZ resp. a maximum return portfolio, the selection of a specific portfolio by investors was ignored so far. Such an optimum portfolio needs to maximize utility based on the investor's attitude towards risk. Initially no risk-free investment is available.

The optimization problem consists of two parts:

1. Determination of the investor's utility function and
2. Determination of an efficient portfolio that maximizes utility:

The utility function, the objective function for this optimization problem, is:

$$U_P = \mu_P - \lambda \cdot \sigma_P^2 \rightarrow max!$$

with
U_P = utility of the portfolio
μ_P = expected return
λ = lambda: parameter measuring the degree of risk aversion
σ_P^2 = variance of the return

The aim is to maximize the utility of the investor. Utility increases as the return goes up. A fundamental assumption is the risk aversion of the investor, which is expressed by a positive lambda (parameter measuring the degree of risk aversion). This implies that the utility of the risk averse investor is reduced by the variance which is weighted by lambda. The higher lambda, the greater the degree of risk aversion and the higher the losses in utility caused by high volatility.

Lambda should be determined when analyzing the investor. In this regard, questionnaires with different market scenarios can be helpful in assigning a specific risk category to the investor, which leads to an individual lambda.[2]

A simpler approach calls for the determination of lambda with the help of a benchmark. It is assumed that the investor would normally hold all assets in the benchmark. In this case the formula for the parameter of risk aversion lambda is as follows:

$$\lambda = \frac{\mu_B - r_f}{2 \cdot \sigma_B^2}$$

with
λ = lambda: parameter measuring the degree of risk aversion
μ_B = expected return of the benchmark
r_f = risk-free rate
σ_B^2 = variance of the benchmark return

The objective function of the optimization problem, respectively the utility function of the portfolio is:

$$f(w) = \mu_P - \lambda \cdot \sigma_P^2 \rightarrow max!$$

In matrix notation:

$$f(w) = w^T \cdot r - \lambda \cdot \left(w^T \cdot V \cdot w\right) \rightarrow \text{max!}$$

Constraints for the optimization:

- Budget restriction: $\sum_{i=1}^{n} w = 1$ resp. $1^T \cdot w = 1$
- Non-negativity constraint,
  no short selling: $w_i \geq 0$, for all i = 1, . . . , n
- Lower/upper bound: $w_i \geq 0.05$ for all i = 1, . . . , n
  $w_i \leq 0.3$ for all i = 1, . . . , n.

The portfolio optimization is done in line with the optimizations of the other portfolios with the help of the Solver and the stated constraints. Lambda is calculated in cell `F164`. The formulas for the determination of the optimal portfolios in the absence of a risk-free investment opportunity are (see Fig. 13.28):

The result for the optimum portfolio without risk-free asset is presented in Fig. 13.29:

Position	Formula	Excel implementation
Objective function (=Absolute_Opt._(3)!F166)	=Portfolio return-Lambda*Portfolio variance	=F161-F164*F162
Portfolios return (=Absolute_Opt._(3)!F161)	{=MMULT(TRANSPOSE(Column vector of the portfolio weights); Expected return}	{=MMULT(TRANSPOSE(F151:F158);'Absolute Opt. (2)'!D45:D52)}
Portfolio variance (=Absolute_Opt._(3)!F162)	{=MMULT(MMULT(TRANSPOSE(Column vector of the portfolio weights); Covariances; Column vector of the portfolio weights)	{=MMULT(MMULT(TRANSPOSE(F151:F158);'Absolute Opt. (2)'!D19:K26);F151:F158)}
Standard deviation of the portfolio (=Absolute_Opt._(3)!F163)	=Square root (Portfolio variance)	=SQRT(F162)
Lambda (=Absolute_Opt._(3)!F164)	=(Benchmark return – Monthly risk-free rate) /(2*Benchmark standard deviation^2)	=('Absolute Opt. (2)'!L12-'Assumptions General'!C213)/(2*'Absolute Opt. (2)'!L13^2)

Fig. 13.28 Calculating the optimum portfolio without risk-free asset

Optimum Portfolio without Riskless Investment

Assets	Starting Weights	Portfolio Weights	Min. Weight	Max. Weight
Equities Europe	0.1250	0.0500	0.05	0.30
Equities USA	0.1250	0.1500	0.05	0.30
Equities UK	0.1250	0.0500	0.05	0.30
Equities Japan	0.1250	0.0500	0.05	0.30
Bonds Germany	0.1250	0.0500	0.05	0.30
Bonds USA	0.1250	0.3000	0.05	0.30
Bonds UK	0.1250	0.3000	0.05	0.30
Bonds Japan	0.1250	0.0500	0.05	0.30
Sum	1.0000	1.0000		

Return Portfolio	0.51%
Variance Portfolio	0.0003
Standard Deviation Portfolio	0.0186
Lambda	1.3463
Target Function	**0.0046**
Budget Restriction	1.0

Target Function
Maximize μ - lσ²
Constraints:
Budget Restriction
No Short Selling
Min and Max Weight

Solver Model:	
Target Function	0.0046
Parameter	8
Budget Restriction	TRUE
Min. Weight	TRUE
Max. Weight	TRUE
Settings	100

Fig. 13.29 Optimum portfolio without risk-free asset (Work File Portfolio Management, Worksheet Absolute_Opt._(3))

4.1.8 Optimum Portfolio with Risk-Free Investment Opportunity

This optimum portfolio also considers a risk-free investment opportunity in addition to the utility function of the investor.

The optimum portfolio with risk-free investment opportunity also considers the attitude of the investor. In addition, an investment at the risk-free rate is also possible. It is possible to either invest in the portfolio or in an asset at the risk-free rate. Furthermore it is possible to obtain a loan at the risk-free rate in order to invest in the risky portfolio and achieve a higher return.

The objective function for the optimization problem is:

$$U_P = \mu_{Mix} - \lambda \cdot \sigma^2_{Mix} \rightarrow \max!$$

The mixed portfolio thus consists of the tangency portfolio and the risk-free investment opportunity, respectively the loan at the risk-free rate. In order to obtain the return and the risk of the optimum portfolios, the shares of the two alternatives in the investor-specific optimum mixed portfolio must be known.

Thus the objective function is rewritten as follows:

$$U_{(r_P)} = x_1 \cdot \mu_{TP} - (1 - x_1) \cdot r_f - \lambda \cdot x_1^2 \cdot \sigma^2_{TP} \rightarrow \max!$$

with
U_P = utility of the portfolio
x_1 = share of the tangency portfolio in the mixed portfolio
μ_{TP} = expected return of the tangency portfolio
r_f = risk-free rate
λ = lambda: parameter of risk aversion
σ^2_{TP} = variance of returns

Position	Formula	Excel implementation
Objective function (=Absolute_Opt._(3)!F187)	=Return Mixed portfolio-Lambda *Variance Mixed portfolio	=F183-F180*F184
Lambda (=Absolute_Opt._(3)!F180)	=(Benchmark return- monthly risk-free rate) /(2*Benchmark standard deviation^2)	=('Absolute Opt. (2)'!L12-'Assumptions General'!C213)/(2*'Absolute Opt. (2)'!L13^2)
Return of the mixed portfolio (=Absolute_Opt._(3)!F183)	=Share x_1 in the tangency portfolio*Return of the tangency portfolio+(1- share x_1 in the tangency portfolio)* monthly risk-free rate	=F182*F176+(1-F182)*F179
Variance of the mixed portfolio (=Absolute_Opt._(3)!F184)	=Share x_1 in the tangency portfolio^2*Variance of the tangency portfolio	=F182^2*F177
Standard deviation of the mixed portfolio (=Absolute_Opt._(3)!F185)	=Square root (Variance of the mixed portfolio)	=SQRT(F184)

Fig. 13.30 Calculating the optimal portfolio with risk-free investment opportunity

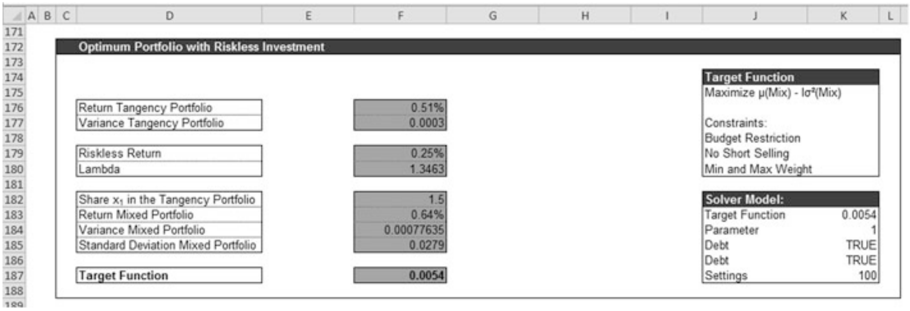
Since the tangency portfolio was already determined, only the parameter x_1 needs to be specified. It is needed for the calculation of the optimum (utility) portfolio.

The parameter x_1 can be interpreted as follows:

- $x_1 < 0$: Tangency portfolio is sold short and the proceeds are invested in the risk-free investment.
- $0 \leq x_1 \leq 1$: The investment capital is split between risk-free investment and the tangency portfolio.
- $1 \leq x_1 \leq b$: with $b > 1$; for $x_1 = b \rightarrow$ Additional capital is borrowed at the risk-free rate in the amount of $b - 1$. The additional amount is invested in the tangency portfolio. The possible choice of $b > 1$ depends on the individual situation of the investor.

The utility function of the portfolio and thus the objective function for this optimization problem is:

$$f(w) = \mu_{Mix} - \lambda \cdot \sigma^2_{Mix} \rightarrow \max!$$



Optimum Portfolio with Riskless Investment

Return Tangency Portfolio	0.51%
Variance Tangency Portfolio	0.0003
Riskless Return	0.25%
Lambda	1.3463
Share x_1 in the Tangency Portfolio	1.5
Return Mixed Portfolio	0.64%
Variance Mixed Portfolio	0.00077635
Standard Deviation Mixed Portfolio	0.0279
Target Function	0.0054

Target Function
Maximize μ(Mix) - lσ²(Mix)

Constraints:
Budget Restriction
No Short Selling
Min and Max Weight

Solver Model:	
Target Function	0.0054
Parameter	1
Debt	TRUE
Debt	TRUE
Settings	100

Fig. 13.31 Optimal portfolio with risk-free investment opportunity (Work File Portfolio Management, Worksheet Absolute_Opt._(3))

In matrix notation:

$$f(w) = x_1 \cdot \mu_{TP} + (1 - x_1) \cdot r_f - \lambda \cdot x_1^2 \cdot \sigma_{TP}^2 \rightarrow \max!$$

The following constraints are assumed for the determination of the optimal portfolio with risk-free investment opportunities and upper and lower bounds:

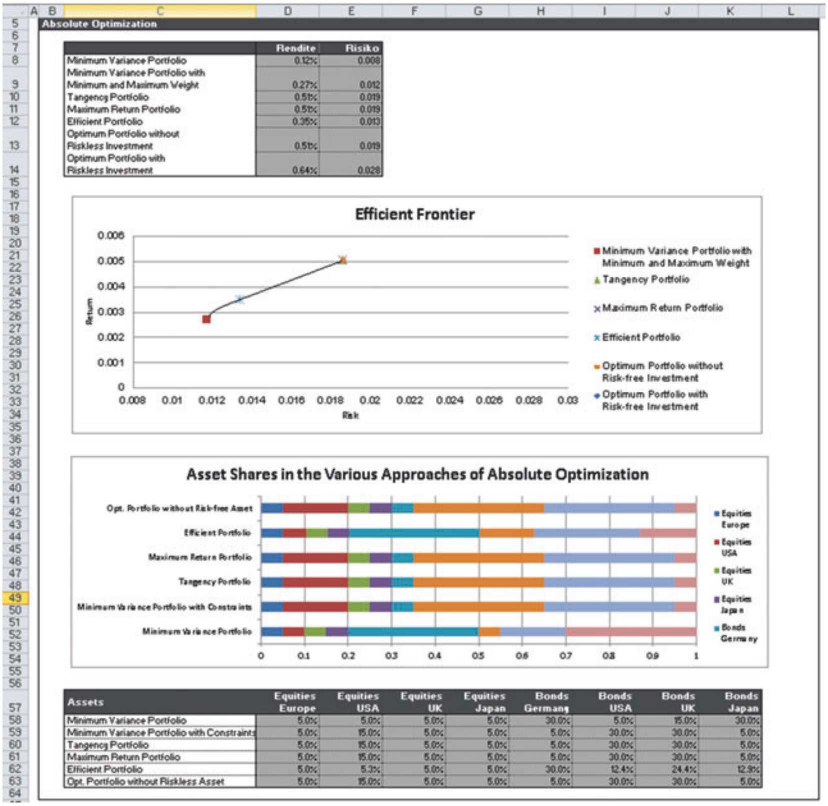
- x_1 $x_1 = 1.5$

The formulas for the determination of the optimal portfolio with risk-free investment opportunity are shown in Fig. 13.30:

The final result for the optimal portfolio with risk-free investment opportunity is provided in Fig. 13.31:

4.1.9 Summary of the Absolute Optimization Results

All the results of the individual optimizations available for active portfolio management are presented and displayed graphically in the worksheet `Absolute_Opt._Summ` (see Fig. 13.32).



	Rendite	Risiko
Minimum Variance Portfolio	0.12%	0.008
Minimum Variance Portfolio with Minimum and Maximum Weight	0.27%	0.012
Tangency Portfolio	0.51%	0.019
Maximum Return Portfolio	0.51%	0.019
Efficient Portfolio	0.35%	0.013
Optimum Portfolio without Riskless Investment	0.51%	0.019
Optimum Portfolio with Riskless Investment	0.64%	0.028

Assets	Equities Europe	Equities USA	Equities UK	Equities Japan	Bonds Germany	Bonds USA	Bonds UK	Bonds Japan
Minimum Variance Portfolio	5.0%	5.0%	5.0%	5.0%	30.0%	5.0%	15.0%	30.0%
Minimum Variance Portfolio with Constraints	5.0%	15.0%	5.0%	5.0%	5.0%	30.0%	30.0%	5.0%
Tangency Portfolio	5.0%	15.0%	5.0%	5.0%	5.0%	30.0%	30.0%	5.0%
Maximum Return Portfolio	5.0%	15.0%	5.0%	5.0%	5.0%	30.0%	30.0%	5.0%
Efficient Portfolio	5.0%	5.3%	5.0%	5.0%	30.0%	12.4%	24.4%	12.9%
Opt. Portfolio without Riskless Asset	5.0%	15.0%	5.0%	5.0%	5.0%	30.0%	30.0%	5.0%

Fig. 13.32 Summary of the absolute optimization results for active portfolio management (Work File Portfolio Management, Worksheet Absolute_Opt._Summ.)

4.2 Relative Optimization

4.2.1 Reasons for the Use of Relative Optimization

> Relative optimization involves the comparison with a benchmark.

Funds or portfolios are usually assigned to specific asset classes in applied portfolio management and the performance is tracked with the help of indexes. The portfolio manager aims at outperforming the benchmark index using active portfolio management. Since the portfolio manager optimizes relative to a benchmark, the approach is called relative optimization. When a benchmark is explicitly considered, the optimization problem changes for the portfolio manager. His aim is to generate a return that exceeds the relevant benchmark. This involves giving higher weights compared to the benchmark to those assets with the highest return expectations. In exchange assets with lower return expectations are underweighted compared to the index.

Relative optimization has a number of advantages compared to absolute optimization, which follow from the criticism levied against absolute optimization. A central issue in absolute optimization is the quality of the estimation of the input parameters. The inherent imprecision of forecasts can lead to significant problems in absolute optimization, since the results are very sensitive to minor changes in the estimated input parameters. Any change in the initial parameters leads to modifications of the "optimum" portfolio structure, which causes reallocation costs.

Also subject to criticism are the assumptions behind expected utility theory. An investor needs to be able to specify his utility function with sufficient precision to allow the identification of an optimal portfolio. In case the utility function of an investor cannot be quantified with sufficient precision, no determination of an optimal portfolio on the basis of the expected utility theory is possible.

Against this backdrop, the use of relative optimization methods appears preferable. This involves the use of the forecasted expected values for the individual securities relative to a specified benchmark in the optimization of the portfolio under consideration. Ultimately, this means that the optimal portfolio is still tied to the benchmark, which results in a more stable portfolio structure. Since the investor basically accepts return and risk of the benchmark, it seems only logical that the portfolio manager is only responsible for the added return in combination with the additional risk. In this context, the terms active return or active risk are frequently used. The optimal "relative" portfolio is characterized by the best possible tradeoff between active return and active risk relative to the benchmark selected.

4.2.2 General Types of Optimization Relative to a Benchmark

> The active return of a portfolio is the difference between portfolio return and benchmark.

Active Return and Tracking Error

The return difference between portfolio and benchmark is called active return or outperformance, which can be either positive or negative. The formula is:

$$r_A = r_P - r_B$$

with
r_A = active return
r_P = return of the active portfolio
r_B = return of the benchmark portfolio

The variance of the active return r_A (respectively its standard deviation) is called active risk. Since this formal description is equally valid for passive portfolio management, which is covered in the next section, alternative terms have been established. The variance of the active return r_A is frequently called tracking error variance (abbreviation TEV). The tracking error variance of a portfolio can thus be determined as follows:

$$TEV = Var\,(r_A)\ resp.\ TEV = Var\,(r_P - r_B)$$

In the form of the standard deviation, this variable is mostly called tracking error.

$$TE = \sqrt{Var\,(r_A)}\ resp.\,TE = \sqrt{Var\,(r_P - r_B)}$$

The following relationship can be derived from the formulas: the lower the tracking error, the closer is the risk of the active portfolio to the risk of the benchmark selected. The higher the tracking error, the larger are the deviations of the portfolio from the benchmark.

> The active position is the difference between the security weights of the portfolio and the security weights of the benchmark.

Active Position

In contrast to absolute optimization, relative optimization is based on a comparison in the form of a benchmark. An active position w_A is established, which is defined as the difference of the security weights in the portfolio w_P and the benchmark w_B.

This can be written as follows:

$$w_A = w_P - w_B$$

The active return of a portfolio is given as the return difference between portfolio and benchmark. The following relationship holds:

$$r_A = r_P - r_B = w_P^T \cdot r - w_B^T \cdot r = (w_P^T - w_B^T) \cdot r = w_A^T \cdot r$$

with r = vector of the expected returns of the securities

The active risk, as measured by the variance of the active portfolio return, is equivalent to the tracking error variance

$$TEV = \sigma_{AP}^2 = w_A^T \cdot \mathrm{V} \cdot w_A$$

respectively the so-called tracking error, which is the customary name for the standard deviation of the active return (outperformance):

$$TE = \sqrt{\sigma_{AP}^2} = \sqrt{w_A^T \cdot \mathrm{V} \cdot w_A}$$

The covariance matrix is the same as in the case of absolute optimization. The objective function is formulated in the same manner as well:

The objective function for the relative optimization in the context of the MARKOWITZ-MODEL minimizes the tracking error variance (active risk) for a targeted active return (outperformance) and is defined analogous to the case of the absolute optimization:

$$f(w) = \sigma_{AP}^2 = w_A^T \cdot \mathrm{V} \cdot w_A \rightarrow \text{min!}$$

The constraints are:

- Targeted active return of the portfolio: $r_A = x\%$
- Budget restriction: $\sum_{i=1}^{n} w_A = 0$ resp. $1^T \cdot w = 0$
- Non-negativity constraint $-w_i \leq w_A \leq 1 - w_i$ for all i = 1, . . . , n

$r_A = 0$ leads to the benchmark portfolio with a tracking error of zero. The highest possible expected active return is achieved if only the asset k with the highest return is selected. If the return of that asset is called r_k, the active weight is 1- $w_{k,B}$ and the active return $r_{A=}r_k - r_B$.

As in the case of the absolute optimization, the relative optimization can be varied by setting the active return as a constraint between $r_A = 0$ and $r_A = r_k - r_B$. Similar to the efficient frontier, a curve of optimal active portfolios is obtained where the active return (respectively outperformance) serves as return measure and the tracking error serves to describe the active risk. Risk thus captures the possibility that the expected active return is missed, including the possibility that ex post a smaller return than the benchmark return is realized.

Since this approach of relative optimization can also be used for the passive management approach, we will present an applied Excel example in the next section and not at this point.

4.2.3 Single-Index Model and Relative Optimization

> The single index model helps to reduce the complexity of the input calculations. At the same time, the single index model offers an analytical foundation.

The application of the described optimization relative to a benchmark causes practical problems when the number of assets in the benchmark becomes relatively large. In the case of N assets, the optimization requires a total of $N \cdot \frac{N+3}{2}$ input parameters, namely N return estimates, N variances and $N \cdot \frac{N-1}{2}$ covariances. If, for example, the benchmark index contains 50 securities, this already amounts to 1325 inputs. If the number of inputs exceeds the size of the data set, no statistically independent estimates are possible, since the results of the calculations directly influence each other. For indexes with several hundred individual securities, very long data series are required, which may no longer capture the current situation, especially in the absence of structural stability. To reduce this increasing complexity and to generate current parameter estimates, factor models are used.

Single Index Model

The Single Index Model (SIM) is a linear one-factor model that is based on capital market theory (CAPM) and allows the comparably simple calculation of the input parameters required for optimization. At the same time, it provides a theoretical foundation. The model also allows conclusions about the quality of portfolio management. Alpha is a key variable in relative optimization, which is utilized to assess a portfolio manager's skills at security selection. The portfolio manager can demonstrate his ability by achieving a comparably high alpha with his portfolio. Alpha and beta result from the split of the asset return into

- a component that correlates with the benchmark and
- an uncorrelated component.

Under the assumption of a linear return generating process, the return of each individual asset can be explained in linear fashion by the benchmark portfolio:

$$r_i' = \alpha_i + \beta_i \cdot r_B' + \varepsilon_i$$

with
α_i = independent return of asset i
β_i = beta factor of asset i relative to the benchmark portfolio B
r_B' = excess return of the benchmark portfolio B
ε_i = unsystematic random error (also called residual return)

> Excess return is the difference between absolute return and risk-free rate.

Excess Return of the Assets
The single index model usually works with excess returns in line with the CAPM, which are calculated as the difference between the absolute return and the risk-free rate (please do not confuse the excess return with the previously mentioned active return). The excess return allows the investor to determine whether he received a sufficient reward for taking on additional risk and which risk premium he obtained[3]:

$$r_i' = r_i - r_f$$

with
r_i' = excess return of asset i
r_i = absolute return of asset i
r_f = risk-free rate

Excess Return of the Portfolio
For the excess return of the portfolio it holds that:

$$r_P' = w_P^T \cdot r'$$

with
r'_P = excess return of portfolio P
w_P^T = transposed vector of weights for the individual assets i in portfolio P
r' = vector of excess returns of all assets in the investable universe

The relative optimization on the basis of SIM respectively the index factor model is contained in the Excel file in the worksheets `Relative_Opt._(1)` to `Relative_Opt._(4)`. In preparation for the optimization, the monthly returns of the individual assets are initially calculated in the cells `C8:J117` in the worksheet `Relative_Opt._(1)`. Next the monthly excess returns for all assets are determined in the worksheet `Relative_Opt._(2)`, also in cells `C8:J117`. The excess returns are calculated by subtracting the monthly risk-free rate the monthly return.

The returns and excess returns for the benchmark World in the worksheets `Relative_Opt._(1)` to `Relative_Opt._(2)` are calculated in Column `K` with the help of the function *MMULT*. The benchmark World consists of a portfolio of the individual assets. The weights are entered in the worksheet `Assumptions_General` in cells `C254:C261`. A naive portfolio was chosen, but other weights are also possible.

> Alpha is a fundamental figure used for relative optimization and captures the ability of a portfolio manager to select appropriate securities.

Calculation of Alpha and Beta of the Assets

Alpha and beta are calculated for the individual assets in the portfolio in cells `D43:E50` in the worksheet `Relative_Opt._(3)`. The function *LINEST* is used in Excel to calculate alpha and beta. This function provides the parameters of a linear trend. The cells for the values of alpha and beta need to be marked in advance.

The inputs for the calculation are the excess returns of the assets as Y-values and the excess returns of the benchmark as X-values. The field constant must be marked TRUE, otherwise $\alpha = 0$ will be used. This regression explicitly calls for an estimate of alpha. Additional Stats is marked as FALSE, since no other regression outputs in addition to alpha and beta need to be displayed. The required input can be seen in the Fig. 13.33 for the example of European equities.

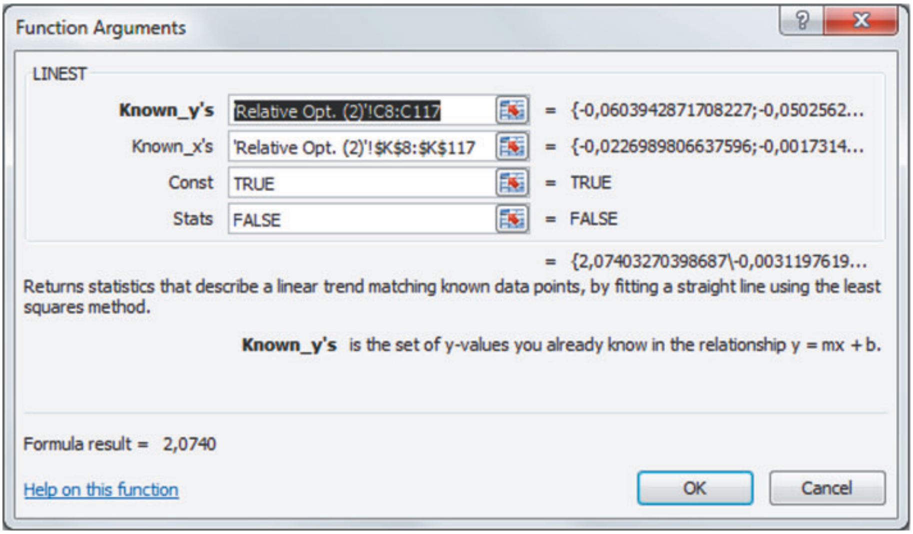


Fig. 13.33 LINEST function

This function is not completed by clicking OK, but as in the case of the matrix multiplication by pressing CTRL + SHIFT + Enter. The result is entered into two cells, the left cell contains beta and the right cell contains alpha.

> The variance of an asset can be split into two components

Variance of an Asset and Covariance (Correlation) between two Assets

The equation for the risk (variance) of an asset i is:

$$\sigma_i^2 = \beta_i^2 \cdot \sigma_B^2 + \sigma_{\varepsilon_i}^2$$

The risk (variance) of each asset can be broken down into two components. The first part of the risk is explained by the benchmark $\beta_i^2 \cdot \sigma_B^2$ and corresponds to the systematic risk. The second part of the risk $\sigma_{\varepsilon_i}^2$ represents the security-specific residual risk, also called unsystematic risk. Rearranging the above equation, the residual risk can also be written as:

$$\sigma_{\varepsilon_i}^2 = \sigma_i^2 - \beta_i^2 \cdot \sigma_B^2$$

Except for the case where the residuals ε_i and ε_j of two assets are uncorrelated (correlation equal to zero), the covariance is given as the product of the beta coefficients of the assets with the variance of the benchmark[4]:

$$\sigma_{i,j} = \beta_i \cdot \beta_j \cdot \sigma_B^2$$

In the cells `D30` and `K37` of the worksheet `Relative_Opt._(3)`, the calculation of a covariance matrix V on the basis of the SIM is implemented. Used are the estimated beta coefficients and the variances of the assets and the benchmark.

The calculation of the covariance on the basis of the SIM is demonstrated with reference to the example European and US equities in cell `E30` (see Fig. 13.34).

The covariance matrix on the basis of the SIM is displayed in Fig. 13.35.

Alpha and Beta of Benchmark and Portfolio

Alpha and beta of the benchmark are formally derived by weighting the assets in the benchmark with their respective alpha or beta values.

Position	Formula	Excel implementation
Covariance between the returns of the equities Europe and US (`=Relative_Opt._(3)!E30`)	=Beta equities Europe * Beta equities USA *Standard deviation of the benchmark^2	`=$D43*$D$43*$L$24^2`

Fig. 13.34 Calculating the covariance on the basis of the SIM

	A	B	C	D	E	F	G	H	I	J	K
26											
27			Covariance								
28–29				Equities Europe	Equities USA	Equities UK	Equities Japan	Bonds Germany	Bonds USA	Bonds UK	Bonds Japan
30			Equities Europe	0.001929	0.001641	0.001547	0.001926	-0.000049	0.000134	0.000251	0.000062
31			Equities USA	0.001641	0.001396	0.001316	0.001639	-0.000042	0.000114	0.000213	0.000053
32			Equities UK	0.001547	0.001316	0.001240	0.001544	-0.000039	0.000107	0.000201	0.000050
33			Equities Japan	0.001926	0.001639	0.001544	0.001923	-0.000049	0.000134	0.000251	0.000062
34			Bonds Germany	-0.000049	-0.000042	-0.000039	-0.000049	0.000001	-0.000003	-0.000006	-0.000002
35			Bonds USA	0.000134	0.000114	0.000107	0.000134	-0.000003	0.000009	0.000017	0.000004
36			Bonds UK	0.000251	0.000213	0.000201	0.000251	-0.000006	0.000017	0.000033	0.000008
37			Bonds Japan	0.000062	0.000053	0.000050	0.000062	-0.000002	0.000004	0.000008	0.000002

Fig. 13.35 Covariance matrix on the basis of the SIM (Work File Portfolio Management, Worksheet Relative_Opt._(3))

The benchmark beta must take on a value of one and the benchmark alpha a value of zero, since the benchmark is merely reproduced.

$$\beta_B = w_B^T \cdot \beta = 1$$
$$\alpha_B = w_B^T \cdot \alpha = 0$$

In the worksheet `Relative_Opt._(3)` in cells `D52:E52` the calculation of alpha and beta of the benchmark is implemented using the functions *MMULT* and *TRANSPOSE*.

Portfolio alpha and portfolio beta are obtained in the same fashion by weighting the assets in the portfolio with their respective alpha and beta values:

$$\beta_P = w_P^T \cdot \beta$$
$$\alpha_P = w_P^T \cdot \alpha$$

The cells `D53` and `E53` contain the calculations of portfolio beta and portfolio alpha.

The formulas for calculating the values of alpha and beta are shown in Fig. 13.36:

> Portfolio risk (variance) can also be split into two components.

Position	Formula	Excel implementation
Values of alpha and beta of the individual assets (=Relative_Opt._(3)!D43:D50)	{=LINEST(Excess return equities Europe 31.01.t_{-9} to 29.02.t_0; Excess return benchmark World 31.01.t_{-9} to 29.02.t_0}	=LINEST('Relative Opt.(2)'!C8:C117;'Relative Opt.(2)'!$K$8:$K$117;TRUE;FALSE)}
Alpha of the benchmark (=Relative_Opt._(3)!E52)	{=MMULT(TRANSPOSE(Benchmark weights) ;Alpha of the assets)}	{=MMULT(TRANSPOSE(E10:E17);E43:E50)}
Beta of the benchmark (=Relative_Opt._(3)!D52)	{=MMULT(TRANSPOSE (Benchmark weights); Beta of the assets)}	{=MMULT(TRANSPOSE(E10:E17);D43:D50)}
Alpha of the portfolio (=Relative_Opt._(3)!E53)	{=MMULT(TRANSPOSE (Portfolio weights); Alpha of the assets)}	{=MMULT(TRANSPOSE(D66:D73);E43:E50)}
Beta of the portfolio (=Relative_Opt._(3)!D53)	{=MMULT(TRANSPOSE (Portfolio weights); Beta of the assets)}	{=MMULT(TRANSPOSE(D66:D73);D43:D50)}

Fig. 13.36 Calculating the values of alpha and beta

Variance of the Portfolio and the Benchmark

The equation for the risk (variance) of the portfolio is already familiar:

$$\sigma_P^2 = \beta_P^2 \cdot \sigma_B^2 + \sigma_\varepsilon^2$$

The risk (variance) of the portfolio can thus be split into two components: systematic risk and the unsystematic risk (also called specific risk or residual risk).

The risk of the benchmark B and the portfolio P is calculated as follows:

$$\sigma_B^2 = w_B^T \cdot V \cdot w_B$$
$$\sigma_P^2 = w_P^T \cdot V \cdot w_P$$

Inserted into the equation for the residual risk it follows that:

$$\sigma_\varepsilon^2 = w_P^T \cdot V \cdot w_P - \left(w_P^T \cdot \beta\right)^2 \cdot w_B^T \cdot V \cdot w_B$$

The formulas for calculating the variance of the portfolio and the benchmark as well as the residual variance of the portfolio are shown in Fig. 13.37:

The active positions of the portfolio assets, based on the provided portfolio weights in cells `D66:D73` and the benchmark weights in `E66:E73` are calculated in cells `F66:F73`. The sum of the weights

Position	Formula	Excel implementation
Portfolio variance (`=Relative_Opt._(3)!D59`)	{=MMULT(MMULT(TRANSPOSE(Column vector of the portfolio weights); Covariances; Column vector of the portfolio weights)	`{=MMULT(MMULT(TRANSPOSE(D66:D73);$D$30:$K$37);D66:D73)}`
Benchmark variance (`=Relative_Opt._(3)!E59`)	{=MMULT(MMULT(TRANSPOSE(Column vector of the benchmark weights); Covariances; Column vector of the benchmark weights)	`{=MMULT(MMULT(TRANSPOSE(E66:E73);$D$30:$K$37);E66:E73)}`
Residual variance of the portfolio (`=Relative_Opt._(3)!D60`)	=PortfolioVariance-Portfoliobeta^2 *Benchmark variance	`=D59-D53^2*E59`

Fig. 13.37 Calculating the variance of the portfolio and the benchmark as well as the residual variance of the portfolio

of the portfolio is calculated in D74, of the benchmark in E74 and of the active positions in F74.

The beta of the active positions, respectively the active beta describes the difference between portfolio and benchmark beta. Since the benchmark beta is equal to one by definition, it follows for the active beta:

$$\beta_{AP} = \beta_P - \beta_B = \beta_P - 1$$

The calculation of the active beta relies on weighting the assets in the portfolio with their corresponding beta values. This can be written in vector notation as:

$$\beta_{AP} = w_{AP}^T \cdot \beta$$

The alpha of the active positions, respectively the active alpha describes the difference between portfolio and benchmark alpha. Since the benchmark alpha is equal to zero by definition, it follows for the active alpha:

$$\alpha_{AP} = \alpha_P - \alpha_B = \alpha_P$$

The calculation of the active alpha relies on weighting the assets in the portfolio with their corresponding alpha values:

$$\alpha_{AP} = w_{AP}^T \cdot \alpha$$

Since the alphas of the assets can be interpreted as temporal residual returns according to the CAPM, historic alphas should be characterized by instability. Due to the fact that alphas are generally not very pronounced, their estimation in a regression model frequently lacks precision and the results are often not statistically significant. The extrapolation of alphas on the basis of a single dataset is therefore problematic.

The beta of the portfolio and the benchmark and the active beta are calculated in cells D75:F75. The alpha of the portfolio and the benchmark and the active alpha are calculated in cells D76:F76.

The following formulas are used (see Fig. 13.38):

The risk which is driven by the active positions w_A is also called active risk, respectively active variance. This variance is identical to the usual term tracking error variance, a fact which is familiar from the passive approach to portfolio management.

Position	Formula	Excel implementation
Beta of the portfolio (=Relative_Opt._(3)!D75)	{=MMULT(TRANSPOSE(Portfolio weights);Beta of the assets)}	{=MMULT(TRANSPOSE(D66:D73);D43:D50)}
Beta of the benchmark (=Relative_Opt._(3)!E75)	{=MMULT(TRANSPOSE(Benchmark weights); Beta of the assets)}	{=MMULT(TRANSPOSE(E66:E73);D43:D50)}
Active beta (=Relative_Opt._(3)!F75)	{=MMULT(TRANSPOSE(Active weights); Beta of the assets)}	{=MMULT(TRANSPOSE(F66:F73);D43:D50)}
Alpha of the portfolio (=Relative_Opt._(3)!D76)	{=MMULT(TRANSPOSE(Portfolio weights); Alpha of the assets)}	{=MMULT(TRANSPOSE(D66:D73);E43:E50)}
Alpha of the benchmark (=Relative_Opt._(3)!E76)	{=MMULT(TRANSPOSE(Benchmark weights); Alpha of the assets)}	{=MMULT(TRANSPOSE(E66:E73);E43:E50)}
Active alpha (=Relative_Opt._(3)!F76)	{=MMULT(TRANSPOSE(Active weights); Alpha of the assets)}	{=MMULT(TRANSPOSE(F66:F73);E43:E50)}

Fig. 13.38 Calculating the betas of the portfolio and the benchmark as well as the active betas, calculating the alphas of the portfolio and the benchmark as well as the active alphas

It is given by:

$$\sigma_{AP}^2 = w_A^T \cdot V \cdot w_A$$

with
σ_{AP}^2 = variance of the excess return of the active portfolios AP
(= tracking error variance)
V = variance-covariance matrix of the individual assets

The tracking error variance can also be estimated on the basis of the SIM:

$$\sigma_{AP}^2 = \beta_{AP}^2 \cdot \sigma_B^2 + \sigma_\varepsilon^2$$

The equation for the tracking error variance can be interpreted more easily with reference to two more types of risk which play a role in relative optimization:

- Selection risk
- Timing risk

$$\underbrace{\sigma_{AP}^2 =}_{\text{Tracking Error Variance}} \underbrace{\beta_{AP}^2 \cdot \sigma_B^2}_{\text{Timing risk}} + \underbrace{\sigma_\varepsilon^2}_{\text{Selection risk}}$$

The timing risk $\beta_{\mathrm{AP}}^2 \cdot \sigma_B^2$ describes the portfolio manager's skill in capturing beta relative to the benchmark. Over time it is possible to obtain a positive excess return relative to the benchmark by actively changing the beta factor (so called tactical asset allocation). Such an ability to time the market can also help during negative market developments to achieve a portfolio value that is declining less than the market. As can be seen from the equation for the portfolio variance in the SIM, the portfolio risk changes as the portfolio beta is varied.

The selection risk $\sigma_{\varepsilon P}^2$ describes the skill of a portfolio manager to increase the portfolio return by selecting and overweighting return enhancing investments. The ability to select securities is confirmed by the existence of a positive alpha for the portfolio.

If the timing component is excluded ($\beta_{AP} = 0$ resp. $\beta_P = 1$), the tracking error variance (σ_{AP}^2) is equal to the residual risk (σ_ε^2):

$$\sigma_{AP}^2 = \sigma_\varepsilon^2 \quad \text{with} \quad \beta_{\mathrm{P}} = \beta_{\mathrm{B}} = 1 \Leftrightarrow \beta_{\mathrm{AP}} = 0$$

In the worksheet `Relative_Opt._(3)`, the variance of the portfolio (`D82`), the variance of the benchmark (`E82`), the variance of the active positions (tracking error variance) (`F82`), the timing risk (`F83`) and the selection risk (`F84`) are calculated.

The following formulas are used (see Fig. 13.39):

Optimization:

> Relative optimization amounts to maximizing the difference between portfolio alpha and the selection risk (residual risk) weighted by the parameter of risk aversion λ.

The objective function for the relative optimization is equivalent to maximizing the difference between portfolio alpha and selection risk (residual risk) weighted by the parameter of risk aversion λ. It formally represents the objective function of a risk averse investor:

$$\alpha_P - \lambda \cdot \sigma_\varepsilon^2 \rightarrow max!$$

Position	Formula	Excel implementation
Variance of the portfolio (`=Relative_Opt._(3)!D82`)	{=MMULT(MMULT(TRANSPOSE(Column vector of the portfolio weights); Covariances; Column vector of the portfolio weights)	`{=MMULT(MMULT(TRANSPOSE(D66:D73);$D$30:$K$37);D66:D73)}`
Variance of the benchmark (`=relative_Opt._(3)!E82`)	{=MMULT(MMULT(TRANSPOSE(Column vector of the benchmark weights); Covariances; Column vector of the benchmark weights)	`{=MMULT(MMULT(TRANSPOSE(E66:E73);$D$30:$K$37);E66:E73)}`
Variance of the active position (tracking error variance) (`=relative_Opt._(3)!F82`)	{=MMULT(MMULT(TRANSPOSE(Column vector of the active weights); Covariances; Column vector of the active weights)	`=MMULT(MMULT(TRANSPOSE(F66:F73);$D$30:$K$37);F66:F73)}`
Timing risk (`=relative_Opt._(3)!F83`)	=Beta of the active weights^2*Variance of the benchmark	`=F75^2*E82`
Selection risk (`=relative_Opt._(3)!F84`)	=Tracking error - Timing risk	`=F82-F83`

Fig. 13.39 Calculating the variance of the portfolio, the variance of the benchmark, the variance of the active positions, the tracking error, the timing risk and the selection risk

In matrix notation:

$$f(w) = w_P^T \cdot \alpha - \lambda \cdot \left(w_A^T \cdot V \cdot w_A\right) \rightarrow max!$$
$$f(w) = w_P^T \cdot \alpha - \lambda \cdot \left(w_P^T \cdot V \cdot w_P - \left(w_P^T \cdot \beta\right)^2\right) \cdot w_B^T \cdot V \cdot w_B) \rightarrow max!$$

If the timing component is set equal to zero (restriction), the risk is equivalent to the selection component alone, in other words the residual risk from the active weights.

The following restrictions are assumed for the relative optimization:

- Budget restriction: $\sum_{i=1}^{N} w_{P_i} = 1 \ resp. \ \sum_{i=1}^{N} w_{AP_i} = 0$

$$1^T \cdot w_P = 1 \quad 1^T \cdot w_{AP} = 0$$

- Non-negativity constraint,
  no short selling: $w_i \geq 0,$ for all i $= 1, \ldots,$ n

Position	Formula	Excel implementation
Alpha of the portfolio (=Relative_Opt._(4)!E30)	{=MMULT(TRANSPOSE(Portfolio weights); Alpha of the assets)}	=MMULT(TRANSPOSE(E9:E16);'Relative Opt. (3)'!E43:E50)}
Residual variance (=Relative_Opt._(4)!E31)	=Variance of the active weights –Timing risk	=I21-I23
Residual standard deviation (=Relative_Opt._(4)!E32)	=Square root(Residual variance)	=SQRT(E31)
Lambda (=Relative_Opt._(4)!E33)	=Excess benchmark return/(2*Benchmark standard deviation^2)	='Relative Opt. (3)'!L23/(2*'Relative Opt. (3)'!L24^2)
Objective function (=Relative_Opt._(4)!E34)	=Alpha Portfolio-Lambda*Residual variance	=E30-E33*E31
Timing restriction (=Relative_Opt._(4)!E37)	=0	=Assumptions General!C287

Fig. 13.40 Calculating the relative optimization

- Lower/upper bound: $w_i \geq 0.05$ for all i $= 1, \ldots, n$
  $w_i \leq 0,3$ for all i $= 1, \ldots, n$
- Timing restriction (exclusion of the timing component):

$$\beta_{\mathrm{P}} = \beta_{\mathrm{B}} = 1 \ \Leftrightarrow \beta_{\mathrm{AP}} = 0$$

with
β_P: beta factor of the portfolio
β_{AP}: active beta of the portfolio relative to the benchmark

It would also be possible to fix lambda at one and use the permissible residual risk as a binding restriction. For this risk, which is equivalent to the tracking error for an active beta of zero, the optimization then determines the maximum outperformance that can be expected (active return).

The weights of the assets in the starting portfolio are initially entered in the cells `D9:D16` in the worksheet `Relative_Opt_(4)`. The values that appear in the worksheet `Relative_Opt_(4)` in cells `E9:E16` are the values after the portfolio optimization. Prior to the portfolio optimization, the weights of the starting portfolio are used, which are overwritten by the optimized weights derived via portfolio optimization.

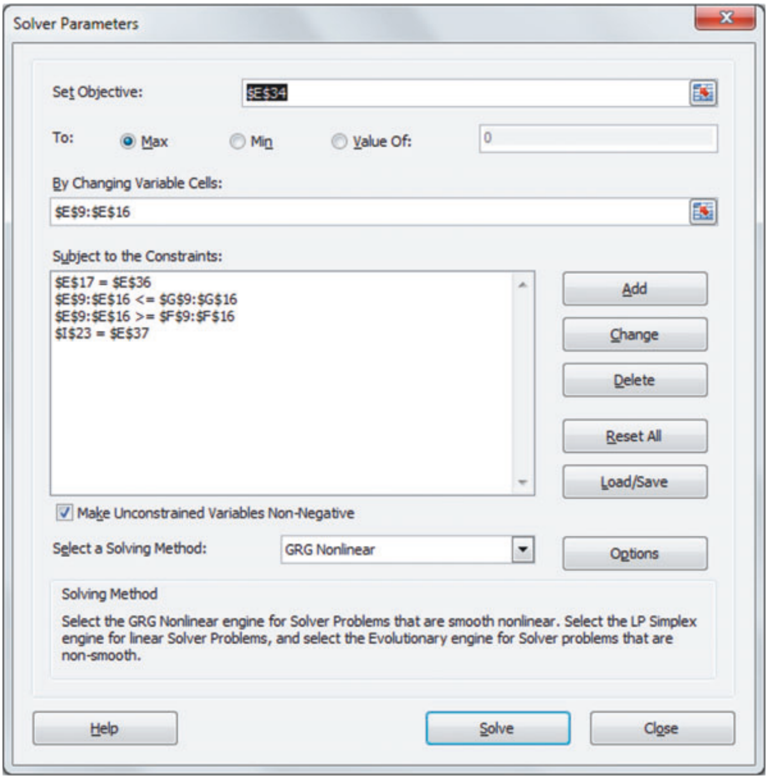
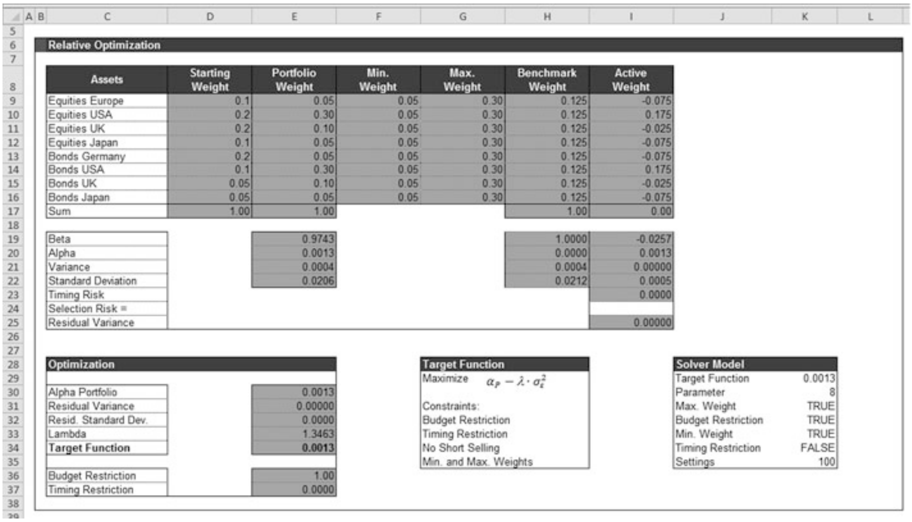


Fig. 13.41 Relative optimization using the Solver function



Relative Optimization

Assets	Starting Weight	Portfolio Weight	Min. Weight	Max. Weight	Benchmark Weight	Active Weight
Equities Europe	0.1	0.05	0.05	0.30	0.125	-0.075
Equities USA	0.2	0.30	0.05	0.30	0.125	0.175
Equities UK	0.2	0.10	0.05	0.30	0.125	-0.025
Equities Japan	0.1	0.05	0.05	0.30	0.125	-0.075
Bonds Germany	0.2	0.05	0.05	0.30	0.125	-0.075
Bonds USA	0.1	0.30	0.05	0.30	0.125	0.175
Bonds UK	0.05	0.10	0.05	0.30	0.125	-0.025
Bonds Japan	0.05	0.05	0.05	0.30	0.125	-0.075
Sum	1.00	1.00			1.00	0.00

Beta	0.9743	1.0000	-0.0257
Alpha	0.0013	0.0000	0.0013
Variance	0.0004	0.0004	0.00000
Standard Deviation	0.0206	0.0212	0.0005
Timing Risk			0.0000
Selection Risk =			
Residual Variance			0.00000

Optimization	
Alpha Portfolio	0.0013
Residual Variance	0.00000
Resid. Standard Dev.	0.0000
Lambda	1.3463
Target Function	**0.0013**
Budget Restriction	1.00
Timing Restriction	0.0000

Target Function
Maximize $\alpha_P - \lambda \cdot \sigma_\varepsilon^2$

Constraints:
Budget Restriction
Timing Restriction
No Short Selling
Min. and Max. Weights

Solver Model	
Target Function	0.0013
Parameter	8
Max. Weight	TRUE
Budget Restriction	TRUE
Min. Weight	TRUE
Timing Restriction	FALSE
Settings	100

Fig. 13.42 Results of the relative optimization (Work File Portfolio Management, Worksheet Relative_Opt._(4))

The formulas for the optimization are equivalent to those in the worksheet `Relative_Opt._(3)`. The following formulas are used during the relative optimization (see Fig. 13.40):

The optimization requires the use of the Solver in the worksheet `Relative_Opt._(4)`. The input values are shown in Fig. 13.41. Figure 13.42 shows the results of the relative optimization:

4.2.4 Summary of the Results of the Relative Optimization

In the worksheet `Relative_Opt._Summ.` the results of the relative optimization in the context of active portfolio management are shown and graphically assessed (see Fig. 13.43).

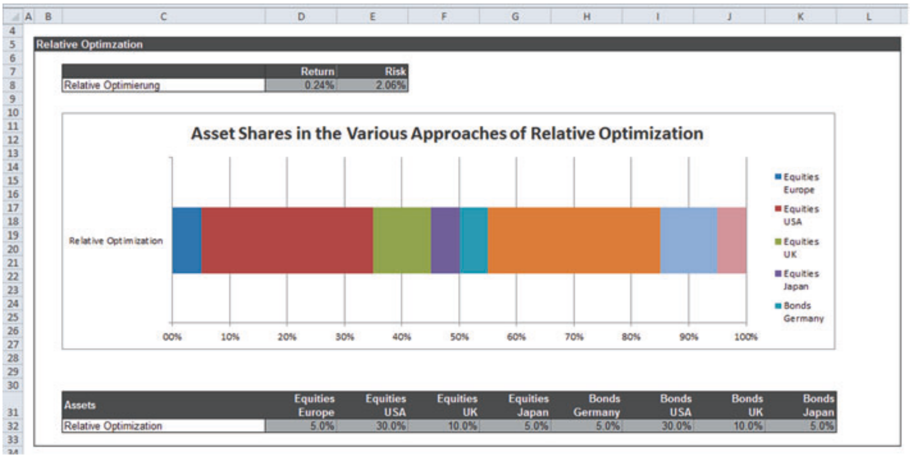


Fig. 13.43 Summary of the results of the relative optimization (Work File Portfolio Management, Worksheet Relative_Opt._Summ.)

5 Passive Portfolio Management

> Passive portfolio management aims at replicating a specific benchmark with high precision and at low cost.

The implementation of passive investment strategies in portfolio management mainly aims at forming a tracking portfolio which continuously replicates the value development of an underlying benchmark. In contrast to the active portfolio management, the passive investment strategy does not attempt to anticipate market developments. The main idea of passive portfolio management is based on the hypothesis of efficient markets and the corresponding difficulty to forecast markets.

Against the backdrop of this difficulty, passive portfolio management fundamentally assumes that the ability to forecast financial markets is extremely limited due to the inherent prediction errors. If the forecasts of the input parameters are not only of insufficient quality, but also very expensive, a passive management strategy is advisable. The aim is to replicate a benchmark portfolio with high precision and at low cost.

A theoretical justification is provided by the CAPM, which classifies deviations from the market portfolio as a zero sum game, where on average the assumption of additional risks is not compensated via higher returns. Similarly, the market efficiency hypothesis does not postulate a systematic informational advantage, which implies that any attempt to anticipate market movements will not be rewarded by an outperformance relative to a well-diversified benchmark index. In other words: the cost involved in obtaining an informational advantage relative to other market participants which results in better forecasts is relatively high due to the expected low quality of the estimates. If capital markets are comparably efficient it thus appears quite reasonable to use passive investment strategies in applied work.

Passive portfolio management can be justified from a

- theoretical,
- empirical and
- applied perspective.

The major theoretical considerations, namely the hypothesis of efficient capital markets and the CAPM, were already reviewed. If markets are in fact highly efficient, the speed and precision of information processing in capital markets makes it very difficult to achieve an outperformance by obtaining and processing information in the context of active portfolio management. However, an efficient market still requires a sufficient number of able participants who assure the efficient outcome. But under the assumption of an already sufficiently high market efficiency, the addition of a marginal participant will by definition not result in a forecast-based informational advantage.

An empirical justification for the success of passive portfolio management can be derived from these theoretical considerations. Empirical research supports the relevance of market efficiency with the insight that the majority of active portfolio managers report a value development of their portfolios that is worse than the index performance. While there are also a few portfolio managers that are able to beat their underlying benchmark, on balance the zero sum game remains a valid description of the market activity. In this comparison it must always be kept in mind that indexes represent price movements without any costs, while investors and fund managers need to consider administrative cost, trading costs, taxes and other factors.

A practical argument for investments in passive strategies follows from the reduced cost structure. Since passive investment strategies are mainly limited to purchasing and holding the market portfolio, the cost-intensive forecast of expectations in the context of an active portfolio management is completely unnecessary. Transaction costs are usually not lower in passive management, but the turnover is significantly reduced. This again reduces the administrative costs.

The aim of passive portfolio management is the precise and cost effective replication of a specific benchmark portfolio. It will be frequently the case that the benchmark cannot be replicated exactly. This is due not only to the necessary administrative costs, but also to the fact that financial assets are not infinitely divisible. For that reason, only an approximate replication of the benchmark is frequently possible. Several approaches exist for replicating a benchmark.

It is possible to

- effectively replicate the benchmark (full replication) or
- approximately replicate the benchmark (sampling).

Figure 13.44 shows the different possibilities for index tracking:

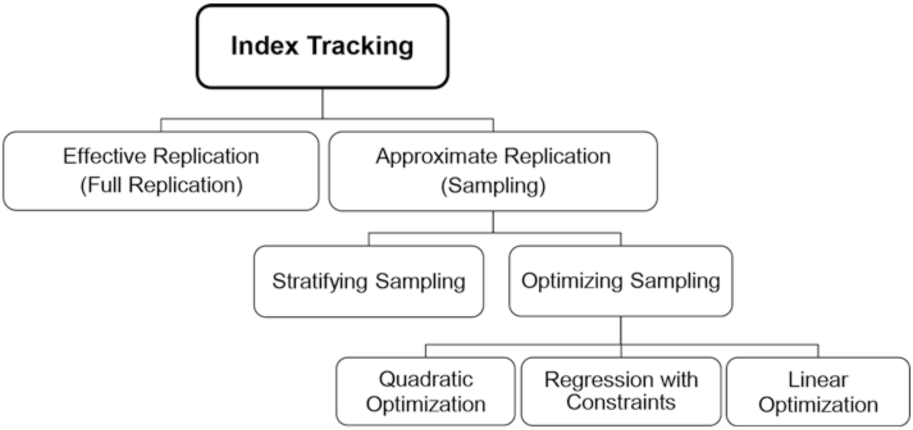


Fig. 13.44 Approaches of index tracking

Effective Replication (Full Replication)

The aim of effective replication is minimization or elimination of unsystematic risk. While exact replication is the most obvious approach, there are several reasons why it cannot be implemented fully in most instances:

- It is a costly method. Especially transaction costs are high, which result from the repeated adjustment and restructuring of the portfolio due to changes in the rules of benchmark construction.
- When the market capitalization changes (for example capital increase), assets in the portfolio must be acquired (in the case of capital-weighted indexes).
- In this context it is also important to realize that no fractional securities exist. When constructing an index, this fact is not considered. Deviations from the benchmark weights, even small ones, must occasionally be eliminated via purchases or sales.
- Effective replication is made even more difficult by the existence of legislation. As an example, there are upper limits for the weights of individual securities in the portfolios of funds. However, exemptions exist for so-called ETFs (Exchange Traded Funds) which replicate the value development of indexes.

Approximate Replication (Tracking)

The approximate replication (tracking) can be broken down into random and targeted security selection. In the case of the naive selection, equally-weighted or market-weighted portfolios are assembled. The methods of the targeted index replication include

- stratified sampling and
- optimizing sampling.

The method of stratified sampling breaks down the index into segments and the titles are selected heuristically with reference to different criteria such as

- capitalization,
- industry,
- region or
- correlation.

For each of these segments, appropriate securities are selected. When applied manually, this method takes a long time and requires a lot of experience on the part of the portfolio manager.

Optimizing sampling aims at reaching the optimum objective function while at the same time capturing the attributes of the tracking portfolio in the constraints. The following methods are used in optimizing sampling:

- Quadratic optimization,
- Regression with constraints as well as
- Linear optimization.

5.1 Quadratic Optimization

The quadratic approaches of index tracking will be presented in the following sections. In line with the previously presented methods, these include:

- Index tracking based on MARKOWITZ and
- Index tracking based on relative optimization with the Single Index Model (SIM).

Quadratic optimization involves solving a quadratic function with linear constraints. This was already shown in the context of active portfolio management. All following quadratic approaches refer to the criterion of minimizing the tracking error variance.

In order to allow a fuller assessment of the various methods we want to briefly review the terms tracking and tracking error. The aim of portfolio tracking or index tracking is to capture the value development of a comparable portfolio or index as closely as possible. The deviation between the underlying portfolio and the so-called tracking portfolio was initially called tracking error and the variance of these return deviations was consequently labeled as tracking error variance.[5] As more work was published on the subject, the term tracking error was used mainly for the square root of the tracking error variance, in other words the standard deviation of the return difference between tracking portfolio and index portfolio. Thus the unit tracking error is identical to the definition of active risk, which focuses in the perspective of active management.

Formally, this is the calculated dispersion (volatility) of the return deviations of a portfolio compared to an alternative portfolio, the benchmark. Only the motivation for the comparison differs with the different intentions. In one case (active portfolio management), the motivation is to exceed the benchmark while the risk of deviations is accepted on purpose. In the other case (passive portfolio management), the aim is to replicate the performance of a benchmark index with as little deviation as possible. Thus index tracking is an attempt to keep the selection risk as low as possible.

5.1.1 Index Tracking Based on Markowitz

> Index tracking based on MARKOWITZ aims at minimizing the tracking error variance.

The index tracking approach can be derived from the fundamental methodology of MARKOWITZ. The aim is the best possible replication of an underlying benchmark. The optimal implementation of a tracking portfolio reduces the active risk and the active return to zero.

The implementation of index tracking requires constraints concerning the active return and the active risk. For that purpose we again utilize the definition of an active position.

$$w_A = w_P - w_B$$

The active return of a portfolio is given by the difference of the return of the tracking portfolio and the benchmark. The following relationship holds:

$$r_A = r_P - r_B = w_P^T \cdot r - w_B^T \cdot r = (w_P^T - w_B^T) \cdot r = w_A^T \cdot r$$

with r =vector of the expected returns of the securities included

The active risk in the sense of the tracking error variance is given by:

$$TEV = \sigma_{AP}^2 = w_A^T \cdot \Sigma \cdot w_A$$

In order to achieve the highest possible precision in mimicking the benchmark with the tracking portfolio, the aim in the context of the optimization based on MARKOWITZ is the minimization of the tracking error variance given binding constraints. In matrix notation, the objective function follows directly from these considerations:

$$f(w) = \mathbf{w}_A^{\mathbf{T}} \cdot V \cdot \mathbf{w}_A \rightarrow min!$$

As discussed at the beginning of this section, the precise implementation of this approach requires a value of zero for the active return. This is taken into consideration in the form of a constraint.

- Return restriction: $r_A = w_A^T \cdot \mathrm{r} = 0$

In addition to this restriction on the active return, other, already familiar restrictions are also used again.

- Budget restriction:

$$\sum_{i=1}^{N} w_{P_i} = 1 \; resp. \; \sum_{i=1}^{N} w_{AP_i} = 0$$

$$1^T \cdot w_P = 1 \quad 1^T \cdot W_{AP} = 0$$

- Non-negativity constraint, $w_i \geq 0$, for all i = 1, ..., n
  no short selling:

Index tracking based on the approach of MARKOWITZ only differs from the previously presented method of relative optimization by setting the active return equal to zero, while active portfolio management targets a positive value. The active risk, in other words the tracking error variance or the tracking error should be as small as possible.

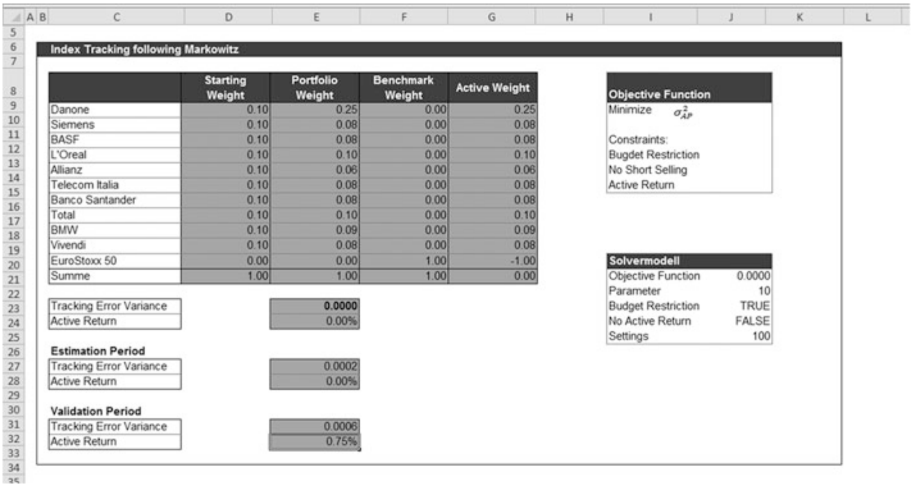
Position	Formula	Excel implementation
Tracking error (=IndexT_Markowitz_(4)!E22)	{=MMULT(MMULT(TRANSPOSE(Column vector of the portfolio weights); Covariances; Column vector of the portfolio weights)	=MMULT(MMULT(TRANSPOSE(G9:G19);'IndexT Markowitz (3)'!D26:N36);G9:G19)}
Active return (=IndexT_Markowitz_(4)!E23)	{=MMULT(TRANSPOSE(Column vector of the portfolio weights); Expected excess return)}	=MMULT(TRANSPOSE(G9:G19);'IndexT Markowitz (3)'!D10:D20)}
Tracking error variance for the estimation period (=IndexT_Markowitz_(4)!E26)	=VAR.P(Active return 31.01.t_9 to 31.07.t_5)	=VAR.P('IndexT Markowitz (2)'!O7:O61)
Active return for the estimation period (=IndexT_Markowitz_(4)!E27)	=AVERAGE(Active return 31.01.t_9 to 31.07.t_5)	=AVERAGE('IndexT Markowitz (2)'!O7:O61)
Tracking error variance for the validation period (=IndexT_Markowitz_(4)!E30)	=VAR.P(Active return 31.08.t_5 to 29.02.t_0)	=VAR.P('IndexT Markowitz (2)'!O62:O116)
Active return for the validation period (=IndexT_Markowitz_(4)!E31)	=AVERAGE(Active return 31.08.t_5 to 29.02.t_0)	=AVERAGE('IndexT Markowitz (2)'!O62:O116)

Fig. 13.45 Calculating the tracking error variance and the active return for the estimation period and the validation period

Index tracking based on the optimization following MARKOWITZ relies on estimates of the variance-covariance matrix. However, against the background of the previously discussed problems posed by a benchmark that consists of many assets, the estimation of the variance-covariance matrix is not a trivial task. In the next section we will therefore also present an index tracking method based on the Single Index Model (SIM).

The calculations needed to optimize the portfolio following MARKOWITZ are identical to the calculations required for both absolute and relative optimization. However, in the worksheet IndexT_Markowitz_(4), the tracking error as well as the active return for the entire time period, the estimation period and the validation period need to be determined.

The following formulas are applied (see Fig. 13.45):



Index Tracking following Markowitz

	Starting Weight	Portfolio Weight	Benchmark Weight	Active Weight
Danone	0.10	0.25	0.00	0.25
Siemens	0.10	0.08	0.00	0.08
BASF	0.10	0.08	0.00	0.08
L'Oreal	0.10	0.10	0.00	0.10
Allianz	0.10	0.06	0.00	0.06
Telecom Italia	0.10	0.08	0.00	0.08
Banco Santander	0.10	0.08	0.00	0.08
Total	0.10	0.10	0.00	0.10
BMW	0.10	0.09	0.00	0.09
Vivendi	0.10	0.08	0.00	0.08
EuroStoxx 50	0.00	0.00	1.00	-1.00
Summe	1.00	1.00	1.00	0.00

Tracking Error Variance	0.0000
Active Return	0.00%
Estimation Period	
Tracking Error Variance	0.0002
Active Return	0.00%
Validation Period	
Tracking Error Variance	0.0006
Active Return	0.75%

Objective Function
Minimize σ^2_{AP}

Constraints:
Bugdet Restriction
No Short Selling
Active Return

Solvermodell	
Objective Function	0.0000
Parameter	10
Budget Restriction	TRUE
No Active Return	FALSE
Settings	100

Fig. 13.46 Results of the index tracking according to Markowitz (Work File Portfolio Management, Worksheet IndexT_Markowitz_(4))

The optimal portfolio is characterized by the following values (see Fig. 13.46):

5.1.2 Index Tracking Starting with Relative Optimization Based on the Single Index Model

Index tracking determines a tracking portfolio with price development and risk structure that correspond as closely as possible to the target portfolio.

Index tracking aims at developing a tracking portfolio which corresponds as closely as possible to a target portfolio (benchmark portfolio) concerning its price development and risk structure. It is possible that the investment universe and the restrictions of the target portfolio and the tracking portfolio differ. The structure of the problem is similar to the case of relative optimization. However, the aim is not to maximize the alpha of the portfolio against the residual risk. Instead the task is to form a portfolio that is as close as possible to the target portfolio.

The attributes of the tracking portfolio in the context of the Single Index Model (SIM) are

- an alpha of zero (the benchmark alpha is equal to zero),

- a beta of one (he benchmark beta is equal to one) and
- a minimum residual risk (tracking error).

This excludes the timing component, so that the tracking error variance, respectively the active risk σ_{AP}^2 is equal to the residual risk σ_ε^2.

Starting from the consideration that the tracking error variance must be minimized, the objective function is:

$$\sigma_\varepsilon^2 \rightarrow min!$$

The constraints are

- Budget restriction
- Non-negativity constraint, no short selling
- Timing restriction (exclusion of the timing component)
- Selection restriction (exclusion of the selection component)

The constraint of an upper and lower bound is not invoked in this case. Otherwise it would frequently not be possible to obtain a valid solution given the low number of assets considered.

It should be noted at this point that the selection effect cannot be eliminated completely. While the constraint states that no systematic selection effect is present, there will be temporary and unsystematic deviations, since the tracking portfolio may have a different asset composition than the benchmark. This risk should be kept as small as possible. Thus the method of index tracking on the basis of the SIM is a specific case of relative optimization, where the objective function needs to be modified slightly and additional constraints are added.

Index tracking based on relative optimization with the SIM involves the estimation of the alpha and beta parameters for the individual securities in the tracking portfolio. This raises the issue of stability of the beta coefficients, which are subject to estimation error. Especially if the data basis is small, the estimated parameters can change significantly over time.

The objective function for index tracking starting with the relative optimization is to minimize the active risk, respectively the residual risk:

$$\sigma_\varepsilon^2 = \sigma_{AP}^2 - \beta_{AP}^2 \cdot \sigma_B^2 \rightarrow min!!$$

In matrix notation:

$$f(w) = w_P^T \cdot V \cdot w_P - \left(w_P^T \cdot \beta\right)^2 \cdot w_B^T \cdot V \cdot w_B \to min!$$

with
w_P = column vector of the weights in the tracking portfolio
V = variance-covariance matrix of the estimated asset returns
β = column vector of the beta factors of the assets relative to the benchmark
w_B = column vector of the weights in the benchmark portfolio

The following restrictions are assumed for index tracking based on relative optimization:

- Budget restriction: $\sum_{i=1}^{N} w_{P_i} = 1 \; resp. \; \sum_{i=1}^{N} w_{AP_i} = 0$
  w_{P_i} : weight of asset $i$in the tracking portfolio
  w_{AP_i} : active weight of asset i in the tracking portfolio, in matrix notation

$$1^{\mathrm{T}} \cdot \mathbf{w}_{\mathrm{P}} = 1 \quad 1^{\mathrm{T}} \cdot \mathbf{w}_{\mathrm{AP}} = 0$$

  Non-negativity constraint, $w_i \geq 0$, for all i = 1, . . . , n
  no short selling:
- Timing restriction (exclusion of the timing component):

$$\beta_{\mathrm{P}} = \beta_{\mathrm{B}} = 1 \Leftrightarrow \beta_{\mathrm{AP}} = 0$$

- with
  β_P: beta factor of the portfolio relative to the benchmark
  $ß_{AP}$: active beta of the portfolios relative to the benchmark
- Selection restriction: $\alpha_p = 0$
  with α_P: alpha of the portfolio

In cells `C7:M116` of the worksheet `IndexT_Rel._Opt._(1)` the monthly index tracking values for all assets and for the Euro Stoxx 50 are initially calculated. In the worksheet `IndexT_Rel._Opt._(2)` the monthly excess returns of the individual assets and the Euro Stoxx are calculated by subtracting the monthly risk-free rate from the monthly index tracking values.

In the worksheet `IndexT_Rel._Opt._(3)` the covariance matrix is determined in cells `D11:N21`. In cells `D27:E37` alpha and beta of the assets and the Euro Stoxx are calculated. Since the following approaches of passive portfolio management require an estimation period (31.12.t_{-9}– 31.07.t_{-5}) and a validation period (31.08.t_{-5}–29.02.t_0), the calculation of the covariance matrix is done for the estimation period (31.12. t_{-9} – 31.07.t_{-5}) for reasons of comparability.

The active position (active weight) of the portfolio assets and the Euro Stoxx are calculated in cells `F48:F58` based on the given portfolio weights (cells `D45:D58`) and the given benchmark weights (cells `E48:E58`). The sum of the portfolio weights, the benchmark and the active positions are calculated in the cells `D59:F59`.

Also required are beta and alpha of the portfolio (`D61` and `D62`), beta and alpha of the benchmark (`E61` and `E62`) and the active beta and alpha (`F61` und `F62`). Prior to the portfolio optimization, the variance of the portfolio (`D63`), the variance of the benchmark (`E63`), the variance of the active positions (`F63`) as well as the residual risk and the selection risk (`F64`) need to be calculated.

The following formulas are used (see Fig. 13.47):

Worksheet `IndexT_Rel._Opt._(4)` is used for the optimization. Initially the weights of the assets in the starting portfolio are entered in cells `D9:D19`. The values that are visible in the worksheet `IndexT_Rel._Opt._(4)` in cells `E9:E19` are the values after the portfolio optimization. The weights of the starting portfolio are initially used for the portfolio optimization and are overwritten with the optimized weights during the optimization.

Finally the portfolio is optimized in the worksheet `IndexT_Rel._Opt._(4)` with the help of the Solver. The formulas for the optimization are those used in the worksheet `IndexT_Rel._Opt._(3)`. Figure 13.48 shows the needed Solver input:

The optimum portfolio has the following values (see Fig. 13.49):

Position	Formula	Excel implementation
Beta of the portfolio (=IndexT_Rel._Opt._(3)!D61)	{=MMULT(TRANSPOSE(Portfolio weights); Beta of the assets)}	{=MMULT(TRANSPOSE(D48:D58);D27:D37)}
Alpha of the portfolio (=IndexT_Rel._Opt._(3)!D62)	{=MMULT(TRANSPOSE(Portfolio weights); Alpha of the assets)}	{=MMULT(TRANSPOSE(D48:D58);E27:E37)}
Variance of the portfolio (=IndexT_Rel._Opt._(3)!D63)	{=MMULT(MMULT(TRANSPOSE(Column vector of the portfolio weights); Co-variances; Column vector of the portfolio weights)	{=MMULT(MMULT(TRANSPOSE(D48:D58);$D$11:$N$21);D48:D58)}
Beta of the benchmark (=IndexT_Rel._Opt._(3)!E61)	{=MMULT(TRANSPOSE(Benchmark weights);Beta of the assets)}	{=MMULT(TRANSPOSE(E48:E58);D27:D37)}
Alpha of the benchmark (=IndexT_Rel._Opt._(3)!E62)	{=MMULT(TRANSPOSE(Benchmark weights); Alpha of the assets)}	{=MMULT(TRANSPOSE(E48:E58);E27:E37)}
Variance of the bench-mark (=IndexT_Rel._Opt._(3)!E63)	{=MMULT(MMULT(TRANSPOSE(Column vector of the benchmark weights); Covariances; Column vector of the benchmark weights)	{=MMULT(MMULT(TRANSPOSE(E48:E58);$D$11:$N$21);E48:E58}
Active beta (=IndexT_Rel._Opt._(3)!F61)	{=MMULT(TRANSPOSE(Active weights); Beta of the assets)}	{=MMULT(TRANSPOSE(F48:F58);D27:D37)}
Active alpha (=IndexT_Rel._Opt._(3)!F62)	{=MMULT(TRANSPOSE(Aktive weights); Alpha of the assets)}	{=MMULT(TRANSPOSE(F48:F58);E27:E37)}
Variance of the active positions (=IndexT_Rel._Opt._(3)!F63)	{=MMULT(MMULT(TRANSPOSE(Column vector of the active weights); Covari-ances; Column vector of the active weights)	{=MMULT(MMULT(TRANSPOSE(F48:F58);$D$11:$N$21);F48:F58}
Residual variance (=IndexT_Rel._Opt._(3)!F64)	= Variance of the active positions - active beta^2* Variance of the benchmark	=D63-D61^2*E63

Fig. 13.47 Calculating different alpha, beta and variance values

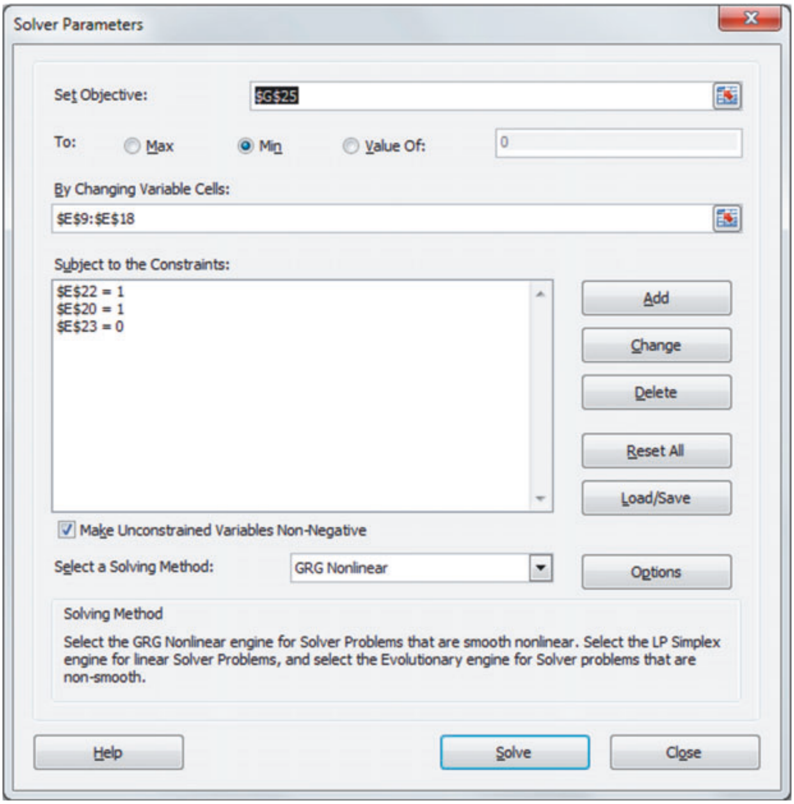
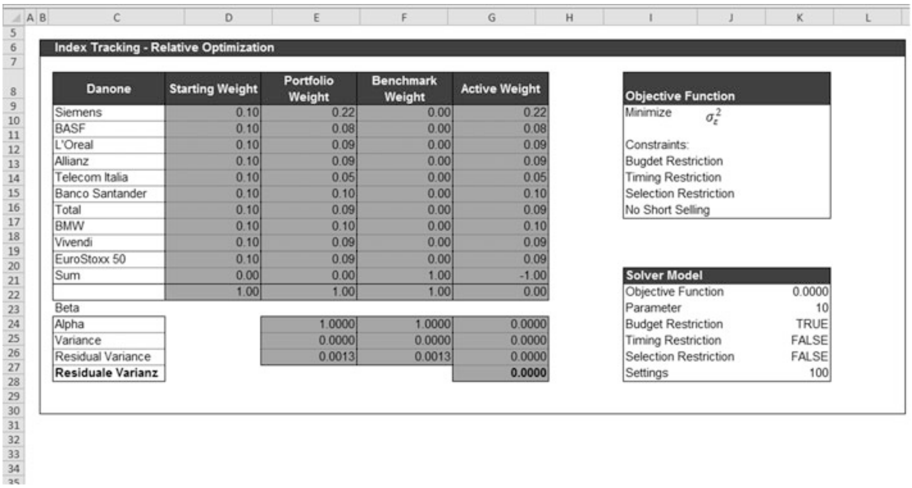


Fig. 13.48 Solver input for index tracking based on relative optimization



Index Tracking - Relative Optimization

Danone	Starting Weight	Portfolio Weight	Benchmark Weight	Active Weight
Siemens	0.10	0.22	0.00	0.22
BASF	0.10	0.08	0.00	0.08
L'Oreal	0.10	0.09	0.00	0.09
Allianz	0.10	0.09	0.00	0.09
Telecom Italia	0.10	0.05	0.00	0.05
Banco Santander	0.10	0.10	0.00	0.10
Total	0.10	0.09	0.00	0.09
BMW	0.10	0.10	0.00	0.10
Vivendi	0.10	0.09	0.00	0.09
EuroStoxx 50	0.10	0.09	0.00	0.09
Sum	0.00	0.00	1.00	-1.00
	1.00	1.00	1.00	0.00
Beta				
Alpha		1.0000	1.0000	0.0000
Variance		0.0000	0.0000	0.0000
Residual Variance		0.0013	0.0013	0.0000
Residuale Varianz				**0.0000**

Objective Function	
Minimize	σ_ε^2
Constraints:	
Bugdet Restriction	
Timing Restriction	
Selection Restriction	
No Short Selling	

Solver Model	
Objective Function	0.0000
Parameter	10
Budget Restriction	TRUE
Timing Restriction	FALSE
Selection Restriction	FALSE
Settings	100

Fig. 13.49 Results of the index based on relative optimization (Work File Portfolio Management, Worksheet IndexT_Rel._Opt. _(4))

5.2 Constrained Regression

In a constrained regression, the portfolio return should move as closely as possible with the index return.

The previously presented index tracking methods primarily focused on the risk aspect when minimizing the objective function. The constrained regression also focuses on minimizing the squared active return and thus on minimizing the tracking error variance. It still holds that the tracking portfolio needs to replicate as closely as possible the development of the underlying benchmark. Regression-based index tracking aims at minimizing the mean squared deviation between the return of the portfolio and the benchmark. Ideally the deviation is zero. The objective function is defined as follows:

$$\hat{\mathrm{E}}\left(r_A^2\right) = \sum_{t=1}^{T} (r_B - r_P)^2 = \sum_{t=1}^{T} r_A^2 \rightarrow min!$$

Regression-based index tracking is also subject to estimation error due the fact that parameters are determined ex ante. In this case, the expected value of the squared return differences is estimated immediately on the basis of historic return observations of the individual securities in the tracking portfolio and the benchmark. The estimate $\hat{E}\left(r_A^2\right)$ is defined as the historic mean value of the squared difference between the return of the tracking portfolio and the benchmark.

$$\hat{E}\left(r_A^2\right) = \frac{1}{T} \sum_{t=1}^{T} \left(r_{B,t} - r_{P,t}\right)^2$$

While the returns of the target portfolio are available either in the form of a benchmark portfolio determined by the investor or a synthetic benchmark, the returns of the tracking portfolio result from the final portfolio structure which is obtained via optimization. The composition of the tracking portfolio is in this context the variable component when solving the optimization problem. Inverting the argument, this implies the assumption that the returns of the tracking portfolio are subject to the portfolio optimization and are thus not directly observable. Thus it holds that:

$$r_{P,t} = \sum_{t=1}^{N} w_{P,i} \cdot r_{i,t} resp.\ r_{P,t} = w^{T} \cdot r_{TR}$$

The aim of the optimization is to find the values which minimize the objective function. Use of the weighted returns of the individual securities implies the following formula:

$$f = \hat{E}\left(r_A^2\right) = \frac{1}{T} \sum_{t=1}^{T} \left(r_{B,t} - \sum_{t=1}^{N} w_{P,i} \cdot r_{i,t} \right)^2$$

This formula leads to a function which is structurally identical to the objective function of the least squares estimation in multivariate linear regression analysis. The approach discussed here involves additional constraints. For that reason the approach is called constrained regression.

The objective of the constrained regression is to minimize the mean squared deviations and thus to minimize the tracking error variance:

$$E\left(r_A^2\right) = \sum_{t=1}^{T} (r_B - r_P)^2 = \sum_{t=1}^{T} r_A^2 \rightarrow min!$$

The value for the active return is again set equal to zero and considered in the form of a constraint.

- Return restriction: $r_A = w_A^T \cdot \mathrm{r} = 0$

Additional constraints are:

- Budget restriction:

$$\sum_{i=1}^{N} w_{P_i} = 1\ resp. \sum_{i=1}^{N} w_{AP_i} = 0$$

$$1^{\mathrm{T}} \cdot \mathbf{w_P} = 1 \quad 1^{\mathrm{T}} \cdot \mathbf{w_{AP}} = 0$$

- Non-negativity constraint, $w_i \geq 0$, for all i = 1, . . . , n

  no short selling:

The problem with the constrained regression is the estimation of constant weights on the basis of a time series. In reality, these weights are subject to drift due to price changes, which need to be neutralized from time via selling or buying. These transactions, however, always involve costs, which lower the performance.

Without adjustment, actual asset weights can deviate significantly over time from the previously determined weights and increase the tracking error. The return which is ultimately realized can thus differ strongly from the result of the benchmark.

If the estimation is repeated after some time with a new data set of equal length, where fresh data is added and old data is deleted, the optimization will most likely suggest new weights and the portfolio needs to be restructured. Just like the previous approaches, the regression method also requires repeated adjustments over longer investment horizons unless it is simply assumed that the input values of the estimates are representative and appropriate over time.

Position	Formula	Excel implementation
Objective function (squared active return) (=IndexT_Regression_(4)!E22)	=SUM (active return 31.01.t_{-9} to 31.07.t_{-5}^2)	=SUM('IndexT Regression (2)'!P7:P61)
Tracking error (=IndexT_Regression_(4)!E23)	=VAR.P(active return 31.01.t_{-9} to 31.07.t_{-5})	= =VAR.P('IndexT Regression (2)'!O7:O61)
Tracking error variance for the estimation period (=IndexT_Regression_(4)!E26)	=VAR.P(active return 31.01.t_{-9} to 31.07.t_{-5})	= =VAR.P('IndexT Regression (2)'!O7:O61)
Active return for the estimation period (=IndexT_Regression_(4)!E27)	=AVERAGE(active return 31.01.t_{-9} to 31.07.t_{-5})	=AVERAGE('IndexT Regression (2)'!O7:O61)
Tracking error variance for the validation period (=IndexT_Regression_(4)!E30)	=VAR.P(active return 31.08.t_{-5} to 29.02.t_0)	=VAR.P('IndexT Regression (2)'!O62:O116)
Active return for the validation period (=IndexT_Regression_(4)!E31)	=AVERAGE(active return 31.08.t_{-5} to 29.02.t_0)	=AVERAGE('IndexT Regression (2)'!O62:O116)

Fig. 13.50 Calculating the tracking error variance and the active return for the entire sample period, the estimation period and the validation period

Constraint Regression

	Starting Weight	Portfolio Weight	Benchmark Weight	Active Weight
Danone	0.10	0.03	0.00	0.03
Siemens	0.10	0.08	0.00	0.08
BASF	0.10	0.14	0.00	0.14
L'Oreal	0.10	0.18	0.00	0.18
Allianz	0.10	0.04	0.00	0.04
Telecom Italia	0.10	0.09	0.00	0.09
Banco Santander	0.10	0.10	0.00	0.10
Total	0.10	0.19	0.00	0.19
BMW	0.10	0.02	0.00	0.02
Vivendi	0.10	0.15	0.00	0.15
EuroStoxx 50	0.00	0.00	1.00	-1.00
Sum	1.00	1.00	1.00	0.00

Target Function	0.62%	Summe der quadrierte aktiven Renditen
Tracking Error Variance	0.0001	

Schätzzeitraum

Tracking Error Variance	0.0001
Active Return	-0.02%

Validation Period

Tracking Error Variance	0.0004
Active Return	-0.59%

Target Function
Minimize E(r-aktiv²)
Constraints:
Bugdet Restriction
No Short Selling
Min. and Max. Weights

Solver Model	
Target Function	0.62%
Parameter	10
Budget Restriction	TRUE
Min. Weight	TRUE
Max. Weight	TRUE
Settings	100

Fig. 13.51 Results of the index tracking using a constrained regression (Work File Portfolio Management, Worksheet IndexT_Regression _(3))

The calculation in Excel follows the previously discussed optimizations in passive portfolio management. These calculations can be found in the worksheets `IndexT_Regression_(1)` to `IndexT_Regression_(3)` in the Excel file.

The following formulas are used (see Fig. 13.50):

The values for the optimum portfolio can be seen in Fig. 13.51:

5.3 Linear Optimization

> In the case of linear optimization, the investor does not want to fall below the benchmark return, while allowing positive deviations.

Linear optimization is an additional method of index tracking. The aim of the linear optimization is to replicate as precisely as possible the return of the target portfolio (benchmark) with a specific set of assets. It also involves the method of regression analysis. The return of the benchmark at time t is given approximately by the weighted returns of the individual assets plus an unavoidable residual error ε_t. As in the previous case, this residual ε_t follows from the assumption of equal weights. In the real portfolio, however, the weights are subject to drift because of changing prices, which requires rebalancing in order to maintain the original weights.

The model-based composition of the benchmark return can be formulated as follows on the basis of the previously presented relationships:

$$r_{B,t} = w_{P,1}r_{1,t} + w_{P,2}r_{2,t} + \ldots w_{P,N}r_{N,t} + \varepsilon_t$$

with
r_B = benchmark return
$w_{P,n}$ = share of security n in the tracking portfolio
r_n = return of security n in the tracking portfolio
ε_t = residual

The problem with this type of index tracking is the inevitable presence of the residual ε_t, which follows from the regression-based optimization. The aim of the previous methods of passive portfolio management was to minimize this inevitable residual ε_t and to achieve a value of zero in the best case. However, index tracking on the basis of linear optimization follows a different approach. Here it is assumed that an investor does not want to fall below the return of the benchmark, but is obviously happy to accept a positive deviation. This assumption strongly reflects an asymmetric understanding of risk by the investor, where only losses in the sense of falling below a target (in this case the benchmark return) play a role.

The objective function to determine the tracking portfolio is:

$$f = \sum_{\substack{t=1 \\ r_{Pt} < r_{Bt}}}^{T} |r_{Pt} - r_{Bt}| \to min!$$

This also requires estimates where the asset and index returns are taken from historical data. The determination of estimates based on historical values again raises the issue of stability of the underlying variables.

In order to simplify the notation for the objective function, two auxiliary parameters are introduced.

- D_t^+ represents the positive difference between portfolio return and benchmark return
- D_t^- represents the negative deviation,

where both are given as positive numbers. Thus it holds for the active return r_A respectively the residual ε:

$$r_A = \varepsilon = D_t^+ - D_t^-$$

For the positive difference D_t^+ it holds that: $D_t^+ = r_{Pt} - r_{Bt}$, if $r_{Pt} > r_{Bt}$, otherwise $D_t^+ = 0$.

For the negative difference D_t^- it holds that: $D_t^- = r_{Pt} - r_{Bt}$, if $r_{Pt} < r_{Bt}$, otherwise $D_t^- = 0$.

From these equations the difference between portfolio return and benchmark return can be stated as follows:

$$r_{Pt} - r_{Bt} = D_t^+ - D_t^-$$

In the following example, the objective function can be stated with the auxiliary variables introduced above. The aim is to minimize the sum of the absolute values of the negative return deviations of the portfolio relative to the benchmark:

$$f = \sum_{\mathrm{t}=1}^{\mathrm{T}} D_t^- \rightarrow \text{min!}$$

The constraints are the budget restriction and the prohibition on short selling as well as the following equation:

$$\sum_{i=1}^{N} w_{P,i} r_{i,t} - D_t^+ + D_t^- = r_{B,t}$$

In addition D_t^+ and D_t^- always need to be greater than or equal to zero and if desired a minimum or maximum weight for the assets can be established.

The following constraints need to be considered in the case of linear optimization:

$$\sum_{i=1}^{N} w_{Pi} r_{it} - D_t^+ + D_t^- = r_{B,t}$$

for each point in time $t = 1, \ldots, T$

- Budget restriction:

$$\sum_{i=1}^{N} w_{P_i} = 1 \; resp. \sum_{i=1}^{N} w_{AP_i} = 0$$
$$1^T \cdot \mathbf{w_P} = 1 \quad 1^T \cdot \mathbf{w_{AP}} = 0$$

- Non-negativity constraint, $w_i \geq 0$, for all i = 1, . . . , n no short selling:

- Values of D:

$$D_t^+ \geq 0$$
$$\text{for each point in time} t = 1, ..., T$$
$$D_t^- \geq 0$$
$$\text{for each point in time} t = 1, ..., T$$

The calculations for the linear optimization again start with the monthly returns in the worksheet `IndexT_Linear_Opt._(1)` (cells `C7:M116`) and the monthly excess returns (cells `C7:M116`) in the worksheet `IndexT_Linear_Opt._(2)`. Additionally the portfolio return is calculated in cells `O7:O116`, which is initially based on the assumption of a naïve portfolio.

In cells `B7:B116` and `C7:C116` in the worksheet `IndexT_Lienare_Opt._(3)` the values of D^+ and D^- are initially set equal to zero. The benchmark return in cells `E7:E116` is calculated with the following formula:

$$\sum_{i=1}^{N} w_{Pi} r_{it} - D_t^+ + D_t^- = r_{Bt}$$

The following formula is used (see Fig. 13.52):

The target returns in cells `G7:G116` of the worksheet `IndexT_Linear_Opt._(3)` correspond to the excess returns of the

Position	Formula	Excel implementation
Benchmark return (`=IndexT_Linear_Opt._(3)!E7`)	=Portfolio return-D^++D^-	`='IndexT Linear Opt.(2)'!O7-B7+C7`

Fig. 13.52 Calculating the benchmark return

EuroStoxx in Column M of the worksheet `IndexT_Linear_Opt._(2)`. The Euro Stoxx is the benchmark of the portfolio and thus its excess return is also the minimum target return which the portfolio needs to achieve.

For the optimization with the Solver, the weights of the naïve portfolio and the stated constraints are utilized.

In an auxiliary calculation, the actual deviations of the portfolio return from the target return are calculated. An *IF* function is used to determine whether the deviations are positive or negative:

The following formulas are used: (see Fig. 13.53):

The sum D^+ and D^- for the estimation period (cells `L22:L23` and cells `L29:L30`) and the validation period (cells `L36:L37`) are calculated next. Also calculated are the tracking error variance for the estimation period (cell `L27`) and the validation period (cell `L34`) as well as the active return as the difference between portfolio return and target return for the estimation period (cell `L28`) and the validation period (cell `L35`). Finally the sum of $D^+$and D^- for the estimation period (cells `L31` and `L38`) and for the validation period is calculated.

The following formulas are used (see Fig. 13.54):

Finally the portfolio is optimized with the help of the Solver in the worksheet `IndexT_Linear_Opt._(3)`. Figure 13.55 shows the input needed for the Solver:

The result of the linear optimization is shown in Fig. 13.56:

Position	Formula	Excel implementation
Deviation positive (=IndexT_Linear_Opt._(3)!U7)	=IF(Portfolio return - Target return>0; Portfolio return - Target return;0)	=IF('IndexT Linear Opt. (2)'!O7-'IndexT Linear Opt. (3)'!G7>0;'IndexT Linear Opt. (2)'!O7-'IndexT Linear Opt. (3)'!G7;0)
Deviation negative (=IndexT_Linear_Opt._(3)!V7)	=IF(Portfolio return - Target return <0; (Portfolio return - Target return)*(-1);0)	=IF('IndexT Linear Opt. (2)'!O7-'IndexT Linear Opt. (3)'!G7<0;('IndexT Linear Opt. (2)'!O7-'IndexT Linear Opt. (3)'!G7)*(-1);0)
Active return (=IndexT_Linear_Opt._(3)!X7)	= Deviation positive - Deviation negative	=U7-V7

Fig. 13.53 Calculating the actual deviations of the portfolio return from the target return

Position	Formula	Excel implementation
Sum D^+ (=IndexT_Linear_Opt._(3)!L22)	=SUM (D^+ 31.01.t_{-9} bis 31.07.t_{-5})	=SUM(B7:B61)
Objective function sum D^- (=IndexT_Linear_Opt._(3)!L23)	=SUM (D^- 31.01.t_{-9} bis 31.07.t_{-5})	=SUM(C7:C61)
Sum D^+ and D^- (=IndexT_Linear_Opt._(3)!L24)	=SUM ($D^{+)}$ + SUM (D^-)	=L22+L23
Tracking error variance for the estimation period (=IndexT_Linear_Opt._(3)!L27)	=VAR.P (active return 31.01.t_{-9} to 31.07.t_{-5})	=VAR.P(X7:X61)
Active return for the estimation period (=IndexT_Linear_Opt._(3)!L28)	=AVERAGE (active return 31.01.t_{-9} to 31.07.t_{-5})	=AVERAGE(X7:X61)
Positive difference D^+ for the estimation period (=IndexT_Linear_Opt._(3)!L29)	=SUM (D^+ 31.01.t_{-9} to 31.07.t_{-5})	=SUM(U7:U61)
Negative difference D^- for the estimation period (=IndexT_Linear_Opt._(3)!L30)	=SUM (D^- 31.01.t_{-9} to 31.07.t_{-5})	=SUM(V7:V61)
Sum D^+ and D^- for the estimation period (=IndexT_Linear_Opt._(3)!L31)	=SUM(D^+) + SUM (D^-)	=L29+L30
Tracking error variance for the validation period (=IndexT_Linea	=VAR.P(active return 31.08.t_{-5} to 29.02.t_0)	=VAR.P(X62:X116)

Fig. 13.54 Calculating different variables used for linear optimization

r_Opt._(3)!L34)		
Active return for the validation period (=IndexT_Linear_Opt._(3)!L35)	=AVERAGE(active return 31.08.t_{-5} to 29.02.t_0)	=AVERAGE(X62:X116)
Positive difference D^+ for the validation period (=IndexT_Linear_Opt._(3)!L36)	=SUM (D^+ return 31.08.t_{-5} to 29.02.t_0)	=SUM(U62:U116)
Negative difference D^- for the validation period (=IndexT_Linear_Opt._(3)!L37)	=SUM (D^- 31.08.t_{-5} to 29.02.t_0)	=SUM(V62:V116)
Sum D^+ and D^- for the validation period (=IndexT_Linear_Opt._(3)!L38)	=SUM (D^+) + SUM (D^-)	=L36+L37

Fig. 13.54 (Continued)

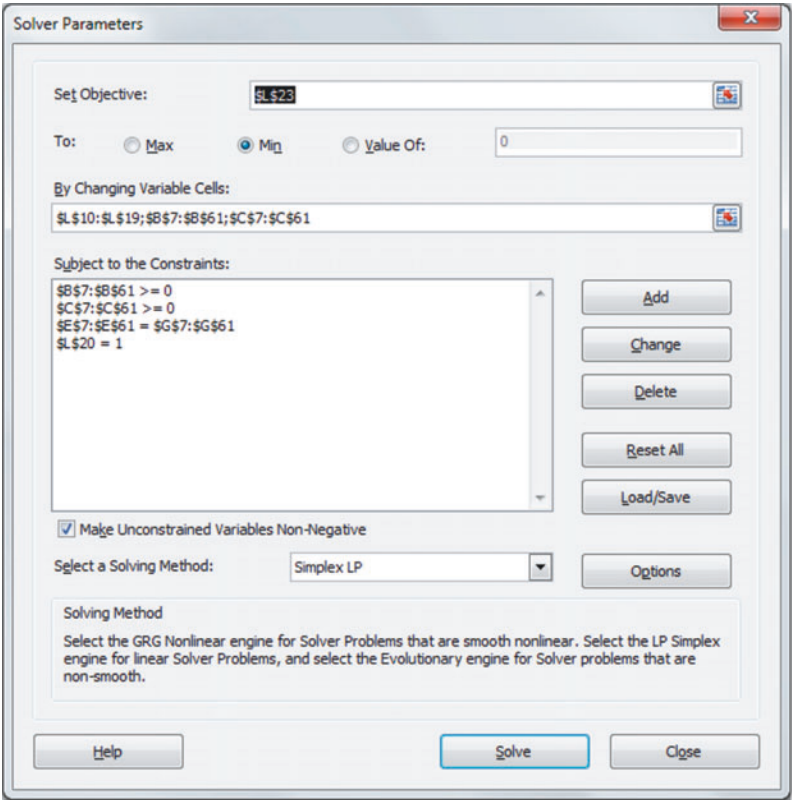


Fig. 13.55 Solver input for the linear optimization

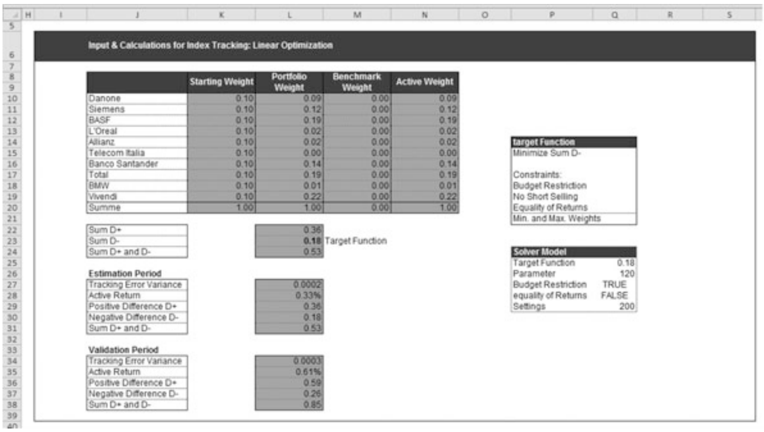
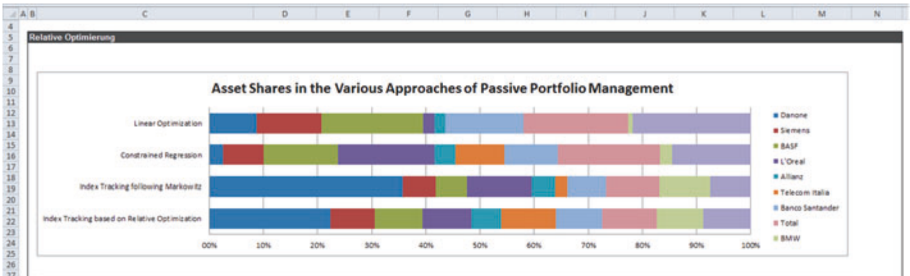


Fig. 13.56 Results of the linear optimization (Work File Portfolio Management, Worksheet IndexT_Linear _Opt._(3))

5.4 Summary of the Results for Passive Portfolio Management

In the worksheet `Passive_PM._Summ.` all the individual optimization results for passive portfolio management are presented and displayed graphically (see Fig. 13.57).



Assets	Danone	Siemens	BASF	L'Oreal	Allianz	Telecom Italia	Banco Santander	Total	BMW	Vivendi
Index Tracking based on Relative Optimization	22.3%	8.2%	8.8%	9.1%	5.4%	10.2%	8.6%	10.0%	8.7%	8.7%
Index Tracking following Markowitz	35.7%	6.1%	5.8%	11.9%	4.4%	2.2%	7.2%	9.8%	9.4%	7.5%
Constrained Regression	2.5%	7.5%	13.7%	17.9%	3.8%	9.0%	9.9%	18.9%	2.3%	14.5%
Linear Optimization	8.7%	12.0%	18.8%	2.0%	2.1%	0.0%	14.3%	19.4%	0.8%	21.8%

Fig. 13.57 Summary for the results of the passive portfolio management (Work File Portfolio Management, Worksheet Passive_PM_Summ.)

6 Summary

In this chapter the financial modeler gained the following insights:

Active Portfolio Management

- The aim of absolute optimization is to get to an optimum portfolio allocation, in other words to achieve the maximum return for a given level of risk.
- Methods of absolute optimization include the minimum variance portfolio, the minimum variance portfolio with lower and upper bounds, the tangency portfolio, the maximum return portfolio, the efficient portfolio for given return, the optimum portfolio without risk-free investment opportunity and the optimum portfolio with risk-free investment opportunity.
- The minimum variance portfolio minimizes the portfolio risk.

- Short selling is the process of selling securities that are not in the possession of the seller at the time of sale.
- Strategic portfolio management frequently stipulates lower and upper bounds.
- The tangency portfolio allows for a risk-free investment opportunity in addition to an investment in the assets of the portfolio.
- The maximum return portfolio aims at maximizing the portfolio return.
- The efficient portfolio for a given return aims at minimizing the portfolio risk for a given minimum return.
- The optimum portfolio takes the utility function of the investor into consideration.
- In addition to the utility function of the investor, the optimum portfolio also includes the possibility of an investment in the risk-free asset.
- In the area of active portfolio management, a distinction is made between absolute optimization and relative optimization.
- Relative optimization bases the optimization on a benchmark.
- Alpha is a fundamental variable in the field of relative optimization and captures the ability of a portfolio manager to select appropriate assets.
- A successful active portfolio manager achieves an outperformance by systematically picking and overweighting the correct securities.
- The active position is the difference between the security weights in the portfolio and the security weights in the benchmark.
- Relative optimization aims at maximizing the difference between the alpha of the portfolio and the selection risk (residual risk) weighted at the corresponding parameter of risk aversion λ.

Passive Portfolio Management

- Passive portfolio management aims at replicating a chosen benchmark portfolio with the greatest possible precision and at low cost.
- The basis of passive portfolio management is the assumption of efficient markets, which does not allow a long-term outperformance of the portfolio relative to the benchmark.

- Among the strategies of passive portfolio management are index tracking, index tracking based on MARKOWITZ, constrained regression and linear optimization.
- Index tracking based on MARKOWITZ aims at minimizing the tracking error variance respectively the tracking error.
- Simple index tracking is based on the idea of a tracking portfolio, which mirrors as much as possible the value development and the risk structure of the target portfolio.
- In the method of constrained regressions, the development of the portfolio return needs to be as close as possible to the development of the index return.
- In the case of linear optimization, the investor wants to rule out a performance that is below the benchmark, while allowing positive deviations.

Notes

1. For the two assets case the variance is: $\sigma_p^2 = w^2\sigma_{r_1}^2 + (1-w)^2\,\sigma_{r_2}^2 + 2\cdot w\cdot(1-w)\cdot\rho_{r_1,r_2}\cdot\sigma_{r_1}\cdot\sigma_{r_2}$ (if the correlation coefficient is used instead of the covariance).
2. A comprehensive discussion of utility theory and risk aversion is provided by Alexander (2008).
3. In applied work frequently only the absolute returns are used. Especially for daily data and a riskless rate close to zero, the results are almost identical.
4. This formula is derived by substituting the return equation of the SIM into the formula of the covariance.
5. S. Roll 1992, Bodie et. al. 2014.

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14

Derivatives

1 Executive Summary

Following financial management, a corporate valuation of Pharma Group and the medium-term investment of liquid funds in equities and bonds, Pharma Group is now interested to invest a small portion of its liquid assets in derivatives. Pharma Group wants to internally assess the market prices of plain vanilla options and therefore conducts a valuation.

In a first step, the market prices of European and American call and put options on RWE shares are assessed using the following methods:

- Duplication
- Binomial model
  - One-period binomial model
  - Multi-period binomial model with 6 steps
  - Multi-period binomial model with 12 steps
- Black-Scholes model
- Black-Scholes-Merton-model

The results of this analysis are then compared to the market prices. The market price is taken from the quoted price of the options on the EUREX as published by Thomson Reuters. Based on this analysis, Pharma Group obtains the following data for European and American call and put options on RWE shares:

J. Häcker and D. Ernst, *Financial Modeling*,
Global Financial Markets, DOI 10.1057/978-1-137-42658-1_14

Call option on RWE shares						Put Option on RWE Shares	
Excluding Dividenc	in €	Including Dividend				Including Dividend	
		European	in €	American	in €	American	
One-period binomial model	3.99	Binomial model (6 steps)	2.73	Binomial model (12 steps)	2.93	Binomial model (12 steps)	2.30
Duplication	3.99	Binomial modell (12 steps)	2.77	Market price at EUREX	2.79	Market price at EUREX	2.31
Black-Scholes model	3.40	Black-Scholes-Merton model	2.798				

Fig. 14.1 Overview of the results from the section on option valuation

As Fig. 14.1 makes clear, a number of conclusions can be derived from case of RWE under consideration:

1. The duplication method and the one-period binominal model without dividend reach the same result. Both methods arrive at a price of €3.99 in the case of call options without dividends. The Black-Scholes model without dividends yields a price of € 3.40. Since this analysis ignores the dividend, all three results are relatively far away from the actual market price of the call of €2.79.
2. Dividend payments directly affect the pricing of the underlying. They imply a decline of the price of the underlying. Due to this direct influence, dividend payments imply price declines for call options and price increases for put options. Based on the Black-Scholes model, the price of the call option has declined from €3.40 (no dividend) to €2.798 (including a dividend of 3.76%).[1]
3. The binomial model converges towards the Black-Scholes model, as the number of steps is increased. This is shown for the case of the European call option. The multi-period model with 6 steps yields a price of €2.73, while doubling the number of steps to twelve already implies a price of €2.77. The continuous Black-Scholes-Merton model arrives at a price of €2.798. Thus it can be stated that an increase in the number of steps in the binomial model results in a convergence towards the results obtained with the Black-Scholes-Merton-model.
4. The multi-period binomial model with 12 steps yields a price of €2.93 in the case of an American call option with dividends. The actual market price according to EUREX is €2.79.
5. The market appears to be basing its pricing on the Black-Scholes-Merton-model. The advantage of this continuous model is the incorporation of dividends, which are important for the pricing and in applied work. The Black-Scholes-Merton-model yields a price of

€ 2.798 while the market price is € 2.79. The deviation can be considered marginal. European options are mostly used for indexes. In option pricing theory, European options are frequently utilized. This is due to the fact that historically, European options were traded more frequently and that their mathematical construction is less abstract.

6. In the case of an American put option including dividends, the multi-period binomial model with 12 steps yields a price of € 2.30. The actual market price according to EUREX is only insignificantly higher at € 2.31.[2]

2 Introduction, Structure, Learning Outcomes and Case study

Structure

This chapter serves as an introduction to the world of exchange-traded derivatives and answers the following questions:

Options:

- What is the definition of an option and what types of options exist?
- What are the differences with regard to type, time of exercise, underlying of an option and settlement of an option?
- What are the value drivers in option pricing?
- How do price of the underlying, volatility, riskless rate of interest, payment of dividends and remaining life influence the option value?
- What is the difference between intrinsic value and time value of an option?
- Is an option at-the-money, in-the-money or out-of-the-money?
- Which models exist for the determination of the option price?
- How is the option price calculated with the duplication model?
- How is the option price calculated with the binomial model?
- How is the option price calculated with the Black-Scholes model?
- What do the Greeks refer to?
- Which Greeks exist?
- How are the Greeks calculated?

- What is meant by put-call-parity?
- How can the price of a put be derived from the price of a call?
- What are the four basic option strategies?
- How are long call, short call, long put and short put utilized?

Futures:

- What is meant by the term “futures?”
- What is the difference between futures and forwards?
- Which futures are essential in applied work?
- What are index futures?
- What are interest rate futures?
- What are currency futures?
- What are commodity futures?
- What are single stock futures?
- How are index futures, interest rate futures, currency futures, commodity futures and single stock futures priced?
- What are the basic strategies involving futures?
- What is meant by the basic strategies long futures, short futures, spreads and cash-and- carry arbitrage?
- How and when are these strategies utilized?

Framework conditions for options and futures:

- What are margin requirements and risk controlling?
- How can a derivatives position be closed out?

A derivative (origin from Latin derivare = derive) is generally a new element which can be traced back to an underlying and which reacts directly to movements in the underlying. Derivatives allow both the hedging of risk as well as the active speculation on an anticipated price movement. Since derivatives usually only require a fraction of the value of the underlying, investors can leverage their position.
Derivatives can be classified as

- conditional forward transactions that involve a choice (for example options) and
- unconditional forward transactions that do not involve a choice (for example futures).

Learning Outcomes

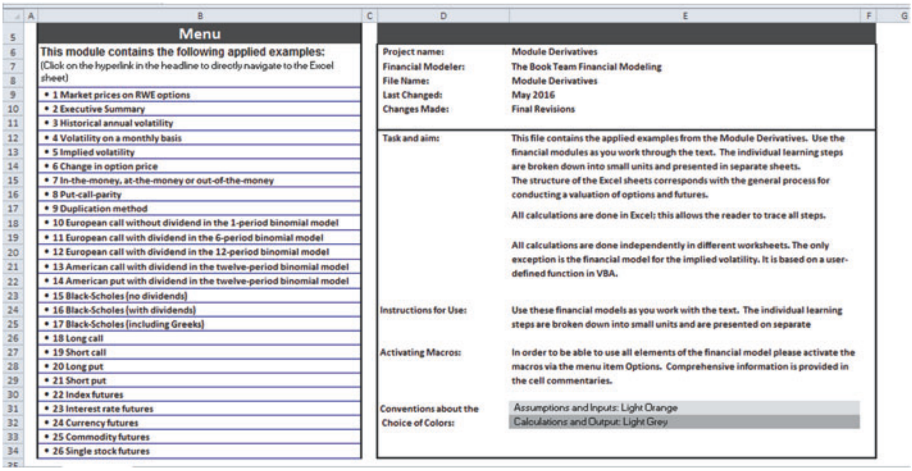
- The model serves to teach the practical implementation. The financial modeler:
- Is familiar with the most important exchange-traded derivatives and can distinguish these.
- Knows the most important types of options and is able to explain how these instruments differ.
- Is able to distinguish the most important types of options with regard to type, exercise terms, underlying and settlement obligations.
- Knows the most important value drivers of an option and can explain their influence on the price.
- Is aware of the relevance of intrinsic value and time value as components of the option price.
- Is able to explain whether an option is in-the-money, at-the-money or out-of-the-money.
- Knows the models used to determine the option price and can state these.
- Is able to calculate option prices with the help of the duplication model, the Black-Scholes model and the binomial model,
- Knows the various Greeks and their derivation.
- Can calculate the Greeks and interpret the results.
- Is able to derive the price of a put option from the price of a call option using put-call parity.
- Is familiar with the four basic option strategies and can implement them adequately.
- Can distinguish between futures and forwards and point out differences,
- Can point out and explain the differences between index futures, interest rate futures, currency futures, commodity futures and single stock futures.
- Is able to calculate the price of index futures, interest rate futures, currency futures, commodity futures and single stock futures.
- Is familiar with the basic futures strategies.
- Can apply the basic strategies long futures, short futures, spread as well as cash-and-carry-arbitrage in a targeted fashion.

- Knows why margins and risk controlling are necessary.
- Knows how to close out a derivatives position.

Case Study

The model is structured as follows and based on the standards presented in the Workshop Excel.

- All calculations are implemented independently on separate Excel sheets.
- All input data is marked in the color light orange. This market data can be used as an input by the financial modeler. See the Workshop Excel (Section 9.2 and 9.3 Data Import) on how to import information about securities in Excel.
- All calculations and output data use the color light gray.
- The structure of the Excel data base is in line with the general process used to calculate prices of options and futures and comprises the following Excel sheets (see Fig. 14.2):
    1. Market prices on RWE options
    2. Executive Summary
    3. Historical annual volatility
    4. Volatility on a monthly basis
    5. Implied volatility
    6. Change in option price
    7. In-the-money, at-the-money or out-of-the-money
    8. Put-call-parity
    9. Duplication method
    10. European call without dividend in the one-period binomial model
    11. European call with dividend in the six-period binomial model
    12. European call with dividend in the twelve-period binomial model
    13. American call with dividend in the twelve-period binomial model
    14. American put with dividend in the twelve-period binomial model



Menu

This module contains the following applied examples:
(Click on the hyperlink in the headline to directly navigate to the Excel sheet)

- 1 Market prices on RWE options
- 2 Executive Summary
- 3 Historical annual volatility
- 4 Volatility on a monthly basis
- 5 Implied volatility
- 6 Change in option price
- 7 In-the-money, at-the-money or out-of-the-money
- 8 Put-call-parity
- 9 Duplication method
- 10 European call without dividend in the 1-period binomial model
- 11 European call with dividend in the 6-period binomial model
- 12 European call with dividend in the 12-period binomial model
- 13 American call with dividend in the twelve-period binomial model
- 14 American put with dividend in the twelve-period binomial model
- 15 Black-Scholes (no dividends)
- 16 Black-Scholes (with dividends)
- 17 Black-Scholes (including Greeks)
- 18 Long call
- 19 Short call
- 20 Long put
- 21 Short put
- 22 Index futures
- 23 Interest rate futures
- 24 Currency futures
- 25 Commodity futures
- 26 Single stock futures

Project name:	Module Derivatives
Financial Modeler:	The Book Team Financial Modeling
File Name:	Module Derivatives
Last Changed:	May 2016
Changes Made:	Final Revisions
Task and aim:	This file contains the applied examples from the Module Derivatives. Use the financial modules as you work through the text. The individual learning steps are broken down into small units and presented in separate sheets. The structure of the Excel sheets corresponds with the general process for conducting a valuation of options and futures. All calculations are done in Excel; this allows the reader to trace all steps. All calculations are done independently in different worksheets. The only exception is the financial model for the implied volatility. It is based on a user-defined function in VBA.
Instructions for Use:	Use these financial models as you work with the text. The individual learning steps are broken down into small units and are presented on separate
Activating Macros:	In order to be able to use all elements of the financial model please activate the macros via the menu item Options. Comprehensive information is provided in the cell commentaries.
Conventions about the Choice of Colors:	Assumptions and Inputs: Light Orange Calculations and Output: Light Grey

Fig. 14.2 Structure of the Excel file derivatives (Excel File Derivatives, Worksheet Menu and Doc)

15. Black-Scholes (no dividends)
16. Black-Scholes (with dividends)
17. Black-Scholes (including Greeks)
18. Long call
19. Short call
20. Long put
21. Short put
22. Index futures
23. Interest rate futures
24. Currency futures
25. Commodity futures
26. Single stock futures

- All calculations are implemented in Excel in order to assure that they can be replicated and understood.
- The only exception is the financial model for the implicit volatility. It relies on a user-defined function in VBA.

An option on RWE AG serves as illustration in the section on derivatives

Applied Example

Options on RWE AG
In order to provide realistic calculations in this chapter, we use the example of options on RWE securities with expiration December 2014. Figure 14.3 displays several of these RWE options expiring in December 2014 as of December 31, 2013. To assure comparability, the same prices for the underlying were used for calls and puts, also stated as percent of the price of RWE shares as of December 31. 2013. Also identical implied volatilities were used.

Date	Share	Expiration	Exercise Price		Type of Option	Option Premium	Price of the Underlying	Implied Volatility	Dividend
31.12.2013	RWE	31.12.2014	95%	25.28	Call	2.79	26.61	25.16	3.76%
31.12.2013	RWE	31.12.2014	100%	26.61	Call	1.03	26.61	24.73	3.76%
31.12.2013	RWE	31.12.2014	105%	27.94	Call	0.74	26.61	24.45	3.76%
31.12.2013	RWE	31.12.2014	95%	25.28	Put	2.31	26.61	25.16	3.76%
31.12.2013	RWE	31.12.2014	100%	26.61	Put	3.00	26.61	24.73	3.76%
31.12.2013	RWE	31.12.2014	105%	27.94	Put	3.82	26.61	24.45	3.76%

Fig. 14.3 Options with a term of one year on RWE AG (*Source:* Thomson Reuters) (Excel File Derivatives, Worksheet Market Prices RWE Options)

In the case study for this chapter, the two options which are highlighted in Fig. 14.3 are analyzed in more detail.

- The price of the call option is € 2.79
- The price of the put option is € 2.31

3 Options Basics

3.1 Terminology and Types of Options

Option is derived from the Latin word optio (= free will or the right to choose). An option is a bilateral contract between two parties with a limited term. An option is the securitized right, but not the obligation to purchase (call option) or to sell (put option) a specified quantity (contract size) of an object (underlying) approved for option trading within a specified period (term or life of the option).

Specific for this agreement is the right to choose. The seller of the options grants the right to the buyer to buy or sell a specific underlying at a specific time. This right to choose is granted to the buyer by the seller of an option in exchange for the payment of an option premium. Since the buyer of the option is not required to exercise, the chances and risks from the option are asymmetric. The profit potential is theoretically unlimited (upside potential), while the maximum loss is limited to the option price which is due at the beginning of the transaction (downside risk). For that reason the distribution of risks is said to be asymmetric.

Standardized option contracts can be traded at derivatives exchanges. In contrast, options that have individual features are only agreed and traded directly between the contract parties without a derivatives exchange as an intermediary. They are also called over-the-counter options (abbreviated OTC options).

Figure 14.4 provides a first overview of the different types of options and their features.

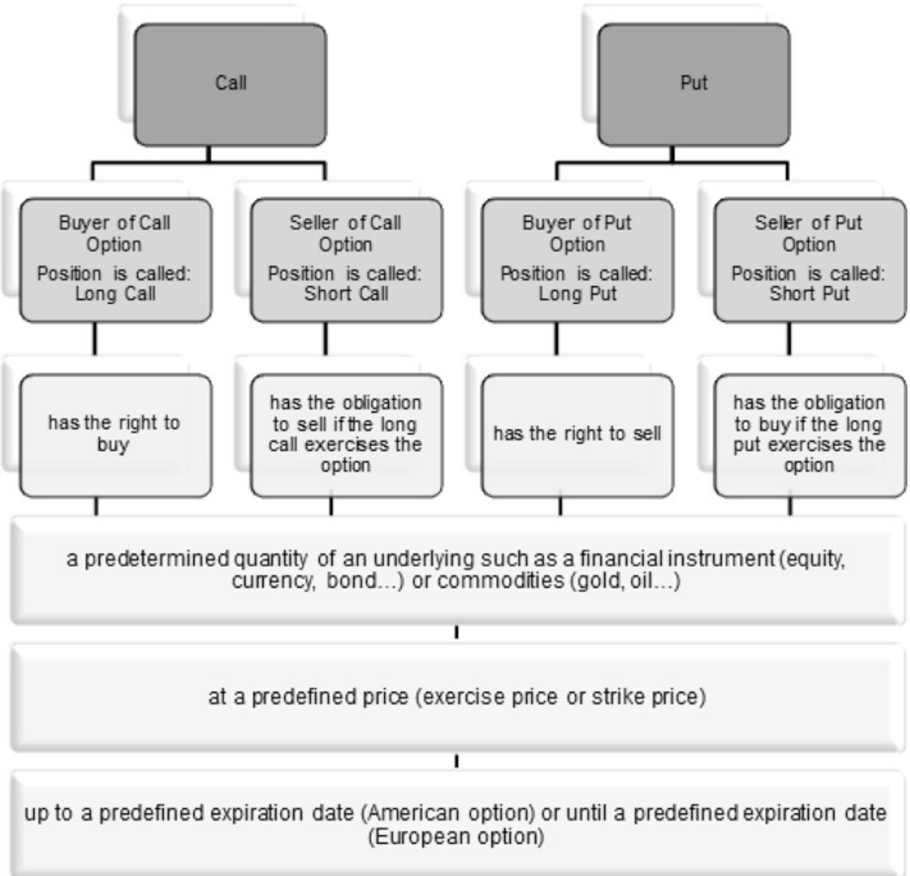


Fig. 14.4 Overview of options (see Pfeifer, 2006, p. 317, own presentation)

3.2 Differentiating Features of Options

3.2.1 Type of Option

A fundamental distinction is made between the two types of options (see Fig. 14.5):

- Call option
- Put option

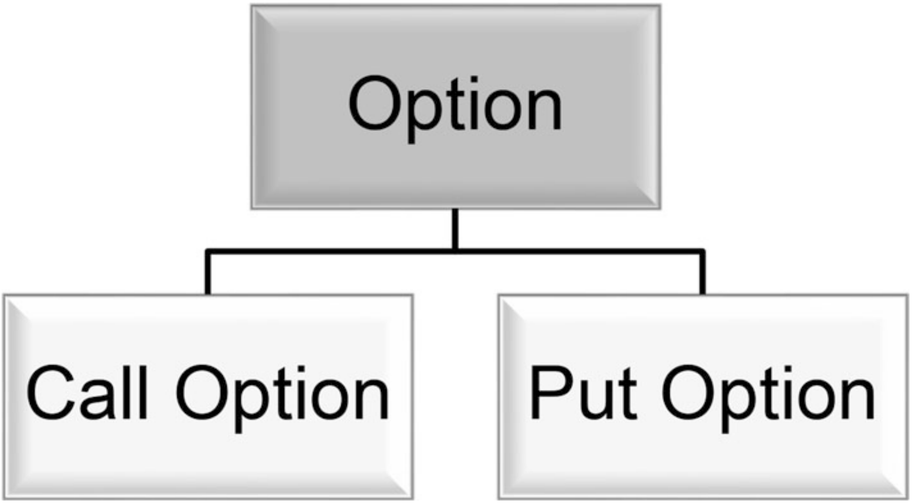


Fig. 14.5 Distinction by type of option

> **Call Option:** A call option gives the buyer the right, but not the obligation, to buy an underlying security in a specified quantity (contract size), within a specified period of time (term) or at a specified date (last day of trading), at a price (exercise price) which is set as the contract is initiated.

Applied Example

Call option on RWE

An investor is looking to take a position in RWE shares. Based on his analysis, he expects a rising share price. Instead of a direct investment in the shares, he purchases a call option. Due to the fact that less capital is needed, he can buy significantly more options than shares. Should the anticipated price movement materialize, his profit is much higher compared to the direct investment, due to the leverage effect.

Put option: A put option gives the buyer the right, but not the obligation, to sell an underlying security in a specified quantity (contract size), within a specified period of time (term) or at a specified date (last day of trading), at a price (exercise price) which is set when the contract is initiated.

Applied Example

Put option on RWE

Another investor already holds RWE shares in his portfolio and is worried about falling prices. To hedge his position, he buys put options on his RWE shares. This provides him with compensation for possible losses in the underlying RWE shares. The value of the put option develops in the opposite direction of the underlying RWE shares.

In the case where the share price of RWE continues to rise, contrary to expectations, the puts will lose value. Thus the investor suffers a loss from his option position. But the increase in the share price serves as compensation. His overall position shows a profit if the increase in the share price exceeds the option premium. Had he sold the shares, he would have no longer profited from the price increase. With the option, he at least realized a partial profit.

The buyer of an option holds a long position, the seller holds a short position and is also called writer. Each buyer (long) is matched by a seller (short) (see Fig. 14.6). The seller of the option has no choice and is required to react to the decision of the buyer. As compensation he receives the premium payment from the buyer. He thus entered into a commitment (he has no choice), in the case of an exercise, to deliver (for a call option) or to accept (for a put option) the defined quantity of the underlying on the agreed date and at the agreed price (see Fig. 14.7).

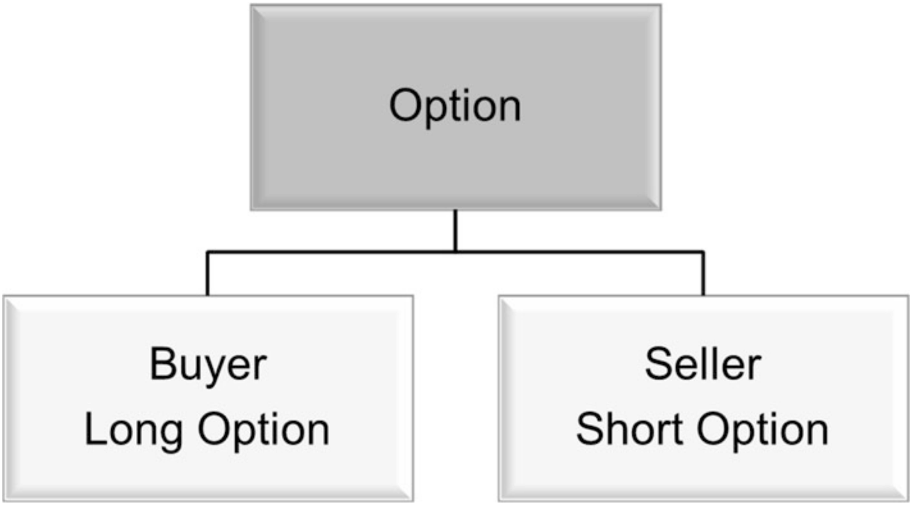


Fig. 14.6 Options and involved parties

	Right	Obligation
Buyer	Exercise	Premium payment
Seller	Receipt of premium	Delivery (call) or receipt (put) or underlying

Fig. 14.7 Rights and obligations in the case of options for buyer and seller

3.2.2 Time of Exercise

A further distinguishing feature is the time of exercise (see Fig. 14.8): options that can be exercised during the entire term are called American-style options. Normally these are options written on individual securities. Options that can only be exercised at expiration are called European-style options. This specification is used mostly for options on indexes.[3]

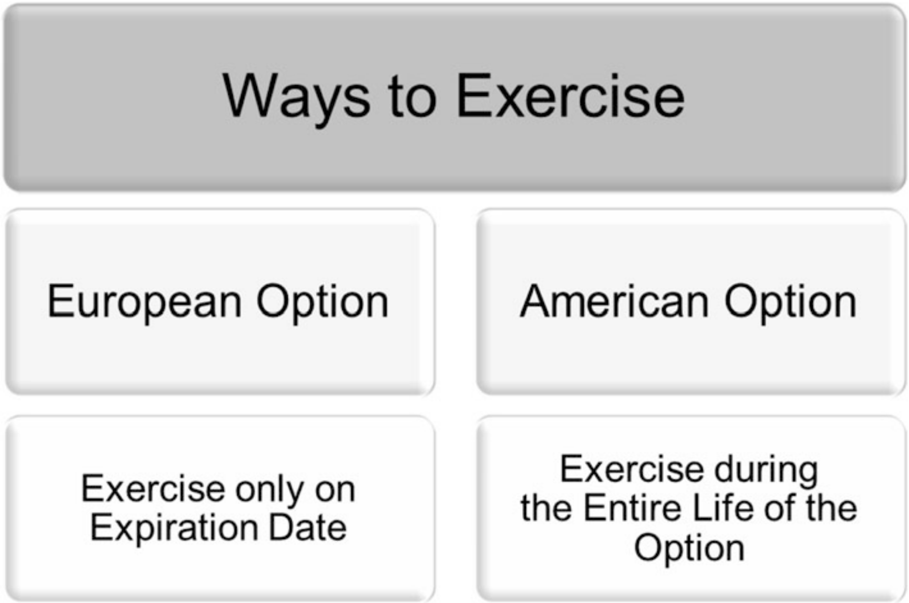


Fig. 14.8 Different ways to exercise options

3.2.3 Underlying of the Option

Options also differ with regard to the underlying, which is the object of the option contract and defines the commodity or security used as the basis for the transaction.

Numerous underlying objects are possible in option trading. They include

- Equities,
- Bonds,
- Currencies,
- Indexes on Equities and Interest Rates,
- Commodities as well as
- Other Derivatives.

Purchase of a(n)...	...Share	...Option on the Share
Relevance	Partial ownership in a company.	The right to buy a share (call) or to sell a share (put) at a predetermined price.
Chances	Participation in share price increase and dividends.	Profit in the case of falling share prices (put); Profit in the case of rising share prices (call).
Risks	Dependence on the economic success of a company. Complete loss is rather rare.	Increased risk, complete loss possible, additional credit risk of issuer.
Additional Rights	In some sense, a shareholder becomes an "entrepreneur." Depending on the type of equity, his rights can vary slightly.	The buyer of an option will always remain an investor. He has no additional rights.
Term	Unlimited.	Limited.

Fig. 14.9 Comparing shares and options

Figure 14.9 makes the comparison between share and option. This clarifies the fundamental differences between underlying and derivative (in this case: option).

3.2.4 Settlement of an Option

Finally there are differences in the way option contracts are settled (see Fig. 14.10). A distinction is made between

- Cash settlement and
- Physical delivery (delivery or receipt of the underlying)

Cash settlement takes place whenever physical delivery is impossible or not wanted. This is true for example for index options. A cash settlement is made in the amount equal to the difference between value of the underlying and exercise price. Physical delivery of the underlying usually takes place in the case of options on individual shares.

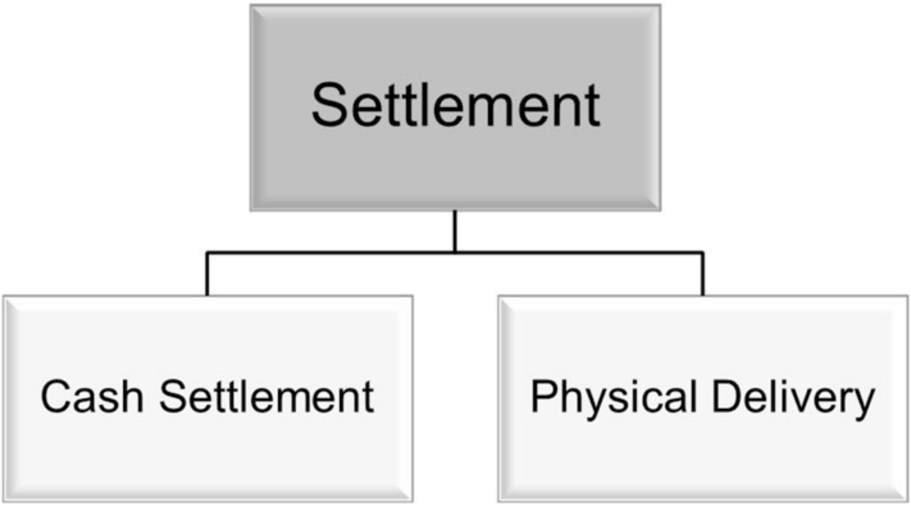


Fig. 14.10 Possibilities for settlement

3.3 What are the Value Drivers in Option Pricing?

3.3.1 The Price of the Underlying

The price of the underlying has the largest influence on the option price, since the option is directly influenced by it. A call goes up in value as the underlying becomes more expensive and loses in value as the underlying goes down. This relationship is exactly reversed in the case of a put. It goes up in value as the price of the underlying falls and loses value as the price of the underlying rises.

This also explains why a derivative (derived from an underlying structure) is directly linked to the underlying. A price change in the underlying will also trigger a price change in the derivative.

3.3.2 The Volatility

The volatility σ (Latin volare = fly) is a statistical measure for the intensity of fluctuation of a variable during a specified time period (aggregated overall risk) around its mean. (Equities for example normally have volatilities of 15%-60%).

Standard deviation as an estimate of volatility: Volatility is only concerned with the magnitude of fluctuations, not with their direction. A volatility of 10 and a mean of 100 mean that the variable moves within a corridor from 90 to 110 with a probability of 68.26 %. Volatility in this case is equal to the standard deviation (s or σ). Standard deviation is defined as the square root of the average squared deviations from the mean. It measures how strongly the individual returns fluctuate around the mean. The squared standard deviation, s^2 or σ^2, is also called variance. Volatility is estimated as follows:

$$s = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(r_i - \overline{\mu})^2}$$

In the above formula n stands for the number of values, r_i stands for the logarithm of the returns and $\overline{\mu}$ for their mean value. To simplify the exposition, the calculations in the following elucidations are always based on the population. The same approach is used in the section on portfolio management.

As a basic principle it can be stated that the option price increases with volatility. This principle is derived from the consideration that a high volatility also implies a high degree of risk. Thus the pricing of a riskier asset must differ from the pricing of a less risky one.

The following two types of volatilities can be distinguished:

- Historic volatility,
- Implied volatility.

Historic volatility deals with past data for an underlying. Historic volatility can be based on different time intervals such as days, weeks, months or years.

In the following, historical annual and historical monthly volatilities will be calculated.

Historical annual volatilities: We start with the historical annual volatilities. We use the closing prices for the year to calculate annual rates of change.

Variable	Formulas	Excel Implementation
Rate of Change (=Historical Annual Volatility!D7)	=ln(Closing Price t / Closing Price t-1)	=LN(C7/C6)
Average Return (=Historical Annual Volatility!D18)	=Mean value of the growth rates	=AVERAGE(D7:D15)
Variance[IV] (=Historical Annual Volatility! D19)	=Variance of the growth rates	=VAR.P(D7:D15)
Standard Deviation (=Historical Annual Volatility! D20)	=Standard deviation of the growth rates	= =STDEV.P(D7:D15)

Fig. 14.11 Calculating historical annual volatility in the applied example

In the next step, the variables average return, variance and standard deviation are determined. The standard deviation is the historical annual volatility of the share and is equal to 32.45% in our example (Fig. 14.11).

Figure 14.12 shows the practical implementation using the example of RWE AG.

Calculating the historical monthly volatility

Historical monthly volatility: In the next step, we will turn to the calculation of monthly volatility (see Figs. 14.13 and 14.14). Instead of annual data, we now use monthly data. All other steps are identical to the calculation of the annual volatility. The historical monthly volatility can be transformed into an annual value by multiplying the mean value and the variance by 12. The annual standard deviation is calculated by taking the square root of the variance.

Implied volatility
The implied volatility can be calculated based on the option price. The implied volatility represents the expectation about future fluctuations of the underlying around its mean. It is derived from market data.

Date	Closing Price	Change
31.12.2004	40.56	
31.12.2005	62.34	42.97%
31.12.2006	83.22	28.89%
31.12.2007	95.68	13.95%
31.12.2008	63.49	- 41.02%
31.12.2009	67.73	6.47%
31.12.2010	49.72	- 30.91%
31.12.2011	27.15	- 60.51%
31.12.2012	31.24	14.03%
31.12.2013	26.61	- 16.06%

Result	
Average Return	- 4.69%
Variance	10.53%
Standard Deviation	32.45%

Fig. 14.12 Average return, variance and standard deviation of RWE AG

The implied volatility reflects the current market opinion. Depending on the term of the option and the exercise price, it can differ significantly from the historical volatility. The implied volatility is derived from current market prices of options. This is done with the help of an iterative procedure and the Black-Scholes formula.

> An iterative process is a mathematical approach which step by step comes closer to the correct solution. The same solution procedure is applied several times.

Calculating the implied volatility: The calculation of implied volatilities cannot be implemented with the standard Excel functions. It requires user-defined functions. Additional information about writing these functions is provided in the Workshop VBA.

Variable	Formulas	Excel Implementation
Rate of Change (=Historical Monthly Volatility!D7)	=ln(Closing Price t / Closing Price t-1)	=LN(C7/C6)
Average Return (monthly) (=Historical Monthly Volatility!D21)	=Mean value of the growth rates	=AVERAGE(D7:D18)
Variance (monthly) (=Historical Monthly Volatility!D22)	=Variance of the growth rates	=VAR.P(D7:D18)
Standard Deviation (monthly) (=Historical Monthly Volatility!D23)	=Standard deviation of the growth rates	=STDEV.P(D7:D18)
Average Return (annual) (=Historical Monthly Volatility!H21)	=12× Average Return (monthly)	=12*D21
Variance (annual) (=Historical Monthly Volatility!H22)	=12× Variance (monthly)	=12*D22
Standard Deviation (annual) (=Historical Monthly Volatility!H23)	=Square Root Variance (annual)	=SQRT(H22)

Fig. 14.13 Calculating the historical, monthly volatility and conversion into historical, annual volatility in the applied example

Date	Closing Price	Change
31.12.2012	31.24	
31.01.2013	27.71	- 12.01%
28.02.2013	28.14	1.54%
31.03.2013	29.08	3.29%
30.04.2013	27.34	- 6.17%
31.05.2013	26.46	- 3.27%
30.06.2013	24.52	- 7.60%
31.07.2013	22.62	- 8.09%
31.08.2013	20.80	- 8.39%
30.09.2013	25.14	18.97%
31.10.2013	27.19	7.84%
30.11.2013	28.26	3.86%
31.12.2013	26.61	- 6.03%

Monthly Perspective	
Average Return	- 1.34%
Variance	0.71%
Standard Deviation	8.42%

Annual Values	
Average Return	- 16.06%
Variance	8.51%
Standard Deviation	29.17%

Fig. 14.14 Average variance and standard deviation of RWE AG on a monthly and annual basis (see Pfeifer, 2006, p. 317, own presentation) (Excel File Derivatives, Worksheet Volatility_Monthly)

Listing 1

Calculation of implied volatility for a call option

Function CallVolatility(Stock, Exercise, Time, Interest, Target)

```
     High = 2
     Low = 0
     Do While (High - Low) > 0.000001
     If CallOption(Stock, Exercise, Time, Interest,
       (High + Low) /2) > _
       Target Then
            High = (High + Low) /2
            Else: Low = (High + Low) /2
     End If
     Loop
     CallVolatility = (High + Low) /2
End Function
```

Listing 2

Calculation of implied volatility for a put option

Function PutVolatility(Stock, Exercise, Time, Interest, Target)

```
     High = 2
     Low = 0
     Do While (High - Low) > 0.000001
     If PutOption(Stock, Exercise, Time, Interest,
       (High + Low) /2) > _
       Target Then
            High = (High + Low) /2
            Else: Low = (High + Low) /2
     End If
     Loop
     PutVolatility = (High + Low) /2
End Function
```

The practical implementation using the example of RWE AG requires the following steps (see Figs. 14.15 and 14.16):

Variable	Formulas	Excel Implementation
Implied Volatility$_{Call}$ (= Implied Volatility!C11)	see Listing 1	=Callvolatility(C6;C7;C8;C9;C10)
Implied Volatility$_{Put}$ (= Implied Volatility!F11)	see Listing 2	=Putvolatility(F6;F7;F8;F9;F10)

Fig. 14.15 Calculating the implied volatility using the example of RWE AG

Implied Volatility from the Call Price	
Price of the Underlying	26.61
Exercise Price	25.28
Maturity in Years	1.00
Risk-free rate	0.6%
Option Price Call	2.79
Implied Volatility	**19.0%**

Deriving the Volatility of the Call from the Put Price	
Price of the Underlying	26.61
Exercise Price	25.28
Maturity in Years	1.00
Risk-free rate	0.6%
Option Price Put	2.31
Implied Volatility	**29.1%**

Fig. 14.16 The implied volatility using the example of RWE AG (Excel File Derivatives, Worksheet Implied Volatility)

Practical Tip

Indexes for implied volatility

A convenient way to get an overview of the current implied volatility of options is provided for example by the volatility index VDAX-NEW of Deutsche Börse. It measures the volatility of the DAX30 for the coming 30 days on the basis of the options on the DAX traded at the derivatives exchange EUREX. Additionally this index offers a certain degree of diversification for investments in the DAX index. Further information and the current development of the index VDAX-NEW are available on the webpage of Deutsche Börse as well as from many market information providers using the Security-ID A0DMX9 or ISIN DE000A0DMX99.

3.3.3 The Riskless Rate of Interest

The riskless rate of interest also influences the determination of option prices. The riskless rate of interest is frequently understood to be a money market rate. It is basically an investment that is rated AAA and has no default risk. When selecting an appropriate riskless rate for the pricing of options, additional factors such as the term to expiration of the option and its currency need to be considered in applied work.

When the riskless rate of interest goes up, the price of a call increases while the price of a put declines. Why is this? On the one hand it can be explained by the fact that higher interest rates make holding cash more attractive and on the other hand it follows from the options basics. The price differences between the direct investment and the investment in options are equalized.

Let us clarify the relation with reference to a call option: the direct investment in an asset would require that we invest an amount X today. This amount of capital would be tied up and no longer available for other uses. If instead an option is purchased on that same underlying, much less capital will be tied up (for example 10% of X) and excess liquidity is available, which can be invested elsewhere. This investment generates additional income. Since the return of an investment in the underlying needs to be equivalent to the return from investing in the option, the difference is equilibrated via the market price of the option (assuming an efficient capital market). Thus an increase in the riskless rate of interest leads to a higher price for the call.

3.3.4 Dividend Payments

Dividend payments have an immediate effect on the price of the underlying. They imply falling prices of the call option and rising prices of the put option.[5] Due to the dividend payment, the share price declines. This implies a decrease of the call price and an increase of the put price.

Practical Tip

Importance of dividends

Some market participants incorrectly view dividends as a type of "additional income." But dividends merely constitute a partial repayment of the invested capital. This is also supported by the fact that the share price quoted on the day following the payment of the dividends is reduced by that amount. If the company did not pay any dividend, its market capitalization would not be reduced by that amount.

3.3.5 The Term to Maturity

The shorter the term to maturity of an option, the lower is its price. The probability increases that the option expires worthless. Hence the remaining life of the option is an important parameter for options that are out-of-the-money or directly at-the-money. Deep-in-the-money options meanwhile are not very sensitive concerning the remaining term, since the function of the time value has already been fulfilled. For that reason, deep-in-the-money options only have a comparably low premium for the time value.

Figure 14.17 shows the above discussed effects of the remaining life on the price of a call option and a put option for the example of RWE AG.

Expiration Date	Price Call Option Exercise Price: 24	Price Put Option Exercise Price: 32
June 14	3.70	4.55
Sep. 14	4.43	4.91
Dec. 14	4.73	4.95
March 15	4.69	5.50
June 15	4.82	6.30
Dec. 15	5.13	6.76
June 16	5.35	7.67
Dec. 16	5.56	8.03
Dec. 17	5.89	8.97

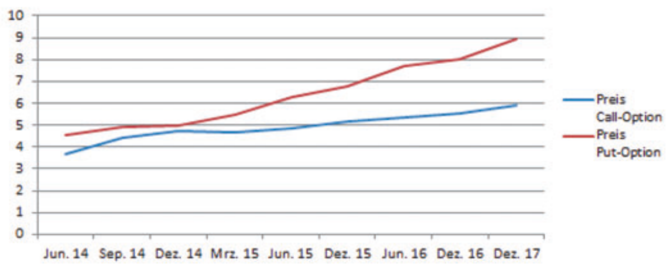


Fig. 14.17 Effects of the remaining life on the option price (Excel File Derivatives, Worksheet Changes in Option Prices)

3.3.6 An Overview of the Value Drivers

Value Driver		Option Price Call	Option Price Put
Exercise price	Higher	Lower	Higher
	Lower	Higher	Lower
Price of underlying	Increasing	Increasing	Decreasing
	Decreasing	Decreasing	Increasing
Volatility	Increasing	Increasing	Increasing
	Decreasing	Decreasing	Decreasing
Remaining life	Decreasing	Decreasing	Decreasing
Riskless rate of interest	Increasing	Increasing	Decreasing
	Decreasing	Decreasing	Increasing
Dividend payment	American	Decreasing	Increasing
	European	Unchanged	Unchanged

Fig. 14.18 Value drivers and their effect on the option price

4 Option Pricing

The price of an option is calculated mathematically. Before delving into the complex topic of price determination, we will first get familiar with the basics and the most important terms used in pricing options.

4.1 Basics of Option Pricing

The price of an option conceptually consists of two different components:

- Intrinsic value
- Time value

4.1.1 Intrinsic Value

The intrinsic value is the positive difference between the current price of the underlying and the exercise price. Per definition, the intrinsic value can never be negative, but can be equal to zero.

In the case of call options, the intrinsic value is equal to the difference between the current price of the underlying (S) and the exercise price (X), for $S > X$. Otherwise it is equal to zero. The intrinsic value of a put option is the mirror-image:

- Intrinsic Value $_{\text{Call}}$ = max ($S - X$; 0)
- Intrinsic Value $_{\text{Put}}$ = max ($X - S$; 0)

Applied Example

Intrinsic Value

Intrinsic Value$_{\text{Call}}$ = $S - X$ = € 30 – € 28 = € 2

Intrinsic Value$_{\text{Put}}$ = $X - S$ = € 30 – € 28 = € 2

A put option has intrinsic value if the price of the underlying is below the exercise price of the option.

4.1.2 Time Value

Difference between actual option price and intrinsic value

In addition to the intrinsic value, each option also has time value. It is the amount that market participants are willing to pay in anticipation of future changes in the market price of the underlying.

The time value is determined as the difference between the actual option price and the intrinsic value.

Time Value = Option Price - Intrinsic Value

The time value of an option depends on a number of value drivers, namely volatility, riskless rate of interest, expected future dividend payments, remaining life of the option and current pricing.

In the case of a call option, the time value reflects the chances for the holder of the option that the price of the underlying will develop favorably, in other words, increase in value.

It is apparent that the probability of a favorable trading day increases as the remaining life of an American option is increased. Thus the time value of an American option increases with the remaining life of the option (see Fig. 14.19).

At the same time, the time value goes down as the term to maturity is reduced and is equal to zero on the last day of trading. The decline in the time value is not linear, but increases exponentially towards the end. The longer there is a possibility that the option will be in the money the higher is the time value. At the same time, this also means that the time value will decline faster if the chances for exercise are small. The shorter the time to expiration, the higher is the risk that the option will expire worthless.

	A	B	C	D	E	F
4						
5		**Implied Volatility from the Call Price**			**Deriving the Volatility of the Call from the Put Price**	
6		Price of the Underlying	26,61		Price of the Underlying	26,61
7		Exercise Price	25,28		Exercise Price	25,28
8		Maturity in Years	1,00		Maturity in Years	1,00
9		Risk-free rate	0,6%		Risk-free rate	0,6%
10		Option Price Call	2,79		Option Price Put	2,31
11		**Implied Volatility**	**19,0%**		**Implied Volatility**	**29,1%**
12						

Fig. 14.19 Time value and term to maturity

4.1.3 Moneyness of an Option

In-, at-, and out-of-the-money

The intrinsic value and the time value allow statements about the moneyness of an option. An option can be in-the-money (ITM), at-the-money (ATM) or out-of-the-money (OTM) (see Figs. 14.20–14.22):

In-the-money: An option is in-the-money if it has intrinsic value.

At-the-money: For at-the-money options, the current price of the underlying is approximately equal to the exercise price.

Out-of-the-money: An option is out-of-the-money if it only has time value, but no intrinsic value. An option that is out-of-the-money on the last day of trading expires worthless.

	In-the-money	At-the-money	Out-of-the money
Call	Price underlying > Exercise price	Price underlying = Exercise price	Price underlying < Exercise price
Put	Price underlying < Exercise price	Price underlying = Exercise price	Price underlying > Exercise price

Fig. 14.20 Moneyness of an option

Variable	Formulas	Excel Implementation
Moneyness Call (=In_At_or_Out_of_the_Money!E7)	=IF(Value of Underlying >= Exercise Price; IF(Value of Underlying = Exercise Price; "AT-THE-MONEY "; "IN-THE-MONEY"); "OUT-OF-THE-MONEY")	=IF($E$4>=C7;IF($E$4=C7;" AT THE MONEY";"IN THE MONEY");"OUT OF THE MONEY")
Moneyness Put (=In_At_or_Out_of_the_Money!E12)	=IF(Exercise Price >= Value of Underlying; IF(Value of Underlying = Exercise Price; "AT-THE-MONEY "; "IN-THE-MONEY"); "OUT-OF-THE-MONEY")	=IF(C12>=$E$4;IF(C12=$E$4;"AT THE MONEY";"IN THE MONEY");"OUT OF THE MONEY")

Fig. 14.21 The formulas to determine the moneyness of an option

Closing Price of RWE Shares on Dec 31, 2013: 26.61

Expiration Date Considered	Exercise Price	Call Price	IN, AT or OUT-OF-THE-MONEY
10.04.14	25.28	2.79	IN-THE-MONEY
10.04.14	26.61	1.03	AT-THE-MONEY
10.04.14	27.94	0.74	OUT-OF-THE-MONEY

Expiration Date Considered	Exercise Price	Put Price	IN, AT or OUT-OF-THE-MONEY
10.04.14	25.28	2.31	IN-THE-MONEY
10.04.14	26.61	3.00	AT-THE-MONEY
10.04.14	27.94	3.82	OUT-OF-THE-MONEY

Fig. 14.22 Moneyness of call and put options using the example of RWE AG (Excel File Derivatives, Worksheet In_At_or_Out_of_the_Money)

4.2 Models for Determining the Option Price

In the following, three financial models for the calculation of the option price will be presented:

- Duplication method
- Binomial model for one and multiple periods
- Black-Scholes model

Figure 14.23 already provides a short overview of the models and their attributes. The figure also shows how the models for the calculation of the option price evolved.

Before starting with the models, the put-call-parity as the basis for all calculations of option prices will be considered.

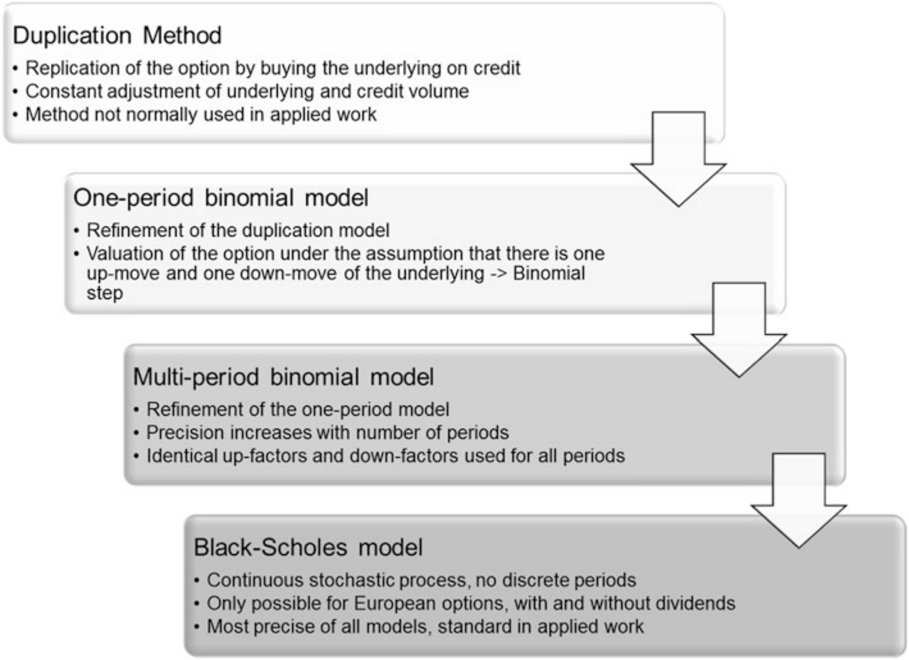


Fig. 14.23 Overview of the various models to calculate option prices

4.2.1 Put-Call-Parity

When considering the individual models, the focus will primarily be on the valuation of call options. This one-sided focus is not a limitation, thanks to the mathematical relation between prices of puts and calls, called put-call-parity. It states that a portfolio can be hedged in two different ways, which lead to an identical result.

Possibility 1: A portfolio is established which consists of a riskless bond and a call option on the underlying. The bond serves as the floor while the call option allows participation in the possibly favorable price development of the underlying. In business practice, this is called a synthetic hedge.

Possibility 2: A portfolio is established which consists of a risky underlying hedged with the help of put options. This leads to the same payoff profile as the above mentioned possibility. This approach is called protective put.

Thus the put price can be derived from the price of the call (see Figs. 14.24 and 14.25) based on put-call-parity, which can be written as follows:

$$c + Xe^{-r_f T} = p + S_0$$

Variable	Formulas	Excel Implementation
Put Price from Put-Call-Parity (=Put-Call-Parity!C14)	=Price of Call + Exercise Price × exp(-Riskless Rate of Interest × Remaining Life of Option) – Price of Underlying)	= C11+C7*EXP(-C9*C8)-C6

Fig. 14.24 The formulas for calculating put-call-parity

	A	B	C
5		**Assumptions**	
6		Price of the Underlying	26.61
7		Exercise Price	25.28
8		Maturity	1.00
9		Risk-free rate	0.60%
10		Implied Volatility	25.16%
11		Call Price	2.79
12			
13		**Calculations**	
14		Put Price (Using Put-Call-Parity)	1.31
15			

Fig. 14.25 Calculating the price of the put with the help of put-call-parity using the example of RWE AG (Excel File Derivatives, Worksheet Put-Call-Parity)

A simple transformation allows the direct derivation of the price of a call or a put option. The price of the put option can be derived by solving the parity relationship for p as follows:

$$p = c + Xe^{-r_f T} - S_0$$

4.2.2 Duplication Method

Theoretical considerations on the determination of option prices

The price of an option can be derived theoretically. This may be surprising, since prices are usually determined by supply and demand, and normally cannot be calculated.

In the case of options, this is different. Options can be replicated one for one by constructing a portfolio of assets (this process is called duplication or replication). The portfolio for the duplication of the option is formed by purchasing a certain amount of the underlying (for example a certain number of shares) financed via a loan. This loan can be in the form, for example, of a zero coupon bond.

This replication requires a dynamic and pro-cyclical approach: if the share price goes up, the number of shares held for duplication needs to be increased and the loan volume adjusted. If the share price declines, the number of shares must be reduced immediately. In this way the value of the option and the price of the underlying are tied together.

If we receive the same payment at maturity from our portfolio and from the option, then the price of the portfolio ought to be identical to the price of the option at the beginning of the period. If this is not the case, an arbitrage opportunity arises. We can make a riskless profit by buying the cheaper of the two positions (portfolio or option) and selling short (without owning it) the more expensive position.

Arbitrage opportunities are extremely rare in practice, since professional market participants would immediately utilize such a mispricing and in that way would assure that the opportunity is quickly eliminated. For that reason we can assume that a replicated portfolio has the same price as the corresponding option when pricing the option. In order to calculate the price of the option, we need to construct such a replicated portfolio in the next step.

Derivation of the option price using the example of RWE options

Let us consider a simplified example[6]: Let us assume that over the course of one year the share (in our example RWE shares) with a starting price of € 26.61 can either decline by exactly 22.22 % or increase by exactly 28.61%. A loan is used to finance the purchase of the shares. The interest rate for a one-year zero bond with a present value of € 26.61 is 0.60%. What is the price of a call option on that share if the exercise price is at 95% of the starting value which is € 25.28?

Before solving this task, let us think about all the information that is not provided. First, all information about supply and demand for the option is missing. Second, we do not know the probability with which the share price will go up or down. But we do not need this information, since we are able to duplicate the option with the help of a portfolio consisting of the share and the zero coupon bond. One could also argue that the missing information is contained in the share price and the interest rate – at any rate all the information needed for the price calculation of the call option is available.

To calculate the price we now take the following approach. We initially consider the value of the call at expiration. If the share price increases by 28.61% it amounts to € 8.94 (€ 34.22-€ 25.28 = € 8.94). In the case of a decline of 22.22%, the option expires worthless.

On the other hand, the share either has a value of € 20.70 or € 34.22; the loan at the end of the period is definitely valued at € 26.77 (given the interest rate of 0.60 %).

Now we want to duplicate the call with a portfolio consisting of share and zero coupon bond. To do so, we purchase x shares which are financed by selling y zero coupon bonds. We now need to determine the values of x and y.

In the case of a price increase, the portfolio provides a payment equal to € 34.22x + € 26.77y, while the call (as previously calculated) pays out € 8.94. Equality between the two payments requires € 34.22x + € 26.77y = € 8.94.

In the case of a price decrease, the portfolio provides a payment equal to € 20.70x + € 26.77y, the call has a value of € 0. This implies the equation € 20.70x + € 26.77y = € 0.

We have two linear equations with two unknown variables. This system of equations can be solved easily to obtain x = 0.66 and y = –0.51.

Duplication of the call thus requires purchasing 0.66 shares financed with 0.51 zero coupon bonds. Thus the price of the call at the beginning must be equal to the price of 0.66 shares (0.66 * € 26.61 = € 17.59) minus the price of 0.51 zero coupon bonds (–0.51 * € 26.61 = € -13.60). This is equal to € 3.99.

This result is completely independent of the probability of an increase or decline of the share price.

Calculating option prices with the help of duplication

The most important formulas for establishing the duplication model and the calculation of the price of the call are as follows (Figs. 14.26 and 14.27):

Variable	Formulas	Excel Implementation
Share Price in t_1 → Price Increase (=Duplication Method!C14)	= Share Price in t_0 × (1 + Increase in %)	=C10*(1+C12)
Share Price in t_1 → Price Decline (=Duplication Method!C15)	= Share Price in t_0 × (1 - Decline in %)	=C10*(1-C13)
Price of the Call at Expiration (=Duplication Method!C16)	=IF(Share Price t_1 (increased) >Strike price; (Share Price t_1 (increased) - Strike price; 0)+ IF(Share Price t_1 (declined) >Strike price; (Share Price t_1 (declined) - Strike price); 0)	=IF(C14>C11;(C14-C11);0)+IF(C15>C11;(C15-C11);0)
Zero Bond in t_1 (=Duplication Method!C26)	= Zero Bond in t_0 × (1 + Riskless Rate of Interest)	=C24*(1+C25)
y % Shares in the Portfolio (=Duplication Method!C36)	=(- Share Price t_1 (declined) × (Call Price at Expiration/ Share Price t_1 (increased)))/(-Share Price t_1 (declined) * Zero Bond t_1) / Share Price (increased) + Zero Bond t_1)	=(-C23*(C16/C22))/(-C23*C26/C22+C26)
x % Zero Bond in the Portfolio (=Duplication Method!C37)	= (Share Price t_1 - Zero Bond t_1 × (y))/ Share Price t_1 (increased)	=(C16-C26*C36)/C22
Portfolio Value = Price of the Call (=Duplication Method!C40)	= x % shares in the Portfolio × Share Price t_0 + y % Zero Bond in the Portfolio × Zero Bond in t_0	=C37*C19+C36*C24

Fig. 14.26 Calculating the call price using duplication

Securities	
Share:	RWE (x)
Bond:	One-year Zero-coupon Bond

Call	
Share price in t_0	26.61
Exercise Price	25.28
Increase in %	28.61%
Decline in %	22.22%
Share Price t_1 ➔ for Increase	34.22
Share price t_1 ➔ for Decline	20.70
Call Price at Expiration	8.94

Duplication Model	
Share price in t0	26.61
Increase in %	28.61%
Decline in %	22.22%
Share Price t_1 ➔ for Increase	34.22
Share price t_1 ➔ for Decline	20.70
Zero-coupon Bond t_0	26.61
Zero-coupon Bond, Riskless Interest Rate (in %)	0.60%
Zero-coupon Bond t_1	26.77

Additional Calculations Needed:	
Price Increase	34,22x + 26,77y = 8,94
Price Decline	20,70x + 26,77y = 0
Solve Scenario Price Increase for x	x = (8,94 - 26,77y)/34,22
Substitute x = (8,94 - 26,77y)/34,22 into Scenario Price Decline	
y =	-0.51
x =	0.66

Portfolio Value	
Call Price	3.99

Fig. 14.27 Calculating the call price for RWE AG using duplication (Excel File Derivatives, Worksheet Duplication)

4.2.3 Binomial Model

Discrete Option Pricing Model

Even though duplication may look more like an academic exercise than a useful method, it can still be expanded to arrive at one of the best known models for the valuation of options, the binomial model by Sharpe and Cox, Ross and Rubinstein. The idea behind this valuation method is the derivation of option prices via duplication. Similar to the method just discussed, the option is mimicked by an equivalent portfolio, consisting of a fraction of the underlying and an amount that is invested or borrowed at the riskless rate of interest.

Hence this is again the duplication method. We formalize this approach in order to generalize it. Our aim is to evaluate the price of the option as the underlying goes up or down in value. The financial model starts with a scenario for $t = 0$ and ends with two possible outcomes in $t = 1$. This is called the one-period model. Since only two possible ending scenarios exist, this is called a binomial step.

- S represents the starting scenario,
- S_u the scenario of an increasing (u = up) and
- S_d (d = down) the scenario of a declining price.

Assumptions of the Binomial Model

The following assumptions are made:

- Perfect capital markets (for example no taxes or transaction costs),
- Unlimited borrowing and lending at the riskless rate r_f,
- All assets are infinitely divisible,
- No limitations on short selling,
- No dividend payments during the life of the option and
- No arbitrage profits are possible.

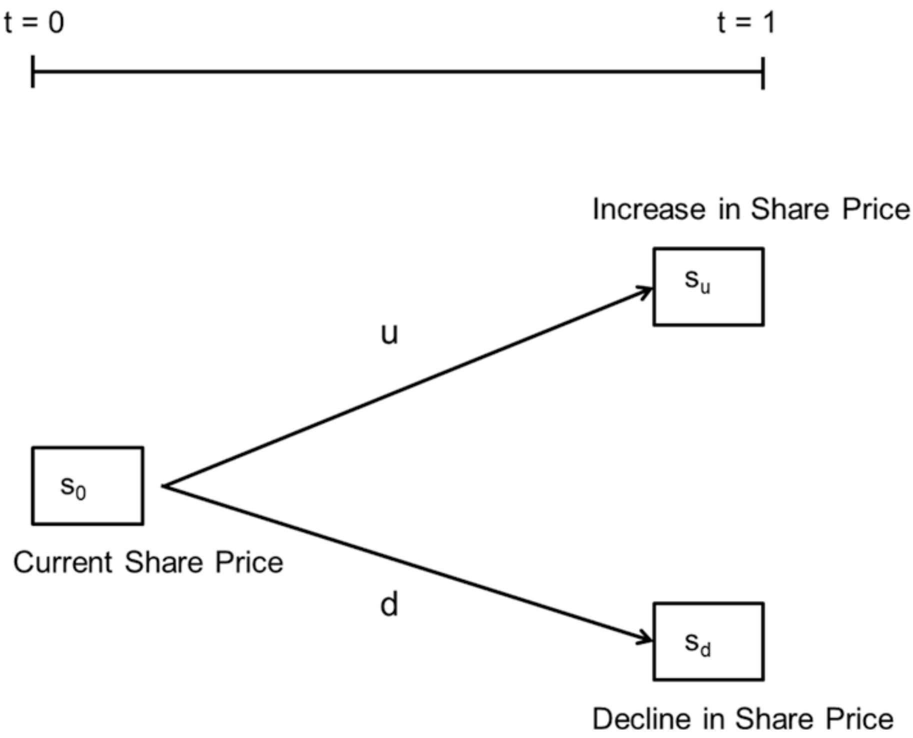


Fig. 14.28 Share price development in the one-period case

Setting Up an Option Tree

It is the initial assumption of this financial model that the price of the underlying can either go up or down by x units (see Fig. 14.28). Also assumed is a discrete stochastic process. It can be described as a discontinuous process with clearly delineated time increments and random behavior.

This is a major difference to the Black-Scholes model, which we will present next and which is based on a continuous stochastic process. A continuous stochastic process is a smooth process without identifiable time steps and random behavior.

The Binomial Model for European Call Options

For each of the discrete periods ΔT considered, the value of the underlying S can either change by a factor u or by a factor d. It must hold that $d < (1 + r_f) < u$.

The up-factor u and the down-factor d can be determined with reference to the volatility σ. These factors depend on the length of time represented by one step as well as the standard deviation and can be calculated according to the following formulas which are based on the so called Wiener process or the geometric Brownian motion used for the modeling of possible price changes of typical capital market products:

$$u = e^{\sigma\sqrt{\Delta T}}$$

$$d = e^{-\sigma\sqrt{\Delta}} = \frac{1}{u}$$

In the binomial model, a call on the underlying at the end of the period has a value of either:

$$\boldsymbol{C_{\mathbf{u}} = max\,\{u * S - X; 0\}}$$

or

$$\boldsymbol{C_{\mathbf{d}} = max\,\{d * S - X; 0\}}$$

where S is the current price of the underlying and X the exercise price.

The option price is determined with the help of an option tree. Initially the value of the option at expiration is calculated by subtracting the exercise price X from the possible values of S. In the case of a European option, the option value at the beginning is calculated as a weighted average of the two possible option payoffs at expiration discounted at the riskless rate of interest. In the one-period case, the option value is calculated as follows:

$$C = \frac{q \cdot C_u + (1-q) \cdot C_d}{1 + r_f}$$

> It must be kept in mind that the probability q is a so-called pseudo probability. It is not estimated, but calculated from the known values u, d and rf.

The pseudo probability can be derived from the option price formula as follows:

$$C = \frac{q \cdot u \cdot C + (1-q) \cdot d \cdot C}{1 + r_f}$$
$$1 = \frac{q \cdot u + (1-q) \cdot d}{1 + r_f}$$
$$1 + r_f = q \cdot u + (1-q) \cdot d$$
$$q \cdot (u-d) = 1 + r_f - d$$
$$q = \frac{\left(1 + r_f\right) - d}{(u-d)}$$

- **Calculating the option price with the one-period binomial model**

The most important formulas for setting up the one-period option tree and for the calculation of the call price in the one period binomial model are as follows (see Figs. 14.29 and 14.30):

The call price in the one-period binomial model is equal to € 3.99 and corresponds to the call price calculated with the help of duplication (€ 3.99).

- **The multi-period binomial model**

The one-period binomial model can now easily be expanded to cover two or multiple periods. Let us consider this case.

> In principle the steps of multi-period binomial models are not directly related to the life of the option in months. An adjustment of the life of the option is possible without adjusting the number of steps. However, the calculated values are always related to the current ratio of steps to the term of the option in months. As an example, a model with six steps and a term to maturity of 12 months generates one step every two months. We will take a closer look at this in the following model.

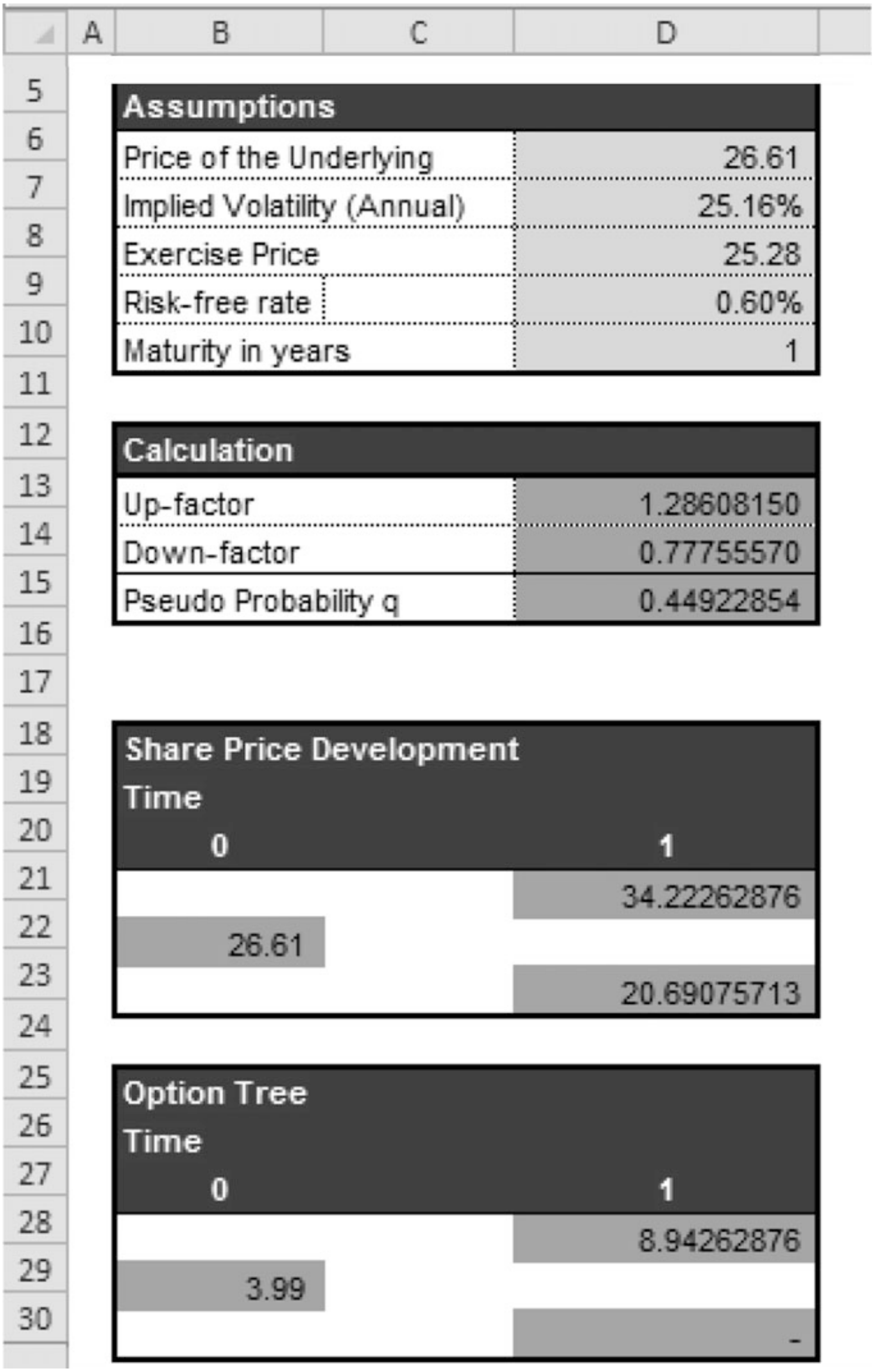
When calculating the possible development of the share price, the up-factor u and the down-factor d for the multi-period binomial model must be calculated first. If the life of the option is broken down into twelve months, the monthly up-factor u_M and the monthly down-factor d_M is calculated with the help of the following formula:

Variable	Formulas	Excel Implementation
Up factor (=Call_Europ.1_Without _Div.!D13)	=exp(Implied Volatility × Square Root (Term of option in years))	=EXP(D7*SQRT(D10))
Down factor (=Call_Europ.1_Without _Div.!D14)	=exp(- Implied Volatility × Square Root (Term of option in years))	=EXP(-D7*SQRT(D10))
Pseudo probability (=Call_Europ.1_Without _Div.!D15)	=(1 + riskless rate of interest – Down factor) / (Up factor – Down factor)	=(1+D9-D14)/(D13-D14)
Price change in the tree for the underlying (increase) (=Call_Europ.1_Without _Div.!D21)	= Price of underlying × Up factor	=B22*D13
Price change in the tree for the underlying (decrease) (=Call_Europ.1_Without _Div.!D23)	= Price of underlying × Up factor	=B22*D14
Intrinsic value in the option tree (=Call_Europ.1_Without _Div.!D28)	=IF(Price after increase > Exercise price; Price after increase - Exercise price;0)	=IF(D21>D8;(D21-D8);0)
Call price (=Call_Europ.1_Without _Div.!B29)	=(Intrinsic Value after Increase × Pseudo Probability)/(1 + Riskless Rate of Interest) + (Intrinsic Value after Decrease × (1 - Pseudo Probability)/(1 + Riskless Rate of Interest)	=D28*D15/(1+D9)+D30*(1-D15)/(1+D9)

Fig. 14.29 Calculating the call price using the one-period binomial model

$$u_M = e^{\sigma\sqrt{\frac{1}{12}}}$$
$$d_M = e^{-\sigma\sqrt{\frac{1}{12}}}$$

In the next step, the option price tree is established. The basis for this calculation is the pseudo-probability, which can be derived from the monthly up-factor, the down-factor and the riskless rate of interest r_f. In this case the monthly interest rate is relevant. Considering the effect



Assumptions	
Price of the Underlying	26.61
Implied Volatility (Annual)	25.16%
Exercise Price	25.28
Risk-free rate	0.60%
Maturity in years	1

Calculation	
Up-factor	1.28608150
Down-factor	0.77755570
Pseudo Probability q	0.44922854

Share Price Development	
Time	
0	1
	34.22262876
26.61	
	20.69075713

Option Tree	
Time	
0	1
	8.94262876
3.99	
	-

Fig. 14.30 Calculating the call price in the one-period binomial model using the example of RWE AG (Excel File Derivatives, Worksheet Call_Europ.1_Without_Div.)

of compounding, the monthly interest rate r_{fM} is calculated based on the following formula:

$$r_{fM} = \sqrt[12]{\left(1 + r_f\right)} - 1$$

The pseudo probability is q for the up-movement and $(1 - q)$ for the down-movement:

$$q = \frac{1 + r_{fM} - d_M}{u_M - d_M}$$

In our multi-period model we now also consider a possible dividend payment made by the underlying. To simplify the model, we assume that the dividend is paid in the middle of the original term to maturity of the option. A dividend reduces the price of the underlying in the relevant step and therefore also has an effect on all following steps.

In our model, the dividend is stated as a percentage of the current price of the underlying.

- **Calculating the option price in a multi-period binomial model involving six steps**

The most important formulas for setting up the multi-period tree for the development of the underlying and the calculation of the call price in the multi-period binomial model with six steps are shown in Figs. 14.31–14.34.

- **Calculating the option price in a multi-period binomial model involving twelve steps**

In the following we will use another multi-period binomial model to calculate the option price for one year involving twelve monthly steps (see Figs. 14.35–14.37). The dividend is once again included in the middle of the period, which is the end of the sixth step. The call price of this model is obviously comparable to the prices obtained with the one-period model and the model with 6 steps. But as we include more steps covering smaller time intervals, the precision of the model increases and the price converges towards the one determined with the help of the continuous Black-Scholes model, which is covered later.

The setup of the formulas for the binomial model with 12 steps is identical to the model with 6 steps. Only the number of steps in the formulas for the up-factor and down-factor per step and the riskless rate of interest per step must be adjusted from 6 to 12. The calculations are needed for twice as many periods and instead of bimonthly values, monthly values must be used.

The refinement of the binomial model in the form of more steps and the consideration of the dividend payment results in a price of the call of €2.77, which is more precise and significantly deviates from the der price obtained with the help of the one-period model of €3.99.

Variable	Formulas	Excel Implementation
Up-factor per step (=Call_Europ._6_with-Div!D14)	=exp(Volatility × Square Root(2-montly intervals / Life of the Option in Months))	=EXP(D7*SQRT(2/D11))
Down-factor per step (=Call_Europ._6_with-Div!D15)	=exp(-Volatility × Square Root(2-montly intervals / Life of the Option in Months))	=EXP(-D7*SQRT(2/D11))
Riskless rate of interest (per step) (=Call_Europ._6_with-Div!D16)	=(1 + Riskless rate of interest (annual) to the power of (2-montly intervals/Life of the option in months)-1)	=((1+D9)^(2/D11)-1)
Pseudo probability (=Call_Europ._6_with-Div!D17)	=(1 + Riskless rate of interest (per step) – Down-factor (per step)) / (Up-factor (per step) – Down-factor (per step)	=(1+D16-D15)/(D14-D15)
Price change of the underlying (increasing) for the first step (=Call_Europ._6_with-Div!C27)	= Price of the underlying × Up-factor (per step)	=B28*$D$14
Price change of the underlying (decreasing) for the first step (=Call_Europ._6_with-Div!C29)	= Price of the underlying × Down-factor (per step)	=B28*$D$15
Price change of the underlying (increasing) at the time of the dividend payment (=Call_Europ._6_with-Div!E25)	= Price of the underlying × Up-factor (per step) × (1 - Dividend)	=(D26*$D$14)*(1-$D$10)

Fig. 14.31 Calculating the call price using the multi-period binomial model with six steps

Price change of the underlying (decreasing) at the time of the dividend payment (=Call_Europ._6_with-Div!E31)	= Price of the underlying × Down-factor (per step) × (1 - Dividend)	=(D30*$D$15)*(1-$D$10)
Price change in the option tree for one step (=Call_Europ._6_with-Div!C47)	= Previous price (increased) × pseudo probability / (1 + riskless rate of interest) + previous price (decreased) × (1 - pseudo probability) / (1 + riskless rate of interest)	=D46*$D$17/(1+$D$16)+D48*(1-$D$17)/(1+$D$16)
Intrinsic value in the option price tree (=Call_Europ._6_with-Div!H42)	=IF(Price of underlying > Exercise price; Price of underlying - Exercise price;0)	=IF(H22>$D$8;(H22-$D$8);0)
Call price (=Call_Europ._6_with-Div!B48)	=(Price (increased) discounted to t_1 × pseudo probability) / (1 + riskless rate of interest) + (Price (decreased) discounted to t_1 × (1 - pseudo probability)) / (1 + riskless rate of interest)	=C47*$D$17/(1+$D$16)+C49*(1-$D$17)/(1+$D$16)

Fig. 14.31 (continued)

The difference between the models with 6 and 12 steps is already very small - the price of the call is € 2.73 in the six-step model compared to € 2.77 for 12 steps. As the number of steps increases, the call price converges to the value obtained with the Black-Scholes model.

Binomial Model for American Call Options

In contrast to European options, which can only be exercised at expiration, American options can be exercised during their entire life. This implies, depending on the values of the various pricing factors, a price that differs from that of European options. This also means that the pricing model needs to be adjusted in order to consider the fact that exercise is possible at each step.

We will consider an American call option with a dividend. To simplify the model we again assume that the dividend is paid exactly in

Assumptions	
Price of the Underlying	26.61
Implied Volatility (Annual)	25.16%
Exercise Price	25.28
Risk-free rate (Annual)	0.60%
Dividend	3.76%
Maturity (in Months)	12

Calculation	
Up-Factor (per Step)	1.10817583
Down-Factor (per Step)	0.90238387
Risk-free rate (per Step)	0.09975%
Pseudo Probability q	0.47919091

Fig. 14.32 Assumptions for the multi-period binomial model with six steps (Excel File Derivatives, Worksheet Call_Europ_6_With_Div.)

Share Price Development						
Time						
0	1	2	3	4	5	6
						47.43
					42.80	
				38.62		38.62
			34.85		34.85	
		32.68		31.45		31.45
	29.49		28.38		28.38	
26.61		26.61		25.61		25.61
	24.01		23.11		23.11	
		21.67		20.85		20.85
			18.82		18.82	
				16.98		16.98
					15.32	
						13.83

Fig. 14.33 The development of the underlying in the multi-period binomial model with six steps (Excel File Derivatives, Worksheet Call_Europ_6_With_Div.)

Option Tree						
Time						
0	1	2	3	4	5	6
						22.15
					17.55	
				13.39		13.34
			9.65		9.60	
		6.59		6.22		6.17
	4.32		3.80		3.12	
2.73		2.23		1.58		0.33
	1.28		0.79		0.16	
		0.40		0.08		-
			0.04		-	
				-		-
					-	
						-

Fig. 14.34 The development of the call price in the multi-period binomial model with six steps (Excel File Derivatives, Worksheet Call_Europ_6_With_Div.)

Assumptions	
Price of the Underlying	26.61
Implied Volatility (Annual)	25.16%
Exercise Price	25.28
Risk-free rate (Annual)	0.60%
Dividend	3.76%
Maturity (in Months)	12

Fig. 14.35 Assumptions for the calculation of the call price in the multi-period binomial model with 12 steps using the example of RWE AG (Excel File Derivatives, Worksheet Call_Europ._12_With_Div.)

the middle of the life of the option. We again utilize the multi-period binomial model with twelve steps for the American call option with a dividend.

The derivation of the price in the case of the binomial model for American call options is similar to the case of the binomial model for European call options. The assumptions and calculations and the

Share Price Development

Time

0	1	2	3	4	5	6	7	8	9	10	11	12
												61.22
											56.93	
										52.95		52.95
									49.24		49.24	
								45.79		45.79		45.79
							42.58		42.58		42.58	
						39.60		39.60		39.60		39.60
					38.26		36.82		36.82		36.82	
				35.58		34.24		34.24		34.24		34.24
			33.09		33.09		31.84		31.84		31.84	
		30.77		30.77		29.61		29.61		29.61		29.61
	28.61		28.61		28.61		27.54		27.54		27.54	
26.61		26.61		26.61		25.61		25.61		25.61		25.61
	24.75		24.75		24.75		23.82		23.82		23.82	
		23.01		23.01		22.15		22.15		22.15		22.15
			21.40		21.40		20.60		20.60		20.60	
				19.90		19.15		19.15		19.15		19.15
					18.51		17.81		17.81		17.81	
						16.56		16.56		16.56		16.56
							15.40		15.40		15.40	
								14.32		14.32		14.32
									13.32		13.32	
										12.39		12.39
											11.52	
												10.71

Fig. 14.36 The development of the underlying in the multi-period binomial model with twelve steps using the example of RWE AG (Excel File Derivatives, Worksheet Call_Europ._12_With_Div.)

Option tree

Time

0	1	2	3	4	5	6	7	8	9	10	11	12
												35.94
											31.67	
										27.69		27.67
									23.99		23.97	
								20.56		20.53		20.51
							17.36		17.34		17.31	
						14.39		14.37		14.34		14.32
					11.66		11.61		11.58		11.56	
				9.21		9.10		9.01		8.99		8.96
			7.08		6.91		6.74		6.60		6.58	
		5.31		5.09		4.85		4.60		4.36		4.33
	3.88		3.64		3.37		3.07		2.72		2.27	
2.77		2.53		2.28		1.98		1.64		1.18		0.33
	1.72		1.50		1.24		0.96		0.61		0.16	
		0.96		0.76		0.55		0.32		0.08		-
			0.46		0.31		0.16		0.04		-	
				0.17		0.08		0.02		-		-
					0.04		0.01		-		-	
						0.00		-		-		-
							-		-		-	
								-		-		-
									-		-	
										-		-
											-	
												-

Fig. 14.37 The development of the call price in the multi-period binomial model with twelve steps using the example of RWE AG (Excel File Derivatives, Worksheet Call_Europ._12_With_Div.)

development of the price of the underlying for the binomial model with twelve steps are thus identical to the ones for the European call option. However, the development of the price of the call option is different. While there is no difference in the formulas for the calculations at the final period, the formulas for the periods 0 to 11 differ. Here the financial modeler needs to work with an IF function to check at each

Variable	Formulas	Excel Implementation
Price change in the option tree for the first time period (=Call_American_12_with_Div.!C65)	= IF(Previous price (increased) × pseudo probability / (1 + riskless rate of interest) + previous price (decreased) × (1 - pseudo probability) / (1 + riskless rate of interest)) < (Price of the underlying in the value tree - Exercise price; Price of the underlying in the value tree – Exercise price; Previous price (increased) × pseudo probability / (1 + riskless rate of interest) + previous price (decreased) × (1 - pseudo probability) / (1 + riskless rate of interest))	=IF((D64*$D$17/(1+$D$16)+D66*(1-$D$17)/(1+$D$16))<(C33-$D$8);C33-$D$8;D64*$D$17/(1+$D$16)+D66*(1-$D$17)/(1+$D$16))

Fig. 14.38 Calculating the price of an American call option using the multi-period binomial model with twelve steps

step whether an early exercise of the option is preferable. This is the case if the calculated option value from the binomial model is below the intrinsic value for the period.

The following formulas (here presented for period 1) require adjustments as presented in Fig. 14.38, if the price of an American call option is calculated in the multi-period binomial model:

This results in the following tree for the development of the option price (see Fig. 14.39):

(Excel File Derivatives, Worksheet Call_American_12_With_Div.)

The price of the American call option with dividend derived with the multi-period binomial model with twelve steps is €2.93.

Binomial Model for American Put Options

In this section we demonstrate the derivation of the price of a put option in the binomial model using the example of the binomial model with twelve steps. The derivation for the American put option is similar to the derivation of the American call option in the binomial model. The assumptions and calculations and the development of the price of the underlying for the binomial model with twelve steps are thus identical to the ones for the call option. However, the development of the price of the put option is different.

Option Tree

Time 0	1	2	3	4	5	6	7	8	9	10	11	12
												35.94
											31.67	
										27.69		27.67
									23.99		23.97	
								20.56		20.53		20.51
							17.36		17.34		17.31	
						14.39		14.37		14.34		14.32
					12.98		11.61		11.58		11.56	
				10.31		9.10		9.01		8.99		8.96
			7.84		7.81		6.74		6.60		6.58	
		5.79		5.52		4.85		4.60		4.36		4.33
	4.16		3.85		3.37		3.07		2.72		2.27	
2.93		2.64		2.28		1.98		1.64		1.18		0.33
	1.77		1.50		1.24		0.96		0.61		0.16	
		0.96		0.76		0.55		0.32		0.08		-
			0.46		0.31		0.16		0.04		-	
				0.17		0.08		0.02		-		-
					0.04		0.01		-		-	
						0.00		-		-		-
							-		-		-	
								-		-		-
									-		-	
										-		-
											-	
												-

Fig. 14.39 The development of the price of an American call option in the multi-period binomial model with twelve steps (Excel File Derivatives, Worksheet Call_American_12_With_Div.)

Variable	Formulas	Excel Implementation
Intrinsic value in the option tree (=Put_American_12_with_Dividend!N54)	=IF (Price of the underlying in the value tree < Exercise price; Exercise price - Price of the underlying in the value tree;0)	=IF(N22<$D$8;($D$8-N22);0)

Fig. 14.40 Main formula for the financial modeler for a put option compared to a call option in the binomial model

While the case of the call option has positive values in the terminal period if the price of the underlying exceeds the exercise price, the case of the put option is characterized by positive values for the cases where the exercise price exceeds the price of the underlying.

Hence the formula in Fig. 14.40 is decisive in the case of the American put option:

The price development of the put option is thus a mirror image of the price development of the call option. The price development of the put option is as follows (Fig. 14.41):

The price of the American put option derived with the multi-period binomial model with 12 steps is € 2.30. This is very close to the market price at EUREX of € 2.31.

Otpion Tree

Time 0	1	2	3	4	5	6	7	8	9	10	11	12
												-
											-	
										-		-
									-		-	
								-		-		-
							-		-		-	
						-		-		-		-
					0.03		-		-		-	
				0.15		0.06		-		-		-
			0.41		0.26		0.11		-		-	
		0.85		0.65		0.44		0.22		-		-
	1.49		1.27		1.03		0.75		0.43		-	
2.30		2.09		1.85		1.58		1.26		0.83		-
	3.06		2.86		2.63		2.36		2.04		1.61	
		3.99		3.81		3.62		3.41		3.19		3.13
			5.06		4.93		4.81		4.70		4.68	
				6.24		6.17		6.13		6.13		6.13
					7.48		7.47		7.47		7.47	
						8.72		8.72		8.72		8.72
							9.88		9.88		9.88	
								10.96		10.96		10.96
									11.96		11.96	
										12.89		12.89
											13.76	
												14.57

Fig. 14.41 The price development of the put option in the multi-period binomial model with twelve steps using the example of the RWE put option (Excel File derivatives, Worksheet Put_American_12_with_Div.)

Even though the binomial approach as a discrete valuation method only provides an approximate solution, it is still suitable for the pricing of options in applied work. The Black-Scholes model which is presented in the following is a special case of the binomial model. If the time period in the binomial model is shortened to an infinitesimally small interval and the assumption of a lognormal distribution of the return fluctuations of the underlying is used, the Black-Scholes model results.

4.2.4 The Black-Scholes Model

> The Black-Scholes model is a continuous option pricing model.

In the beginning of the seventies the work of Black and Scholes as well as the refinements by Merton provided the true foundation for the current methods to calculate option prices. The Black-Scholes model allows the mathematically precise valuation of European options on securities that pay no dividends. It is again based on the idea of replication which was already introduced previously. In principle the idea of replication and the binomial method are simply applied in continuous time.

Assumptions of the Black-Scholes Model

- The capital market can be considered to be complete:
- Information is available to all investors simultaneously. No barriers to entry exist, which could limit access of market participants to any market.
- No arbitrage profits are possible:
- Should a riskless profit opportunity be present due to the mispricing of an asset, it will immediately be eliminated via changes in supply or demand.
- There are no information or transaction costs.
- There are no taxes.
- The volatility of the price of the underlying remains constant during the life of the option and is known in advance.
- All options considered can only be exercised at expiration. They are European options.
- All assets and derivatives are infinitely divisible and do not react to changes in liquidity.
- Investing and lending are both possible without limit at the riskless rate. The riskless rate of interest is known and is constant throughout the life of the option.
- Short selling is possible without limit.
- No dividend payments are made on the underlying during the life of the option. There are no stock splits and no subscription rights are granted.
- The probability distribution of potential share prices follows a lognormal distribution.
- Investors act rationally.

The Black-Scholes Formula

Influenced by the assumptions and the approach listed above, Black and Scholes developed the following model for the determination of the fair value of a European call option in the year 1973:

$$c = S_0 N(d_1) - X e^{-r_f T} N(d_2)$$

with

$$d_1 = \frac{\ln(S_0) + \left(r_f + \sigma^2/2\right) T}{\sigma\sqrt{T}}$$

$$d_2 = d_1 - \sigma\sqrt{T}.$$

$N(d)$ is the standard normal distribution. Defined are:
c = price of the call option
S_0 = price of the underlying
X = exercise price of the call
ln = natural logarithm
e = basis of the natural logarithm = 2.7128. . .
r_f = riskless rate of interest
$N(d)$ = cumulative standard normal distribution
σ = volatility
T = term of the option

For the value of a put option p, the following formula holds:

$$p = Xe^{-r_f T} N(-d_2) - S_0 N(-d_1)$$

The valuation of an option at time $t = 0$ (c or p) is thus influenced by the current share price S_0, the exercise price X, the term of the option T, the riskless rate of interest r_f as well as two weights $N(d)$. The volatility σ is either determined from historical data (historical volatility) or derived from the option prices (implied volatility), if all other parameters are given.

We initially follow the typical textbook treatment and present the case which excludes dividends (see Figs. 14.42 and 14.43).

The Black-Scholes-Merton Model

If the above model is expanded to include a constant dividend payment[7] (D), the following formula can be used:

$$c = S_0 e^{-DT} N(d_1) - Xe^{-r_f T} N(\mathbf{d}_2)$$

The most important formulas of the classical Black-Scholes model with dividends are (see Figs. 14.44 and 14.45):

Variable	Formulas	Excel Implementation
d_1 (=Black-Scholes_without_Dividends!C13)	=ln((Price of the underlying/Exercise price) + (Riskless rate of interest + 0,5 ×Implied Volatility^2) / (Implied Volatility × Square root (Term of the option))	=(LN(C6/C7)+(C9+0.5*C10^2)*C8)/(C10*SQRT(C8))
d_2 (=Black-Scholes_ without _Dividends!C14)	=d_1 - Square root (Term of the option) × Implied volatility	=C13-SQRT(C8)*C10
$N(d_1)$ (=Black-Scholes_ without _Dividends!C15)[8]	=Standard normal distribution (d_1)	=NORM.S.DIST(C13; TRUE)
$N(d_2)$ (=Black-Scholes_ without _Dividends!C16)	= Standard normal distribution (d_2)	=NORM.S.DIST(C14; TRUE)
Call price (=Black-Scholes_ without _Dividends!C19)	= Price of the underlying × Standard normal distribution (d_1) - Exercise price × exp(-Riskless rate of interest × Term of the option) × Standard normal distribution (d_2)	=C6*C15-C7*EXP(-C9*C8)*C16
Put price (=Black-Scholes_ without _Dividends!C20)	=Call price - Price of the underlying + Exercise price × exp(-Riskless rate of interest × Term of the option)	=C19-C6+C7*EXP(-C9*C8)

Fig. 14.42 Calculating the call price and put price in the Black-Scholes model.

In the Black-Scholes model,dividends imply that the price of the call option declines while the price of the put option increases.

	A	B	C
4			
5		**Assumptions**	
6		Price of the Underlying	26.61
7		Exercise Price	25.28
8		Maturity	1
9		Risk-free rate	0.60%
10		Implied Volatility	25.16%
11			
12		**Calculations**	
13		d_1	0.3534
14		d_2	0.1018
15		$N(d_1)$	0.6381
16		$N(d_2)$	0.5406
17			
18		**Result**	
19		Call Price	3.40
20		Put Price	1.92
21			

Fig. 14.43 Calculation of call price and put price in the Black-Scholes model for RWE AG (Excel File Derivatives, Worksheet Black-Scholes_No_Dividends)

Variable	Formulas	Excel Implementation
Exp(-r_f×T) (=Black-Scholes_with_Dividends!C14)	=exp(-Riskless rate of interest × Term of the option in years)	=EXP(-C11*C9)
Exp(-DT) (=Black-Scholes_with_Dividends!C15)	=exp(-Dividends × Term of the option in years)	=EXP(-C8*C9)
(r_f-D+0.5×V^2) (=Black-Scholes_with_Dividends!C16)	=(Riskless rate of interest - Dividends + 0,5×Volatility^2)	=(C11-C8+0.5*C10^2)
d_1 (=Black-Scholes_with_Dividends!C17)	=ln((Price of the underlying/Exercise price) + (r-D+0.5×V^2) × Term of the option in years) / (Volatility × Square root (Term of the option))	=(LN(C6/C7)+C16*C9)/(C10*SQRT(C9))
N(d_1) (=Black-Scholes_with_Dividends!C18)	=Standard normal distribution (d_1)	=NORM.S.DIST(C17; TRUE)
N(-d_1) (=Black-Scholes_with_Dividends!C19)	=1 - Standard normal distribution (d_1)	=1-C18
d_2 (=Black-Scholes_with_Dividends!C20)	=d_1 - (Volatility × Square root(Term of the option))	=C17-(C10*SQRT(C9))
N(d_2) (=Black-Scholes_with_Dividends!C21)	=Standard normal distribution (d_2)	=NORM.S.DIST(C20; TRUE)
N(-d_2) (=Black-Scholes_with_Dividends!C22)	=1 - Standard normal distribution (d_2)	=1-C21
Price of the call option (=Black-Scholes_with_Dividends!C25)	= Price of the underlying × exp(-DT) × Standard normal distribution (d_1) – Exercise price × exp(-rT) × Standard normal distribution (d_2)	=C6*C15*C18-C7*C14*C21
Put price (=Black-Scholes_with_Dividends!C26)	=- Price of the underlying exp(-DT) × Standard normal distribution (-d_1) + Exercise price × exp(-rT) × Standard normal distribution (-d_2)	=-C6*C15*C19+C7*C14*C22

Fig. 14.44 Calculating the call price and the put price in the Black-Scholes-Merton model

Assumptions	
Price of the Underlying	26.61
Exercise Price	25.28
Dividends	3.76%
Maturity (in Years)	1.00
Implied Volatility	25.16%
Risk-free rate (rf)	0.60%

Calculations	
Exp(-rf *T)	0.9940
Exp(-DT)	0.9631
(rf-D+0.5*V^2)	0.0001
d1	0.2040
N (d1)	0.5808
N (-d1)	0.4192
d2	-0.0476
N(d2)	0.4810
N(-d2)	0.5190

Result	
Call Price	2.798
Put Price	2.30

Fig. 14.45 Calculation of the call price and the put price in the Black-Scholes-Merton model for RWE AG (Excel File Derivatives, Worksheet Black-Scholes_with_Dividends)

4.2.5 Model Assessment

Both the Black-Scholes model and the binomial model following Cox-Ross-Rubinstein can be criticized. The following aspects among others can be criticized with regard to the Black-Scholes model:

- Volatility and interest rates are not constant in reality.
- Dividends are considered to be constant.
- The valuation of American options is not possible.[9]
- Share prices in reality do not follow a lognormal distribution.
- In reality we need to be concerned with taxes and transaction costs.

The biggest problem in applied work is the assumption of the Black-Scholes model that volatility can be considered to be constant. If the option price (for example by providing binding quotes from a market maker[10]) and all the other parameters of the Black-Scholes pricing formula are known, the implied volatility can be derived from the pricing formula. A comparison of these implied volatilities on an identical underlying with identical or similar terms to maturity, but different exercise prices reveals so-called volatility smiles. Options that are deep-in-the-money of deep-out-of-the-money have higher implied volatilities than options which are at the money. This relationship between implied volatility and the exercise prices needs to be kept in mind when applying the Black-Scholes pricing formula and can be displayed graphically as in Fig. 14.46.

The following issues should be assessed critically in the binomial model:

- Share prices are quoted continuously.
- Dividends are not considered, at least in general.
- Investors are not risk-neutral in reality.
- The level of interest rates need not be constant.
- In reality we need to be concerned with taxes and transaction costs.

But it needs to be stressed that the models are particularly suitable for pricing relatively straightforward derivatives. For more complex derivatives, Monte Carlo simulations are usually applied.

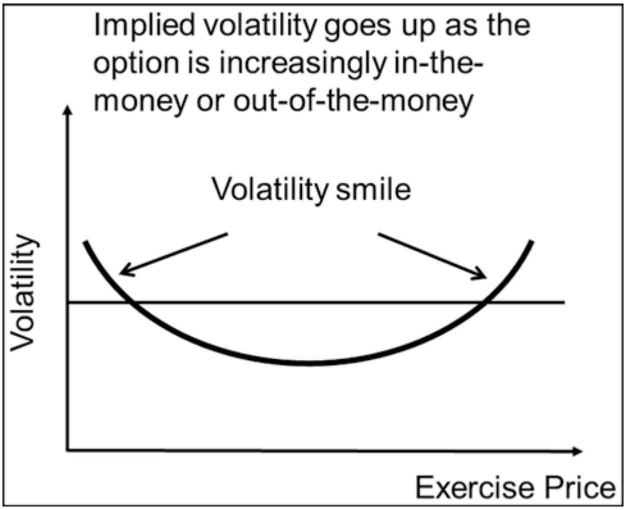


Fig. 14.46 Volatility smile versus constant volatility

4.2.6 Greeks

Important and useful concepts in the application of options are sensitivity figures, the so-called Greeks. Greeks refer to the reaction of the option price to various value drivers. They provide information about the change of the option price if, for example, the price of the underlying or its volatility change (ceteris paribus analysis). Mathematically the various derivatives follow from the Black-Scholes formula.

The sensitivities of the option price play a major role in many strategies. They facilitate the implementation of efficient and effective strategies. Based on the Black-Scholes model with dividends, the derivation of the Greeks is shown in the following (Fig. 14.47).[11]

Delta

Mathematically, delta is the first partial derivative of the option price with respect to the price of the underlying. Delta is a sensitivity which establishes the change of the option price for changes of the price of the underlying. It is thus the direct sensitivity of the option price to a change in the price of the underlying.

	A	B	C	D
5		**Assumptions**		
6		Price of the Underlying	26.61	
7		Exercise Price	25.28	
8		Dividends	3.76%	
9		Maturity (in years)	1.00	
10		Implied Volatility	25.16%	
11		Risk-free Rate	0.60%	
12				
13		**Calculations**		
14		Exp(-rT)	0.9940	
15		Exp(-DT)	0.9631	
16		$(r-D+0.5*V^2)$	0.0001	
17		d1	0.2040	
18		N (d1)	0.5808	
19		N (-d1)	0.4192	
20		d2	-0.0476	
21		N(d2)	0.4810	
22		N(-d2)	0.5190	
23		Distribution Function of the Standard Normal Distributic	0.3907	
24				
25		**Results**	**Long Call**	**Long Put**
26		Option Price	2.80	2.30
27		Delta	0.5594	-0.4037
28		Gamma	0.0562	0.0562
29		Theta	-0.0031	-0.0063
30		Rho	12.0873	-13.0419
31		Vega	10.0136	10.0136
32		Leverage Factor	9.5104	11.5760
33		Omega	5.3200	-4.6734
34				

Fig. 14.47 Black-Scholes model including the derivation of the Greeks (Excel File Derivatives, worksheet Black-Scholes_including_Greeks)

$$Delta = \Delta = \frac{Absolute\ Change\ of\ the\ Option\ Price}{Absolute\ Change\ of\ the\ Price\ of\ the\ Underlying}$$

For call options, delta can take on values in the interval [0,1] when using the Black-Scholes model. For put options this interval is $[-1, 0]$.

Delta of	Out-of-the-money	At-the-money	In-the-money
Long call / short put	approx. 0 to 0.5	approx. 0.5	approx. 0.5 to 1
Long put / short call	approx. 0 to -0.5	approx. -0.5	approx. -0.5 to -1

Fig. 14.48 Delta values

Variable	Formulas	Excel Implementation
Delta call option (=Black-Scholes_including_Greeks!C27)	= exp(-DT) × Standard normal distribution (d_1)	=C15*C18
Delta put option (=Black-Scholes_including_Greeks!D27)	= exp(-DT) × (Standard normal distribution (d_1) - 1)	=C15*(C18-1)

Fig. 14.49 The formulas for the calculation of the delta of a call option and a put option using the example of RWE AG

A delta of 0.5 for example means that the price of an option will go up by 0.5 units if the price of the underlying increases by one unit (see Figs. 14.48 and 14.49).

From the Black-Scholes model, delta can be calculated as follows:

$$\Delta Call = N(d_1)$$
$$\Delta Put = N(d_1) - 1$$

The replication portfolio which forms the basis of the Black-Scholes model can be interpreted as a delta-neutral portfolio, where constant portfolio rebalancing assures that the delta is equal to zero at each point in time.

Delta for the RWE option:

- Call option: 0.5594
- Put option: –0.4037

In the example of the call option, this implies that the call increases (decreases) by € 0.56 when RWE shares increase (decrease) by € 1.

Applied Example

Delta hedging

Delta hedging describes a strategy for the hedging of option positions. It involves establishing a holding in the underlying that reacts contrary to the option in the case of price changes of the option. In order to obtain an effective delta hedge, short selling is needed in the case of a long call or a short put. For a short call respectively a long put, the underlying must be purchased. When the delta of the option changes, the position in the underlying needs to be adjusted accordingly. This assures the effectiveness of the hedge.

Gamma

Delta of the delta: The change in the delta is described by gamma. Gamma provides information about the change in delta if the price of the underlying changes. It measures the increase in delta for an increase of the underlying of one unit. Thus gamma is the second derivative and can be called the delta of delta (Fig. 14.50).

$$Gamma = \frac{Absolute\ Change\ of\ the\ Delta}{Absolute\ Change\ of\ the\ Price\ of\ the\ Underlying}$$

Gamma for die RWE option:

- Call option: 0.0562
- Put option: 0.0562

This means that the delta of the option goes up by € 0.06 when RWE shares increase by € 1.

Variable	Formulas	Excel Implementation
Distribution function of the standard normal distribution (=Black-Scholes_including_Greeks!C23)	=exp(-(d_1^2) / 2) / Square root(2×π)	=EXP(-(C17^2)/2)/SQRT(2*PI())
Gamma call option (=Black-Scholes_including_Greeks!C28)	= Distribution function of the standard normal distribution × exp(-DT) / (Price of the underlying × Implied volatility × Square root (Term of the option in years))	=C23*C15/(C6*C10*SQRT(C9))
Gamma Put-Option (=Black-Scholes_including_Greeks!D28)	= Distribution function of the standard normal distribution × exp(-DT) / (Price of the underlying × Implied volatility × Square root (Term of the option in years))	=C23*C15/(C6*C10*SQRT(C9))

Fig. 14.50 The formulas for the calculation of the gamma of a call option and a put option

Theta

Theta provides information about the change in the price of the option if one day of time value is lost. It thus measures the sensitivity to loss of time value.

$$Theta = \frac{Change\ \ of\ the\ \ Option\ \ Price}{Change\ in\ the\ Term\ of\ the\ Option}$$

Since the option price formula is based on the term to maturity of the option in years, the result needs to be converted to one day. Two different approaches are applied: the transformation on the basis of one calendar year (365 days) and the transformation based on trading

Varia- ble	Formulas	Excel Implementation
Theta call option (=Black-Scholes_including_Greeks!C29)	= (-((Price of the underlying × Distribution function of the standard normal distribution × Implied volatility × exp(-DT) / (2 × Square root (Term of the option in years))) + (Dividends × Price of the underlying × N(d_1) × exp(-DT)) - (Riskless rate of interest × exp(-rT) × N(d_2))) / 250	=(-((C6*C23*C10*C15)/(2*SQRT(C9)))+(C8*C6*C18*C15)-(C11*C7*C14*C21))/250
Theta put option (=Black-Scholes_including_Greeks!D29)	= (-((Price of the underlying × Distribution function of the standard normal distribution × Implied volatility × exp(-DT) / (2 × Square root (Term of the option in years))) - (Dividends × Price of the underlying × N(-d_1) × exp(-DT)) + (Riskless rate of interest × exp(-rT) × N(-d_2))) / 250	=(-((C6*C23*C10*C15)/(2*SQRT(C9)))-(C8*C6*C19*C15)+(C11*C7*C14*C22))/250

Fig. 14.51 The formulas for the calculation of the theta of a call option and a put option

days (250 trading days).[12] There is a linear relationship between the daily change and the annual change. In the following calculations as well as in the chapter on Portfolio Management, the trading year is assumed. The formula can be changed quickly by substituting the number of days in a year into the formula (see Fig. 14.51).

Theta for the RWE option:

- Call option: –0.0031
- Put option: –0.0063

> In the example of the call option, this implies that the call declines "over night" by € 0.003

Rho

Rho measures changes in the option price resulting from changes in interest rates. Rho measures the influence of a change in the riskless rate of interest r_f on the price of the option. Thus rho is the first partial derivative of the option value with respect to the riskless rate of interest (Fig. 14.52).

Variable	Formulas	Excel Implementation
Rho call option (=Black-Scholes_including_Greeks!C30)	=Exercise price of the option × Term of the option in years × exp(-rT) × N(d_2)	=C7*C9*C14*C21
Rho put option (=Black-Scholes_including_Greeks!D30)	= Exercise price of the option × Term of the option in years × exp(-rT) × N(-d_2)	=-C7*C9*C14*C22

Fig. 14.52 Calculating rho of a call option and a put option

$$Rho = \frac{Change\ \ of\ the\ \ Option\ \ Price}{Change\ in\ the\ Cost\ of\ Financing}$$

Rho for the RWE option:

- Call option: 12.0873
- Put option: –13.0415

In the example of the call option, this implies that the call increases by €0.12 if the riskless rate of interest goes up by 1% in absolute terms, meaning that it goes up from 0.60% to 1.60%.

Vega

Vega measures the change in the price of the option for changes in volatility σ. The symbol for vega is the Greek letter kappa (K).

$$Vega = \frac{Change\ \ in\ the\ \ Option\ \ Price}{Change\ \ in\ Volatility\ (Implied)}$$

Vega for the RWE option (Fig. 14.53):

- Call option: 10.0136
- Put option: 10.0136

Variable	Formulas	Excel Implementation
Vega Call-Option (=Black-Scholes_including_Greeks!C31)	=Price of the underlying × Square root (Term of the option in years) × Distribution function of the standard normal distribution × exp(-DT)	=C6*SQRT(C9)*C23*C15
Vega Put-Option (=Black-Scholes_including_Greeks!D31)	= Price of the underlying × Square root (Term of the option in years) × Distribution function of the standard normal distribution × exp(-DT)	=C6*SQRT(C9)*C23*C15

Fig. 14.53 The formulas for the calculation of the vega of a call option and a put option

This implies for example, that the price of the option increases by €0.10 when the implied volatility goes up by 1% in absolute terms, meaning that it goes up from 25.61% to 26.61%.

4.2.7 Additional Measures

Leverage Factor

Strictly speaking, measures of leverage are not among the Greeks. But leverage is watched carefully, especially among private investors. It basically states the number of warrants that can be obtained for one unit of the underlying. In the formula, the possibility of a conversion ratio that differs from 1:1 must be taken into consideration.

$$\textit{Leverage Factor} = \frac{\textit{Price of the Underlying} \times \textit{Ratio}}{\textit{Price of the Warrant}}$$

The leverage factor may initially appear to be an interesting variable for assessing the return expectations for a warrant, but it completely ignores the future development of the two parameters. Such a snapshot does not constitute a solid foundation concerning the chances that an option offers. A more suitable method for the assessment of the future performance is omega, also considered as theoretical leverage,

Variable	Formulas	Excel Implementation
Leverage factor call (=Black-Scholes_including_Greeks! C32)	=Price of the underlying / Price of the call	=C6/C26
Leverage factor put (=Black-Scholes_including_Greeks! D32)	= Price of the underlying / Price of the put	=C6/D26

Fig. 14.54 Calculating the leverage factor of a call and a put

which will be analyzed in the following. For the following calculations we assume a standard warrant with a conversion ratio of 1:1 (Fig. 14.54).

The leverage factor for the RWE warrant:

- Call: 9.5104
- Put: 11.5760

> In the example of the call warrant, this implies that the investor only needs to invest one tenth of the amount needed for a direct investment

Omega

Since the simple leverage factor alone is only of limited use for the true leverage implied in an option for most stages of their life, an additional parameter is needed: delta. To review: delta measures how the price of an option changes as the underlying changes by one unit. Omega, also called theoretical leverage, now measures the percentage change of the warrant[13] price relative to the percentage change of the price of the underlying. The following formula once again shows the dependence of omega on delta as well as the proximity to the simple leverage factor:

$$\textit{Omega} = \Omega = \textit{Delta} \times \frac{\textit{Price of the Underlying} \times \textit{Ratio}}{\textit{Price of the Warrant}}$$

Variable	Formulas	Excel Implementation
Omega call (=Black-Scholes_including_Greeks! C33)	= exp(-DT) × Standard normal distribution (d_1) × (Price of the underlying / Price of the call)	=C15*C18*(C6/C26)
Omega put (=Black-Scholes_including_Greeks! D33)	= (exp(-DT) × (Standard normal distribution (d_1) – 1) × (Price of the underlying / Price of the put))	=(C15*(C18-1)*(C6/D26))

Fig. 14.55 Calculation omega of a call and a put

Just as the previous Greeks, omega can also be calculated independently from the Black-Scholes formula.

Since delta is not a constant, omega can only serve as an estimate for the leverage effect. But especially in the case of options that are not deep-in-the-money, it allows a more realistic assessment of the leverage effect compared to the simple leverage factor. For the following calculations we again assume a standard warrant with conversion ratio of 1:1 (Figs. 14.55 and 14.56).

Omega for the RWE warrant:

- Call: 5.3200
- Put: –4.6734

In the example of the call warrant, this implies that the price of the call increases by 5.32% when the price of RWE shares goes up by 1% to €26.88

Overview: Signs of the Greeks and Other Measures

	Delta	Gamma	Theta	Rho	Vega	Leverage	Omega
Long call	positive	positive	negative	positive	positive	positive	positive
Short call	negative	negative	positive	negative	negative	positive	negative
Long put	negative	positive	negative	negative	positive	positive	negative
Short put	positive	negative	positive	positive	negative	positive	positive

Fig. 14.56 The interpretation of the signs of the Greeks and other measures

5 What Is Involved in the Four Basic Option Strategies?

The basic strategies

Option trading relies on four basic strategies on which all extended strategies are based.[14]

- **Long call:** In the case of a long call the investor (buyer) is convinced that the value of the underlying will go up. He obtains the right to buy the underlying via the call, which will increase in value if his expectation materializes. Alternatively, the investor could directly purchase the underlying, but would be required to tie up significantly more capital. With the call option he can leverage his capital. His loss potential is limited to the initial investment (payment of the premium). He has no obligation to provide additional funds. At the same time, he has the opportunity to participate in unlimited price advances.
- **Short call:** The investor who enters into a short call position expects constant or declining prices and wants to generate additional income. The selling of the calls generates a maximum profit equal to the premium payment. The risk of the short call consists of the possibility that the underlying must be delivered at the exercise price. This risk can be reduced if the underlying is already in the possession of the seller of the option at the time of entering into the transaction. Such an approach is called covered call writing, since the obligation to deliver can be met by selling the existing holding and therefore no large loss can accrue.
- **Long put:** In the case of a long put the investor (buyer) expects declining prices. He either wants to hedge an existing holding or speculate on declining prices with the purchase of this option. The maximum loss is again limited to the option premium paid. The profit is only theoretically unlimited, since no asset can fall below a value of zero. This establishes an upper bound for the profit.
- **Short put:** The investor who enters into a short put position expects unchanged or increasing markets. He wants to participate in this development and actively accepts risks. He receives the option

premium as compensation, which simultaneously constitutes his maximum profit. Since he is absolutely required to accept the underlying, this involves a large potential for losses. His maximum loss is equal to the exercise price minus the premium (complete loss), if the shares become worthless, for example in the case of insolvency.

In the following, the basic strategies are explained thoroughly with reference to applied examples.

5.1 Long Call

With a long call an investor acquires the right, but not the obligation, to purchase an underlying at expiration or during the term of the option. For this right he makes a payment to the counterparty (short call), the option premium. The short is required to deliver the underlying to the long on demand.

Applied Example

Long call on RWE shares (American option)

Exercise price:	€ 20.00
Expiration:	December
Option premium:	€ 1.00

Thus the buyer has the right to acquire the RWE shares during the entire life of the option (until the third Friday in December) at a price of € 20. For this right, he has made a premium payment of € 1 to the seller, which is due at the beginning of the transaction.

If the share price of RWE exceeds the exercise price, which is € 20 in our applied example, the buyer of the option (long) will make use of his right and exercise the option. The seller (short) is required to deliver the underlying at € 20 per share.

The breakeven point for the option position is at € 21, because the buyer of the call option was required to pay the premium of € 1 when he entered into the transaction. This needs to be included in the overall consideration.

Variable	Formulas	Excel Implementation
Decision to exercise (=Long_Call!C9)	=If(Price of the underlying > Exercise price; Exercise; Do not exercise)	=IF(B9>$C$6;"yes";"no")
Profit (=Long_Call!D9)	=If(Price of the underlying > Exercise price; Price of the underlying – Exercise price – Price of the call ; - Price of the call)	=IF(B9>$C$6;B9-$C$6-$C$5;-$C$5)

Fig. 14.57 The formula to decide whether an option should be exercised or not

Practical Tip

Disciplined use of long calls

An investor should only purchase a long call if he attaches a high probability to a price increase of the underlying. This can be the case, for example, if changes in the capital structure become apparent or outstanding earnings figures are expected.

Scenario analysis: Three different scenarios are possible:

- The share price is below €20: The buyer of the call suffers a compete loss of €1 at expiration. The option expires worthless.
- The share price is between €20 and €21: The buyer of the call suffers a slight loss. The value of the option is equal to its intrinsic value, since the option is in-the-money.
- The share price is above €21: The buyer of the call makes a profit. The value of the option at expiration is greater than it was when the transaction was initiated.

Summary: In the case of a long call, the underlying must exceed the breakeven price for the exercise to be profitable for the buyer (see Fig. 14.57).

Figure 14.58 shows the decision process graphically.

Assumptions	
Call Price upon conclusion	1.00
Exercise Price	20.00

Price of the Underlying	Will the Option be Exercised?	Profit
0.00	no	-1.00
5.00	no	-1.00
10.00	no	-1.00
15.00	no	-1.00
20.00	no	-1.00
20.50	yes	-0.50
21.00	yes	-
22.00	yes	1.00
24.00	yes	3.00
26.00	yes	5.00
28.00	yes	7.00
30.00	yes	9.00
32.00	yes	11.00

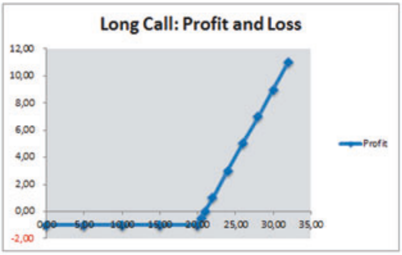


Fig. 14.58 Deciding whether an option should be exercised or not

5.2 Short Call

In the above applied example a call option was purchased. In the second case, a call option is sold. We make use of a similar applied example:

Applied Example

Short call on RWE shares

Exercise price: € 20.00
Expiration: December
Option premium: € 1.00

As the seller of the call option on RWE, we received the option premium of € 1.00. Thus we are obligated to deliver the underlying upon request. Two situations need to be assessed separately: on the one hand short call positions on an underlying that is in our possession (covered call writing) and on the other hand uncovered short call positions (naked call writing).

Naked call writing involves the selling of call options on an underlying which is not in the possession of the writer of the call option. This is the most speculative of all option strategies, since the risk is unlimited.[15] In comparison: while the seller of a put option in an extreme scenario is exposed to the risk of paying the full exercise price minus the premium (in case of an insolvency of the underlying

Variable	Formulas	Excel Implementation
Decision to exercise (=Short_Call!C9)	=If(Price of the underlying > Exercise price; Exercise; Do not exercise)	=IF(B9>$C$6;"yes";"no")
Profit (=Short_Call!D9)	=If(Price of the underlying > Exercise price; Exercise Price – Price of the underlying + Price of the call; Price of the call)	=IF(B9>$C$6;$C$6-B9+$C$5;$C$5)

Fig. 14.59 Formula to decide whether the option should be exercised or not and to calculate the profit

the lower limit on the share price is zero), the risk of the naked call is unlimited, since no upper limit exists for the price increase of the underlying.

Considerably less speculative is covered call writing, where the seller of the call option holds the underlying in her portfolio.

5.2.1 Naked Call Writing

Let us initially contemplate the example of naked call writing.

Scenario analysis:

- The share price is below the exercise price of € 20.00: The investor who holds the short call obtains the maximum profit. He has collected the premium and the option expires worthless.
- The share price is between € 20.00 and € 21.00: The investor who holds the short call makes a reduced profit. Since the option will be exercised by the investor who bought it, the short call investor must deliver the underlying. He needs to purchase them in the market and delivers them (Reminder: this is the case of naked call writing). The profit is the difference between the option premium already received and the cost of obtaining the securities minus exercise price.
- The share price is above the breakeven point of € 21.00: The investor is suffering a loss. He has an obligation to purchase the underlying at the market price and to deliver at the exercise price.

Assumptions	
Call Price upon conclusion	1.00
Exercise Price	20.00

Price of the Underlying	Will the Option be Exercised?	Profit
0.00	no	1.00
5.00	no	1.00
10.00	no	1.00
15.00	no	1.00
20.00	no	1.00
20.50	yes	0.50
21.00	yes	-
22.00	yes	-1.00
24.00	yes	-3.00
26.00	yes	-5.00
28.00	yes	-7.00
30.00	yes	-9.00
32.00	yes	-11.00

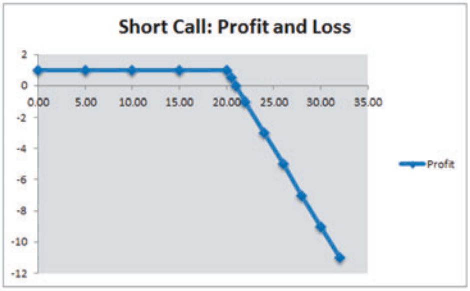


Fig. 14.60 Deciding whether the option should be exercised (Excel File Derivatives, Worksheet Short_Call)

The formula to decide whether a short call will be exercised is shown in Fig. 14.59.
Figure 14.60 shows the decision process graphically.

5.2.2 Covered Call Writing

The potential for losses of the strategy short call is unlimited in a rising market. The conservative version of a short call is covered call writing (CCW), which involves selling of calls on an underlying that is held in the portfolio. If the option is exercised, the investor in the short call can deliver the underlying from her portfolio. Covered call writing is a strategy to enhance yield. Especially the return of long-term holdings can be increased by collection premium payments.

The risk is limited to a missed profit opportunity. If the underlying exceeds the exercise price, the writer of the covered call is obligated to deliver the underlying and can no longer participate in further price advances. At the same time, the income from the option also cushions losses in the underlying.

Strategy: The strategy covered call writing is used on the portfolio during periods when no dividend payments can be expected. The calls should initially be out-of-the-money. The premium payment constitutes a positive cash flow. In the case of an exercise of the position (long call) the risk is reduced, since the underlying is already in the portfolio. The premium income provides a safety cushion for the investor in the case of minor declines in the price of the underlying.

Practical Tip

Securing a second dividend with short calls

Short call investments provide the investor with an opportunity to activate her portfolio holdings, in other words to achieve an active return in addition to dividends and price increases. This is accomplished by writing calls on the underlying during the year. If they are exercised, delivery from the portfolio of the investor is possible. If the option expires worthless, an additional source of income has been created.

5.3 Long Put

With a long put an investor acquires the right, but not the obligation, to sell an underlying at expiration or during the term of the option to the seller (short put). To obtain this right he makes a payment to the counterparty (short put), which is called the option premium. The long put investor thus has the right to sell the underlying by exercising the option.

In our applied example, this can be shown as follows:

Applied Example

Long put on RWE shares

Exercise price:	€ 20.00
Expiration:	December
Option premium:	€ 1.00

The long put investor has acquired the right to sell the RWE shares until December to the short put investor. This right is valued at € 1,

Variable	Formulas	Excel Implementation
Decision to exercise (=Long_Put!C9)	=If(Price of the underlying < Exercise Price; Exercise; Do not exercise)	=IF(B9<$C$6;"yes";"no")
Profit (=Long_Put!D9)	=If(Price of the underlying < Exercise Price; Exercise price – Price of the underlying - Price of the put; - Price of the put)	=IF(B9<$C$6;$C$6-B9-$C$5;-$C$5)

Fig. 14.61 Formula to decide whether the option should be exercised or not and to calculate the profit

an amount which is paid to the short put investor at the beginning of the transaction. At the same time the exercise price of the option is set at € 20.

Sold at:	€ 20
Premium:	€ 1 (already paid)

Breakeven point:	€ 19
Scenario analysis:	

- The share price declines below € 19: The long put investor makes a profit. His maximum profit is obtained if the price of the underlying falls to zero.
- The share price is between € 19 and € 20: The investor suffers a reduced loss, since the option only has a value equal to its intrinsic value at expiration.
- Contrary to the expectations of the investor, the underlying is increasing in value (above € 20): The investor suffers the maximum loss equal to the option premium paid.

This strategy can be used both for hedging and for speculation. If long puts are used for hedging, the option premium paid can be interpreted as an insurance premium during the life of the option. The formula to decide whether a long put will be exercised is shown in Fig. 14.61.

Figure 14.62 shows the decision process graphically.

Assumptions	
Put Price upon conclusion	1.00
Exercise Price	20.00

Price of the Underlying	Will the Option be Exercised?	Profit
0.00	yes	19.00
5.00	yes	14.00
10.00	yes	9.00
15.00	yes	4.00
19.00	yes	-
19.50	yes	-0.50
20.00	no	-1.00
22.00	no	-1.00
24.00	no	-1.00
26.00	no	-1.00
28.00	no	-1.00
30.00	no	-1.00
32.00	no	-1.00

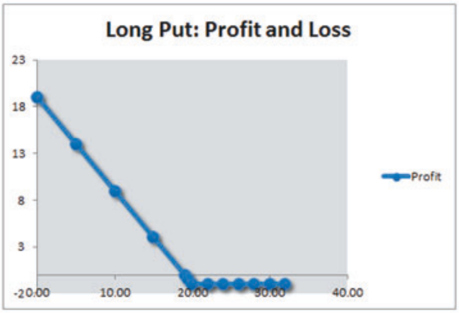


Fig. 14.62 Deciding whether the option should be exercised (Excel File Derivatives, Worksheet Long_Put)

5.4 Short Put

The counterparty in the previously described put strategy is called the short put. A short put investor agrees to acquire the underlying on a specific day (or during a specified time period) at a specified price. In exchange he receives the option premium, which constitutes his maximum profit. His loss potential is limited only by the exercise price, since he has an obligation to purchase the underlying at this price. In a worst case scenario, the underlying is worthless.

In our applied example which we already presented, the short put investor has an obligation to purchase the shares at € 20 in case the option is exercised. Since he already received € 1, his actual breakeven point is € 19. If the share price falls below € 19, the short put investor is suffering a loss.

Scenario analysis:

- The share price falls below € 19: The short put investor is suffering a loss.
- The share price is between € 19 and € 20: The short put position is characterized by a reduced profit.
- The share price is above € 20: The investor has collected the option premium while the option expires worthless. This is the maximum profit for the investor.

This strategy is very risky if prices decline. There is a danger that significant losses accrue, while the possible profit is limited to the collection of the premium.

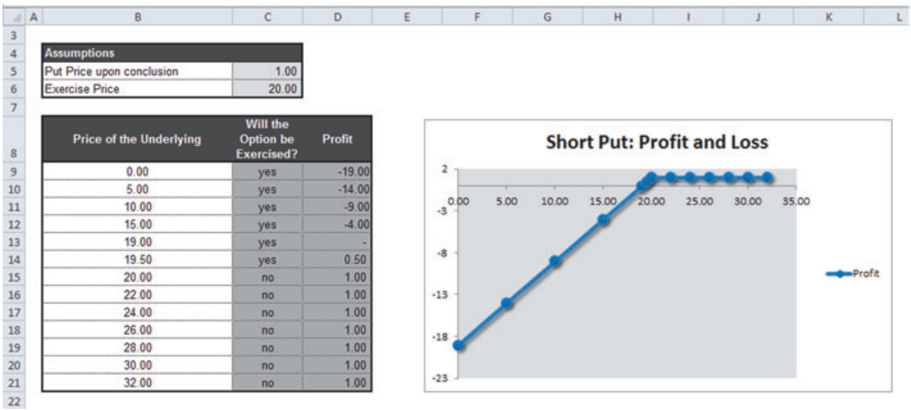
Practical Tip

Use of short puts

A short put position should only be assumed if there is also a willingness to hold the underlying. This allows the active establishment of portfolio positions while collecting a premium at the same time. The investor thus acquires the shares at a price that is equal to the exercise price minus the premium. But this involves the risk that he is obligated to buy the shares. The longer the life of the option, the higher is

Variable	Formulas	Excel Implementation
Decision to exercise (=Short_Put!C9)	=If(Price of the underlying < Exercise Price; Exercise; Do not exercise)	=IF(B9<$C$6;"yes";"no")
Profit (=Short_Put!D9)	= If(Price of the underlying < Exercise Price; Price of the put – Exercise price + Price of the underlying; Price of the put)	=IF(B9<$C$6;$C$5-$C$6+B9;$C$5)

Fig. 14.63 Formula to decide whether the option should be exercised or not and to calculate the profit



Assumptions	
Put Price upon conclusion	1.00
Exercise Price	20.00

Price of the Underlying	Will the Option be Exercised?	Profit
0.00	yes	-19.00
5.00	yes	-14.00
10.00	yes	-9.00
15.00	yes	-4.00
19.00	yes	-
19.50	yes	0.50
20.00	no	1.00
22.00	no	1.00
24.00	no	1.00
26.00	no	1.00
28.00	no	1.00
30.00	no	1.00
32.00	no	1.00

Fig. 14.64 Deciding whether the option should be exercised (Excel File Derivatives, Worksheet Short_Put)

the risk that the assessment of the underlying changes. The formula to decide whether a short put will be exercised is shown in Fig. 14.63.

Figure 14.64 shows the decision process graphically.

6 Fundamentals of Futures

6.1 What Are Futures?

Classical derivatives transactions have been used for centuries – already in the 16th century derivatives on rice were traded in Japan. The first financial futures were traded in August 1977 in Chicago. They were based on the 30-year US Treasury Bond (T-Bond). Today a large number of futures on all types of underlying instruments exist.

> A futures contract is a standardized and unconditional derivatives transaction which is concluded between two contract parties at a futures exchange. Unconditional derivatives transactions which are traded OTC or individually are called forwards. A forward is the contractual agreement between two parties to acquire (long position) or to sell (short position) a defined underlying at a future point in time at a price set at initiation (Fig. 14.65).

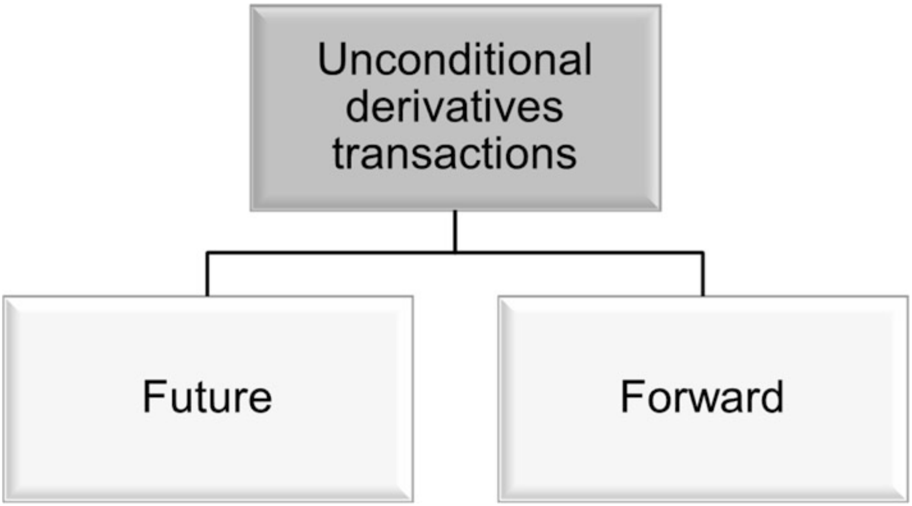


Fig. 14.65 Unconditional derivatives transactions

In a forward contract the forward price is set in such a way that the value of the contract is initially zero. This means that no payments are due initially. Forward contracts are always specified individually and no trading takes place. In the following, we will focus on futures contracts.

A futures contract is defined as a derivatives contract which entails the obligation to acquire (long) or to deliver (short) an underlying at a pre-specified price on a pre-specified date in a set quality and quantity. There is no choice, the obligation must be fulfilled.

In contrast to forwards, futures contracts are traded at a derivatives exchange. The most important derivatives exchanges are the European Exchange (Eurex) and the Chicago Board Options Exchange (CBOE). In order to facilitate exchange trading, futures contracts are standardized with respect to their size, their qualitative and quantitative specifications of the underlying, their delivery dates and delivery locations. Due to the continuous trading at the exchange, futures contracts, in contrast to forward contracts, are considerably more liquid. Continuous market pricing allows quick trading of futures contracts.

The exchange not only brings together supply and demand of the market participants, but also acts as counterparty to the transaction up to a certain transaction size. This policy assures that the transaction can take place, even if no other market participant is willing to enter into the opposing position. Since the exchange serves as counterparty, there is no market price risk. At the same time, the exchange establishes margin accounts to protect against possible losses. The exchange requires the deposit of funds when a position is established and also in cases of unfavorable price developments of the futures contract.

Several factors need to be taken into consideration for the theoretical determination of the futures price.

Initially there are no costs for the buyer of the futures contract. He has the advantage of earning interest on his funds, but at the same time does not have the right to get dividends.

In the simplest case of constant interest rates and dividends, the following formula for the price of a futures contract at time $t = 0$ is obtained:

$$\boldsymbol{F_0 = S_0 \times e^{(r_f - D)T}}$$

	Forwards	Futures
Market	OTC	Derivatives exchange
Contract specification	Individually structured in all dimensions.	Standardized concerning quantity, quality, delivery date, no possibility for individual structuring.
Liquidity	Essentially no trading.	High liquidity as a result of continuous exchange trading.
Counterparty risk	Yes, as in any other contract.	No, the clearing house acts as counter party.
Settlement	At the end via final settlement.	Daily – via variations in the margin account as well as at the end via final settlement.
Exercise	Are mostly exercised; this implies delivery or final cash settlement.	Are mostly settled prior to exercise.
Transaction costs	Possibly lawyers' fees, structuring fees of the bank involved, and so forth.	Brokerage fees.

Fig. 14.66 Comparing forwards and futures (see Rieger, 2009, p. 44)

S_0 is the spot price at time $t = 0$, r_f is the riskless rate of interest and D is the expected average annual dividend yield of the underlying. The futures price is equal to this calculated fair value.

In both cases continuous payment of interest is assumed for simplification. T is the remaining term to maturity of the futures contract in years. Figure 14.66 summarizes the main distinguishing features of forward and futures contracts:

6.2 Which Futures Contracts Are Essential in Applied Work?

In applied work the most important futures contracts are:

- Index futures
- Interest futures
- Currency futures
- Commodity futures
- Single stock futures

6.2.1 Index Futures

In practice there are many futures on indexes. A full understanding of the underlying is crucial for dealing with index futures.

- Is it a performance of price index?
- How many securities are represented in the index?
- How is the index calculated?
- What is the index multiplier?
- What are the trading hours?

Trading in index futures should begin only after all these questions have been answered.

We want to show a few examples with reference to the futures contract on the DAX® Index (FDAX).

Applied Example

DAX® Index Futures

The underlying is the DAX® Performance Index of Deutsche Börse AG, which contains thirty individual securities. Each security is selected based on rules which are determined and defined (free float, size…) by Deutsche Börse AG. Index adjustments are conducted at predefined points of time (the index weights, for example, are adjusted quarterly or if underlying terms are changing. Since it is a performance index, dividend payments are included in the index as reinvestments. This is a difference to the Dow Jones Industrial Average, which is a price index. The adjustment of dividend payments is done on the day of the dividend payment (ex-dividend date) with the help of an adjustment factor.

A further important aspect is the settlement. Since delivery of an index is not possible, cash settlement takes place, which is a payment of the difference between futures price and spot price. In practice the majority of futures contracts are settled prior to expiration (Fig. 14.67).

Index	Futures
DAX®	DAX®-Index-Futures (FDAX)
Standard & Poor's 500 Index	S&P 500-Futures
Dow Jones Industrial Average	DJI-Futures
FTSE	FTSE-Futures
Dow-Jones-Euro-STOXX-50®	Dow-Jones-Euro-STOXX-50®-Futures
Nikkei 225	Nikkei 225 Futures

Fig. 14.67 The most important indexes and their futures

6.2.2 Interest Rate Futures

Interest rate futures are the largest market segment

Interest rate futures are the largest futures markets. Different maturities are available for the underlying and can be used to cover relevant yield expectations. Most frequently traded are contracts on Euro-Bund-Futures as well as on the 30y Treasury Futures in the US (futures on 30-year US government bonds).

Interest rate futures such as Euro-Bund-Futures (FGBL) call for physical delivery. Underlying is a synthetic government bond with a term to maturity of 8.5–10.5 years. Since it is a fictitious government bond, physical delivery requires the definition of a suitable basket of bonds. These bonds do not satisfy the fictitious ratio of 1:1 and therefore must be adjusted with the help of a conversion factor. It serves as the basis for achieving comparability among the various bonds. With the help of the factors, the different coupons and maturities as well as the standardized contract specifications of the Euro-Bund-Futures can be aligned. It must be kept in mind in this regard that the majority of the contracts is not effectively delivered, but instead closed out or rolled over prior to expiration.

Trading in interest rate futures such as Euro-Bund-Futures and the 30-year Treasury Bond Futures (T-Bond) is both very intense and liquid. Due to the availability of different futures contracts (term structure of the bonds), investors can benefit from changes in interest rates as well as imbalances and shifts in the term structure of interest rates. An investor who expects increasing interest rates (long maturities) will sell contracts on the Euro-Bund-Future. With the help of such a transaction, the investor covers both ends of the term structure of interest rates and with suitable modeling he can also place investments on changes in the term structure of interest rates.

6.2.3 Currency Futures

Currency futures (also called FX futures) are traded for example at the CME in Chicago. Fixed currency pairs such as Euro/USD can be traded. One contract is equivalent to a sum of € 125,000. An investor can position himself for an increase of the Euro relative to the USD by buying (long) the contract. Alternatively speculating on a weaker Euro relative to the USD requires the selling (short) of this contract. Obviously this relationship also holds for the other currency pairs offered. Thanks to the quick and liquid trading opportunities, these futures are also suitable for short-term speculation and not only for the medium to long-term investment horizon. Increases in return can possibly be accomplished via short-term auxiliary trades in an active derivatives trading book.

Compared to OTC transactions, currency futures are of limited relevance. Only about 5% of the total market volume relates to futures while 95% of all transactions are directly traded between banks.

6.2.4 Commodity Futures

Commodity futures as origin of all derivatives trading

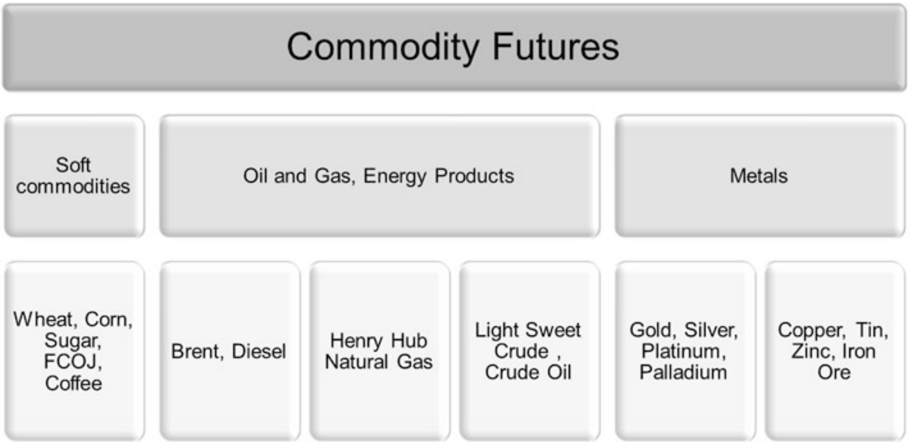


Fig. 14.68 Product types at US Commodity Exchanges (Selection)

Derivatives trading originated with commodity futures. Today they are not only used for hedging, but also for speculation. Figure 14.68 shows some of the product types that are traded at US commodity exchanges.

6.2.5 Single Stock Futures

Different versions of futures are single stock futures, where individual securities serve as the underlying. Eurex for example supports trading of single stock futures on all Dow-Jones-Euro-STOXX-50®companies. This enables investors to position themselves for rising or falling prices of the underlying. They can synthetically replicate the underlying (in this case a single stock) for their trading book. One advantage is the immediate and simple implementation of short selling.

7 Pricing of Futures Contracts

Pricing of futures contracts is much easier than pricing of options, since their risk profile is not asymmetric.

7.1 Index Futures

Index futures are priced with the help of the following formula (see Figs. 14.69 and 14.70):

Theoretical futures price = price of the underlying + (financing cost – income lost)

$$F_0 = C_t + \left(C_{t \cdot r_f} \cdot \left(\frac{T - t}{360} \right) - D_{t,T} \right)$$

F_0 = futures price

C_t = price of underlying, for example index value

r_f = riskless rate of interest (money market interest rate; in percent; actual/360)

t = date of the spot market transaction

T = settlement date of the futures contract

Variable	Formulas	Excel Implementation
Futures price $_{\text{Index}}$ (=Index-Futures!C10)	=(Spot price + (Financing cost – Income lost))	=C5+C6-C7

Fig. 14.69 Calculating the price of an index futures contract

	A	B	C
3			
4		**Assumptions**	
5		Spot Price	5,000.00
6		Financing Cost	250.00
7		Foregone Income	100.00
8			
9		**Calculation**	
10		Futures Price	5,150.00
11			
12			

Fig. 14.70 An example to demonstrate the calculation of the price of the index futures contract (Workbook Derivatives, Worksheet Index-Futures)

$T - t$ = remaining term to maturity of the futures contract

$D_{t,T}$ = expected dividend payments from t to T

As we can see, the futures price consists of the spot price of the underlying plus the financing cost over the term to maturity. Subtracted from these financing costs is the income which is lost during the term of the contract.

Why does this relationship hold? The investor in the futures contract does not have access to the income distributed by the underlying. The financing cost equilibrates the difference between the purchase of the underlying at the spot price and the purchase of the forward contract. In the case were the underlying is a performance index (such as DAX®Index of Deutsche Börse AG), where a reinvestment of dividends takes place, the foregone income need not be considered, since it is already included in the spot price (due to the performance adjustment). In this case the spot price only needs to be adjusted for the financing costs, which are also basis.

The closer the futures contract comes to the last day of trading, the smaller is the basis. On the last day of trading, the spot price is equal to the forward price. This phenomenon is called basis convergence. Since financing cost and income from the investment become smaller, the basis is equal to zero on the last day of trading. Spot price and futures price are now identical (also see Fig. 14.71).

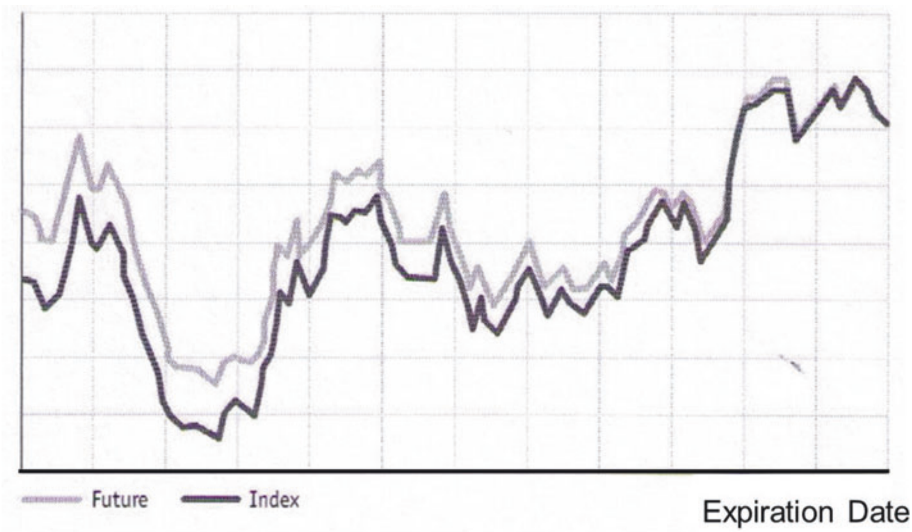


Fig. 14.71 Graphical representation of basis convergence (*source*: Eurex)

7.2 Interest Rate Futures

The term structure of interest rates has a large influence on the pricing of futures contracts.

Short-term interest rates influence the refinancing of a bond investment, while long-term interest rates determine the return in the form of the coupon. It thus follows that the coupon return exceeds the financing costs in the case of a normally sloped yield curve. The forward price will thus have a positive basis, since the spot price is above the forward price. In this context it can be recognized that a futures contract will become cheaper as its maturity increases. The opposite situation arises in the case of an inverted term structure of interest rates. The basis of the futures contract is negative and the financing cost exceeds the return. This results in futures prices that are higher as the term to maturity lengthens. In Fig. 14.72 we present the three possible shapes of the term structure of interest rates:

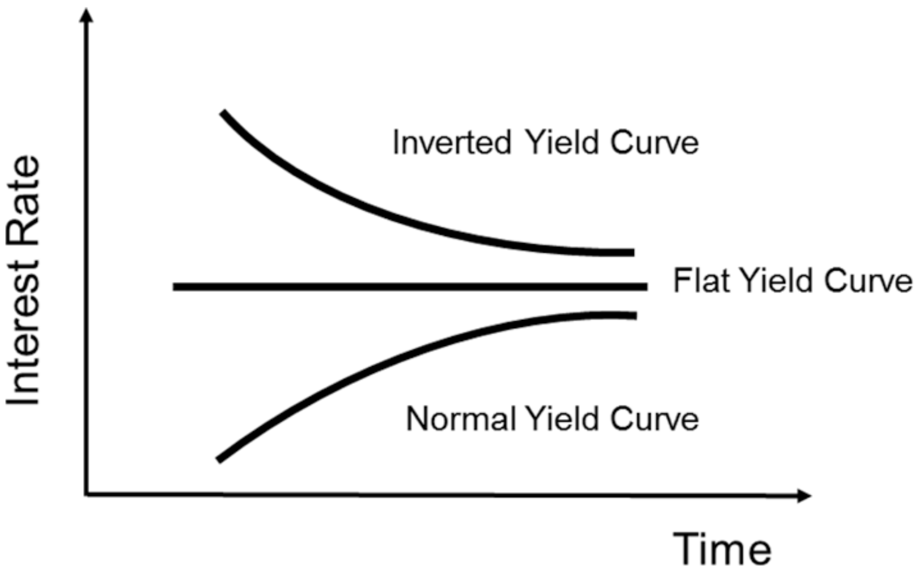


Fig. 14.72 An Overview of possible yield curves

The price of an interest rate futures contract is determined with the help of the following formula. (Note: Interest rate futures, in contrast to index futures, require physical delivery. Index futures in comparison are cash settled.)

$$F_0 = \left(\frac{U}{P} - Z + C\right)$$

F_0 = Futures price
U = Spot position
P = Price factor
Z = Coupon payments
C = Financing cost of the spot position

The price factor assures compatibility of the bonds that need to be delivered. This is necessary since the bonds which can be delivered are not homogeneous. While they are from the same issuer, they have different coupons and maturities and therefore also different prices.

Variable	Formulas	Excel Implementation
Futures price $_{\text{Interest Rate}}$ (=Interest Rate-Futures!C11)	= ((Spot price / Price factor) - (Coupon returns + Financing cost))	=C5/C6-C7+C8

Fig. 14.73 Formula for calculating the price of the interest rate futures contract

	A	B	C
3			
4		**Assumptions**	
5		Cash Position	101.00
6		Price Factor	1.00
7		Coupon Yield	4.00
8		Financing Cost	2.00
9			
10		**Calculation**	
11		Futures Price	99.00
12			

Fig. 14.74 Calculating the price of an interest rate futures contract (Excel File Derivatives, Worksheet Interest Rate-Futures)

In the following applied example we simulate an interest rate futures contract which is based on a spot position at 101% (Figs. 14.73 and 14.74).

The futures contract is priced correctly when theoretical and current basis are equal. Put differently: The futures price is equal to the price of the underlying plus financing cost minus the coupon payments (income) received during the investment period.

7.3 Currency Futures

The pricing of currency futures is closely related to the pricing of index futures and can therefore be compared with the above calculations (see Figs. 14.75 and 14.76). The majority of currency transactions is conducted OTC and not via the futures market. Only about 5% of all transactions are traded in the futures market. The futures market is therefore more appropriate for portfolio managers than for trading organizations.

The formula for the calculation of the price of a currency futures contract is given by:

$$\boldsymbol{F_0 = S_0 \left(\frac{(1 + r^1)\, T}{(1 + r^2)\, T} \right)}$$

F_0 = Price of the futures contract

S_0 = Spot price

r^1 = Foreign interest rate

r^2 = Domestic interest rate

T = Term to maturity

Variable	Formulas	Excel Implementation
Futures price $_{FX}$ (=Currency-Futures!C10)	= (Currency spot rate + (Financing cost $_{Currency}$ − Foregone income $_{Currency}$))	=C5+C6-C7

Fig. 14.75 Calculating the price of a currency futures contract

	A	B	C
3			
4		**Assumptions**	
5		Currency Spot Price	1.12
6		Financing Cost Currency	0.0021
7		Income Currency	0.0010
8			
9		**Calculation**	
10		Futures Price	1.1211
11			

Fig. 14.76 Example of calculating the price of the currency futures contract (Excel File Derivatives, Worksheet Currency-Futures)

7.4 Commodity Futures

Pricing commodity futures

Pricing of commodity futures resembles the pricing of index futures, but the convenience yield is one additional component that must be considered (see Figs. 14.77 and 14.78).

> The convenience yield of the investor is the advantage derived from holding the physical good.

If convenience yield is a relevant factor, the price of a commodity futures contract can be calculated based on the following formula:

$$F_0 = S_0 \cdot \frac{\left(1 + r_f + Cos\right)^T}{\left(1 + y\right)^T}$$

Variable	Formulas	Excel Implementation
Futures price $_{\text{Commodity}}$ (=Commodity-Futures!C12)	= Spot price × (((1 + riskless rate of interest + Cost of storage)^Term in years) / (1+ Convenience Yield)^Term in years)	=C5*(((1+C8+C7)^C9)/(1+C6)^C9)

Fig. 14.77 Calculating the price of a commodity futures contract

	A	B	C	D
3				
4		**Assumptions**		
5		Spot Price	100.00	
6		Convenience Yield	15%	
7		Storage Cost	6%	
8		Risk-free Rate	4%	
9		Maturity (in years)	1.00	
10				
11		**Calculation**		
12		Futures Price	95.65	
13				

Fig. 14.78 Example of calculating the price of the commodity futures contract (Excel File Derivatives, Worksheet Commodity-Futures)

F_0 = Futures price
S_0 = Spot price
COS = Cost of Storage
r_f = Riskless rate of interest
y = Convenience yield
T = Term to maturity in years

An economic interpretation of the convenience yield relates to the expectation of market participants about future market uncertainty, caused for example by a bad harvest. Simply put, it expresses the scarcity of a commodity. As long as sufficient supply is assumed, y will be small or even non-existent. In the case of excess supply, $-y$ leads to a discount.

Example of the price calculation

Contango and backwardation
The two terms "contango" and "backwardation" are of specific relevance for commodity futures. A commodity market is in contango if the price of a commodity futures contract increases with the term to maturity. Backwardation describes a situation where futures contracts with a longer term to maturity have lower prices than futures contracts with a shorter term to maturity.

Contango: Contango of a commodity futures contract can be explained with reference to its price calculation. When calculating the futures price, the cost of carry is added to the spot price. Cost of carry consists of financing costs plus storage and insurance costs minus foregone income. In contrast to an index futures contract (where dividends are used) or a bond futures contract (where accrued interest is used) these foregone earnings are constructed synthetically in the case of commodity futures. This implies an artificial return of the good that is underlying the futures contract. One reason for this is the ability of the investor to lend out the physical good during the term of the contract and collect a premium. The resulting convenience yield and the calculated costs are thus directly influencing the prices of the futures contract.

Backwardation: In backwardation, the price of the commodity futures contract is below the spot price. The difference can again be explained with reference to the previously discussed elements of the price calculation.

Especially when rolling futures positions, knowledge about the situation in the relevant market is important, since the costs of rolling a position can quickly add up to a substantial loss. Forward curves, which plot the prices of a number of futures contracts with different maturities, can be helpful in assessing the market. The prices of many futures contracts of different maturity are plotted and can thus be assessed. At current, most commodity markets are in contango, but backwardation is also observable on occasion. This can be explained with inventory levels and demand. Figure 14.79 provides graphs of the possible price developments.

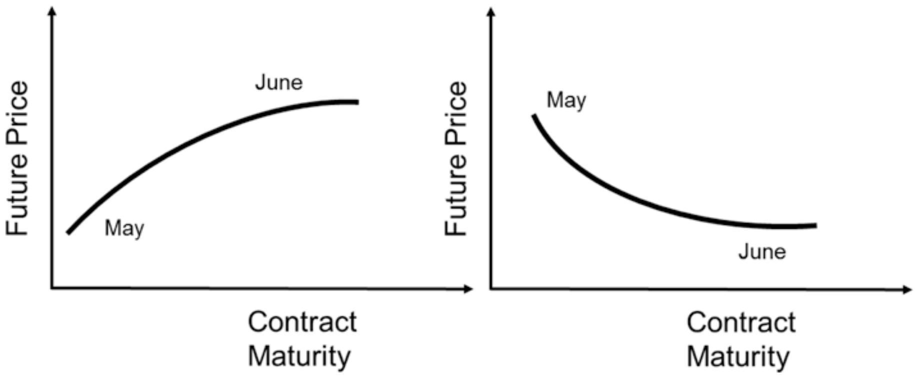


Fig. 14.79 Contango and backwardation (*Source*: RBS/ABN Amro)

7.5 Futures on Single Stocks

Futures on single stocks are merely synthetic replications of the underlying. Their pricing is thus related to the pricing of index futures. Added to the spot price are the financing costs while the income received during the term to maturity is subtracted. Income received in this case can only mean dividends. The formula for the calculation of the price of a futures contract on a single stock is as follows (see Figs. 14.80 and 14.81):

Futures price = Spot price (Share price) + Cost of financing (Interest rate) – Income lost (Dividends)

Variable	Formulas	Excel Implementation
Futures price $_{\text{Single-Stock}}$ (=Futures on Single Stocks!C10)	=Spot price + (Financing cost – Income lost)	=C5+C6-C7

Fig. 14.80 Calculating the price of a futures contract on single stocks

	A	B	C
3			
4		**Assumptions**	
5		Spot Price	20.00
6		Financing Cost	1.34
7		Foregone Income	0.20
8			
9		**Calculation**	
10		Futures Price	21.14
11			

Fig. 14.81 Example of calculating the price of a futures contract on single stocks (Excel File Derivatives, Worksheet Futures on Single Stocks)

8 What is involved in the Basic Futures Strategies?

There are three basic strategies in futures trading which serve as the foundation for all extended strategies:

- Long futures
- Short futures
- Spreads

8.1 Long Futures

A long futures position involves the assumption of the investor that the underlying will increase in value. He is acquiring it with the help of the futures transaction at a rate of 1:1 (thus the term delta-1-instrument). The investor profits if the underlying increases and suffers a loss if the underlying declines. The futures position is thus a synthetic replication of the underlying. Figure 14.82 shows the payoff of a long futures position.

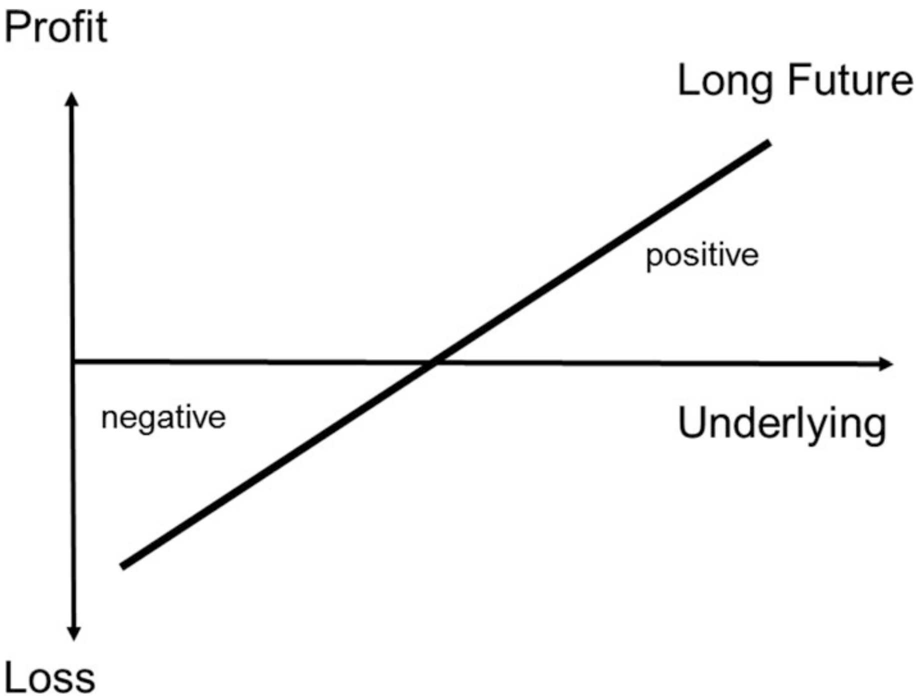


Fig. 14.82 Payoff of a long futures position

Practical Tip

Futures should only be used with stop limits

Futures positions can quickly lead to big profits, but also to major losses. A careful consideration of the risks is therefore absolutely essential. Frequently the first loss is the smallest. Inexperienced financial modelers should therefore set profit and loss limits which must be implemented consistently. A plan for establishing and exiting the positions as well as profit and loss accounting are very useful, especially for inexperienced financial modelers, and therefore highly recommended. This plan should definitely be put in writing and adjusted only in exceptional circumstances.

8.2 Short Futures

A short futures position involves the assumption of the investor that the underlying will decline in value. The short futures position is equivalent to a synthetic sale of the underlying, which is profitable if the value of the underlying goes down. The investor suffers a loss if the underlying increases. The instrument enables an investor to sell an asset even though it is not in his possession. This allows the active positioning for a declining market (see Fig. 14.83).

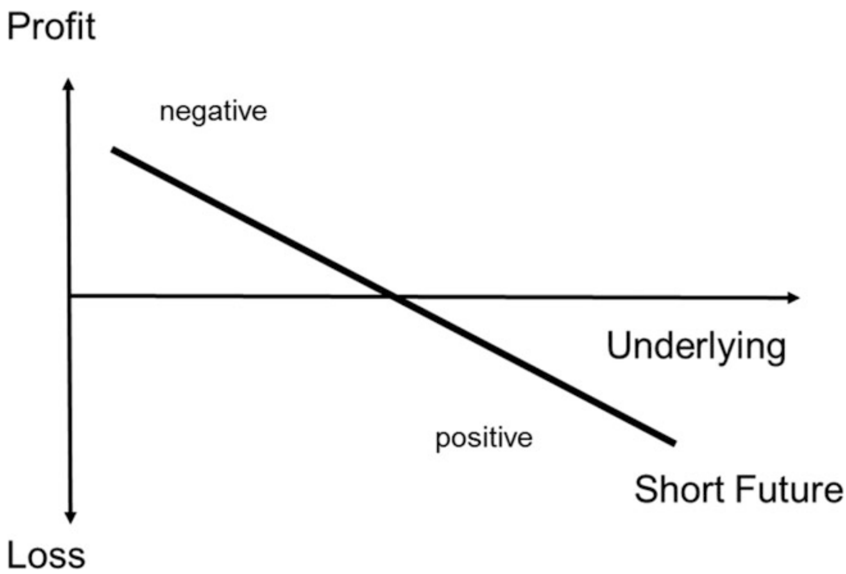


Fig. 14.83 The payoff of a short futures position

8.3 Spreads

8.3.1 Purchase of a Spread

The purchase of a spread means that the investor acquires the early contract and sells the contract which follows later on the time axis.

8.3.2 Inter-Market Spread

In an inter-market spread the investor buys and sells the same contract at two different exchanges. He thus benefits from pricing differences at two different trading places. Thanks to the advanced state of information technology, such a spread can rarely be traded in the current environment.

8.3.3 Inter-Contract Spread and Intra-Contract Spread

In an inter-contract spread, two futures contract with different contract specifications are traded. The investor thus expects a change in the underlying situation for both contracts. In an intra-contract-spread, two futures positions with different expiration dates are traded against each other. The investor expects a change in the contracts due to the difference in the expiration dates.

- Inter-contract spread: Euro-Bund-Future vs. Euro-Bobl-Future
- Intra-contract spread: Euro-Bund-Futures with different expiration dates

For both operations profits arise from the difference between the two contracts. Thus profits are derived from relative pricing differences.

Applied Example

Intra-contract spread

Purchase: Euro-Bund Futures, Expiration: September

Sale: Euro-Bund-Futures, Expiration: December

8.3.4 Cash-and-Carry Arbitrage

> Arbitrage aims at generating a riskless profit by exploiting a pricing imbalance. These pricing imbalances are present whenever there is a difference between forward price and spot price.

Thus a positive difference between the current basis and the theoretical basis allows arbitrage profits. If the futures contract is too expensive compared to the theoretical fair value, it will be sold and the underlying is purchased. This is called cash-and-carry arbitrage. If the situation is reversed and the futures contract is too cheap, it is purchased and the underlying is sold. This is called reverse-cash-and-carry arbitrage:

9 Conclusions and Outlook

Conclusions

Derivatives are among the most exciting and at the same time complex instruments in the financial world. Barriers to entry into the world of derivatives include the solid knowledge about mathematics and statistics needed to understand these instruments. The units in financial engineering departments where derivatives are structured are frequently staffed with mathematicians and physicists. The classical textbooks about derivatives occasionally require quantitative skills that frequently exceed the knowledge of students of business management. It is the aim of this chapter to present the material in a way which makes it understandable without substantial prior knowledge. Financial modeling is a very suitable way of presenting the formulas for the calculation of futures and options in a transparent manner which assures easy comprehension.

The financial models presented are a solid starting point for the professional valuation of derivatives. They include all important aspects which form the current basis for the modern valuation of derivatives. The professional valuation of derivatives by trading desks relies on certified standard models, where only the input parameters need to be provided. It is rare that active financial modeling takes place. This is different in the field of financial engineering, where clients demand tailor-made products. In this case solid foundational knowledge about financial modeling is absolutely indispensable.

Outlook

The topic of derivatives relies on methodologies and covers topics that are also useful for the other financial topics of corporate finance, financial management and portfolio management presented in this book. As in the case of corporate valuation, the pricing of derivatives also relies on the discounting of future cash flows. Approaches based on capital market theories are used in both disciplines. While risk in corporate valuation is measured in line with the Capital Asset Pricing Model (CAPM) in the denominator and future expected cash flows are discounted at the risk-adjusted interest rate, risk in the case of derivatives is captured in the numerator via the volatility in the distribution of future streams of payment, while the riskless rate is used for discounting. In portfolio management derivatives are used actively to structure the portfolio. They serve as a speculative asset class and also as a hedging instrument for entire portfolios. And with respect to methodology there are also examples for similarities between the areas of derivatives and portfolio management such as the determination of volatility.

Derivatives play an important role in the field of corporate finance, for example when making payments in the context of corporate transactions. Depending on the sector, options are used for payment in addition to shares and cash.

10 Summary

In this chapter, the financial modeler has mastered the following topics:

Basic knowledge about derivatives

- A derivative is a new element which is derived from an underlying and stands in a direct relation to the underlying.
- Derivatives allow the hedging of risks as well as speculation.
- Derivatives normally do not require a capital commitment equal to the value of the underlying. This allows investors to control large volumes while only using limited amounts of capital.

- Derivatives can be classified as conditional derivatives which provide a choice (such as options) and unconditional derivatives which do not involve the right to choose (such as futures).
- Standardized contracts can only be traded at derivatives exchanges while individually structured contracts require the agreement of two contracting parties and do not involve a derivatives exchange. They are called Over-the-Counter (OTC) transactions.

Introduction to the field of options

- An option is a bilateral contract which gives the purchaser the right to buy (call option) or sell (put option) the underlying at a specified time and at a predetermined price.
- The right to choose is provided by the seller of the option to the buyer in exchange for a cash payment (option premium).
- Options that can be exercised during their entire life are called American-style options. Options that can only be exercised on the last day of trading are called European-style options.
- The price of the underlying, the volatility, the riskless rate of interest, the dividend and the term to maturity of the option are the most important value drivers when calculating the option price.
- The intrinsic value of a call is the positive difference between the current price of the underlying and the exercise price. For puts, it is the positive difference between the exercise price and the current price of the underlying. The intrinsic value can never be negative, but it can be equal to zero.
- The time value is the amount that investors are willing to pay in expectation of changes in the market price.
- The intrinsic value allows statements about the price range of an option. An option can be at-the-money (ATM), in-the-money (ITM) or out-of-the-money (OTM).

Option price calculation

- The duplication model, the Black-Scholes model and the binomial model are the major methods to calculate option prices.
- The duplication model is based on the idea that options can be replicated exactly with the help of a portfolio consisting of the underlying and a zero coupon bond. If this portfolio has the same

value as the option at expiration, the price of this portfolio at the beginning of the investment period should also be equal to the price of the option.

- The idea of duplication is used both in the Black-Scholes model and the binomial model.
- The binomial model is a financial model in discrete time for the modeling of the price development of securities. In each time period there are exactly two possible price developments of the underlying. The binomial model is used to determine the fair value of an option. It relies on the method of replication, which in its most simplified version evaluates the price of the option for one time period where the underlying can either increase or decrease. The price of the call is independent of the probability of the price increase or decline and also independent of the market participants' attitude towards risk.
- The Black-Scholes model can be interpreted as a continuous time version of the binomial model.
- Greeks are the sensitivities of the option price with respect to the various value drivers of an option. They provide information, for example, about the change in the option price for changes in the price of the underlying or its volatility. Mathematically, the various Greeks are partial derivatives from the Black-Scholes formula.
- These sensitivities of the option price play a major role in many strategies. They allow the construction of inexpensive and targeted strategies.

Strategies in option trading

- Option trading relies on four basic strategies, which serve as the foundation for all extended strategies.
- Long call: The investor (buyer) in a long call is convinced that the value of the underlying will go up. He obtains the right to purchase the underlying via a call. If his expectation is correct, the call will also go up in value.
- Short call: The investor (seller) in a short call expects a scenario of constant or slightly declining prices and plans to generate additional income. He sells calls and obtains a maximum profit equal to

the premium. The risk of a short call investor results from increasing prices of the underlying and the corresponding exercise of the option by the buyer. The underlying must be delivered at the exercise price. In the case of uncovered call writing this implies the possibility of virtually unlimited losses.

- Long put: The investor (buyer) in a long put expects a decline in the price of the underlying. He either wants to hedge his holding with the purchase of the put option or position himself for a decline in price. The maximum loss is limited to the premium paid. The maximum profit is obtained if the price of the underlying, for example in the case of insolvency, declines to zero. In this case, the profit is equal to the exercise price minus the premium.
- Short put: The investor (seller) in a short put expects a scenario of constant or slightly increasing prices. He wants to participate in this market development and actively assumes risk. In exchange he receives the option premium, which constitutes his maximum profit. His loss meanwhile is only limited by the exercise price. In a worst case scenario the price of the underlying will decline to zero, for example in case of insolvency, and the investor is required to buy this underlying at the strike price.

Introduction to the topic of futures

- A futures contract is defined as a derivatives transaction that entails the obligation to purchase (long) or deliver (short) a predefined underlying at a predetermined price and date in a quality and quantity that has been pre-specified. There is no choice; the derivatives transaction must be fulfilled.
- A forward is a contractual agreement between two parties to purchase (long) or deliver (short) a predefined underlying at a future point in time at a price that was set when the parties entered into the contract. The forward price is set in such a way that the value of the contract is initially zero and no payment is required at initiation. Forward contracts are always individually structured OTC (Over-the-Counter) transactions and are not exchange traded.
- The most important futures contracts used in applied work are index futures, interest rate futures, currency futures, commodity futures and futures on single stocks.

- Pricing of futures is much simpler than option pricing, since no asymmetric risk profile is present. The precise formula for calculating the futures price depends on the type of futures contract.

Strategies in futures trading

- The trading of futures contracts is characterized by two basic strategies which serve as the foundation for all extended strategies.
- Long futures: This strategy is used if the investor expects an increase in the price of the underlying. With the futures contract the investor can buy the underlying at a rate of 1:1 for delivery at a later point in time. He benefits if the price of the underlying is increasing and suffers a loss if it is decreasing.
- Short futures: Establishing a short futures position makes sense if the investor expects a decline in the price of the underlying. With the short futures position he synthetically sells the underlying and profits if it actually goes down in value. In case of an increase in the value of the underlying, the investor suffers a loss. This strategy shows that it is possible to sell an asset that is not in the possession of an investor.
- The following spread strategies are distinguished: purchase of a spread, an inter-market spread, an inter-contract spread and an intra-contract spread.
- Purchase of a spread means that the investor purchases the earlier futures contract and sells the contract that follows later on the time axis.
- In the case of an inter-market spread, the investor buys and sells an identical contract at two different exchanges. He benefits from pricing differences at two different exchanges.
- In the case of an inter-contract spread, two futures contracts with different contract specifications are traded against each other. The investor thus assumes that there will be a change in the fundamentals for the two contracts. In the case of an intra-contract spread futures positions with different expiration days are traded against each other. The investor assumes a change in the contracts due to the maturity difference.

Notes

1. At the same time, the price of a put option has increased in the Black-Scholes model from € 1.92 (no dividend) to € 2.30 (including a dividend of 3.76%).
2. Even though not directly comparable, it should still be pointed out that the Black-Scholes-Merton model calculates a price of the put of € 2.30.
3. In general, most options are American options. In applied work, European options are of limited importance outside the field of index options. In this context, the focus is nonetheless on European options, due to their less abstract mathematical construction.
4. Here as well as in all other sections of the book, we always work with the general formula for the variance to assure comparability and clarity of exposition (even though we are really dealing with a sample). In an actual application, the financial modeler will utilize the variance of a sample instead.
5. This is primarily caused by the effect of the dividend payment on the price of the underlying.
6. See Rieger, 2009, pp. 66 following.
7. Merton assumes that the dividend payment is continuous and the dividend return is constant over the remaining term to maturity.
8. Alternatively it is also possible – at least in older versions of Excel – to use the following formula: =NORMSDIST(C13)
9. Since the price of American options is frequently equal to the price of European options, it is still possible to obtain an approximation.
10. Market makers are financial market participants who are obligated to provide bid and ask quotes for securities that are traded at an exchange.
11. The Greeks listed here have been calculated using the brute force method. This method implies minor deviations between the values of the Greeks and the corresponding values in the numerator.
12. 360 days are used in the chapter "Investment Appraisal" since it deals with company data. In the chapter "Portfolio Management," 250 days are employed, since the reference values are market data – as in the chapter on "Derivatives."
13. Strictly speaking, omega is used for warrants and not for options.
14. The premise is that this is assessed as the option is about to expire. In this case the time value is zero and the respective profits and losses can be determined.
15. It is possible, strictly speaking, both empirically and stochastically, to estimate an upper limit for the (still extremely high) risk.

Literature and Suggestions

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