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Strategic Competition in Oligopolies with Fluctuating Demand

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Contents

1	Introduction	1
2	The State of the Research	11
2.1	Long-Term Competition without Strategic Decisions	11
2.1.1	Constant Demand	11
2.1.2	Demand Fluctuations	20
2.2	Long-Term Competition with Strategic Decisions	23
3	Empirical Evidence on Long-Term Competition	43
3.1	Long-Term Competition without Strategic Decisions	43
3.1.1	Constant Demand	44
3.1.2	Demand Fluctuations	47
3.2	Long-Term Competition with Strategic Decisions	61
3.2.1	Investment in Physical Capital	61
3.2.2	Financing	63
3.2.3	Management Compensation	65
4	Fluctuating Demand with Fluctuating Demand	69
4.1	Product Market	69
4.2	Constant Demand	73
4.3	Demand Shocks	78
4.4	Demand Cycles	84
4.5	Demand Cycles Subject to Stochastic Shocks	97
4.6	Comparison of the Market Results	100
4.7	Number of Firms	100
4.8	Sensitivity of the Price to the Market Size	103
4.9	Welfare	106
4.10	Discussion	109
4.11	Summary and Policy Conclusions	112

5	Strategic Investment with Fluctuating Demand	115
5.1	Organization of Production	116
5.1.1	Market Results	118
5.1.2	Feasibility of Collusion	124
5.1.3	Profitability of Cooperation in Production	132
5.1.4	Number of Firms, Market Size and Welfare	133
5.2	Demand Fluctuations	137
5.2.1	Demand Shocks	139
5.2.2	Demand Cycles	142
5.2.3	Demand Cycles Subject to Stochastic Shocks	147
5.3	Discussion	148
5.4	Summary and Policy Conclusions	151
6	Strategic Financing with Fluctuating Demand	155
6.1	Financing by Bonds	156
6.1.1	Market Results	158
6.1.2	Number of Firms, Market Size and Welfare	162
6.2	Demand Fluctuations	163
6.2.1	Demand Shocks	163
6.2.2	Demand Cycles	168
6.2.3	Demand Cycles Subject to Stochastic Shocks	173
6.3	Discussion	174
6.4	Summary and Policy Conclusions	176
7	Strategic Management Compensation with Fluctuating Demand	179
7.1	Stock-Based Management Compensation	179
7.1.1	Stock Market and Labor Market for Managers	181
7.1.2	Share-Price-Dependent Payments	185
7.1.3	Stock Options and Stock Grants	187
7.1.4	Deferred Compensation Components	188
7.1.5	Restricted Stock	191
7.1.6	Dividend Policy	192
7.1.7	Number of Firms, Market Size and Welfare	193
7.2	Demand Fluctuations	193
7.2.1	Demand Shocks	194
7.2.2	Demand Cycles	197
7.2.3	Demand Cycles Subject to Shocks	200
7.3	Discussion	200
7.4	Summary and Policy Conclusions	202
8	Discussion and Summary	205
8.1	Criticism of the Supergame Approach	205
8.2	Summary of the Main Results	208
8.3	Conclusions with Respect to Antitrust Policy	210

References	213
List of Tables	227
List of Figures	229
List of Symbols	231

Introduction

Dynamic oligopolistic competition has implications both for the strategic management of firms and for the design of an effective competition policy. Since the competitors' actions are strongly interdependent in markets with a small number of firms, each must consider the reaction of rivals to their own decisions when choosing their short- and long-term strategies. Those strategies that require high sunk expenditures bind a firm for a long time. Hence, they restrict the choices of short-term decisions on pricing and production and thereby change the competitive conditions in the market. This endogeneity of the market conditions may lead to greater market power of the competitors. Firms might even make their decisions strategically to shape the market conditions in a way that reduces competition and increases their profits. Through their effect on the market outcome, strategies with commitment value determine the economic situation of firms and consumers alike. Consequently, dynamic competition in oligopolistic markets must be analyzed both from a private and social perspective.

As the firms' long-term decisions might reduce the social welfare, competition policy must be devised to preclude adverse welfare effects and to balance the interests of firms and consumers. Since many types of investments, an example being in research or production, as well as cooperation between competitors give rise to new knowledge or efficiency gains, antitrust policy should encourage such endeavors. At the same time, it must be designed to prevent adverse effects of all types of collusive agreements, i.e. of firms' attempts to maximize their joint profits by coordinating their competitive strategies. The effect of such an anticompetitive behavior on the market performance is the same irrespective of whether it is achieved by a formal or implicit agreement. Prime examples of such practices are price-fixing conspiracies and quota agreements. However, firms often additionally use other decisions, e.g. on collaboration in joint projects or financing, to facilitate coordination.

Collusion between horizontal competitors is indeed widespread in national as well as international markets. In recent years, a large number of illegal agreements, predominantly price-fixing conspiracies, came to light. *Evenett*

et. al. (2001) survey over forty cases of international scope. Examples include price agreements in the paper, industrial gases, lysine, zinc phosphate and citric acid industries in Europe. However, these are only the most striking examples that became prominent because these cartels affected large volumes of commerce and lead to fines at record levels.

According to oligopoly theory, such anticompetitive agreements are not stable if the firms compete only once. Such one-shot interaction amounts to a prisoners' dilemma: Compared to individual profit maximization, the firms gain by choosing the action that maximizes the sum of their profits. At the same time, however, each of the parties involved can do even better by unilaterally taking the action that maximizes its individual profit, thereby damaging the cooperating competitors. Not to be cheated in that way, the firms do not cooperate from the outset. Therefore, unrestrained oligopolistic competition is the only *Nash* equilibrium in one-shot interaction. As is well known, the same argument holds if firms compete for a finite number of times. Then, they will not cooperate in their last interaction because continued cooperation by the competitors is not individually optimal. As in a one-shot setting, a firm realizes a high profit by acting individually if all others chose the cooperative strategy. If there is no possibility to punish such a deviation, a firm thus expects to be cheated upon for sure and does not cooperate itself. Consequently, the firms compete in the last period. For the same reason, there is no cooperation in the last but one interaction: Unrestricted competition in the last period is certain, retaliation for cheating again impossible. This reasoning also applies to all earlier periods. Due to this *backward unraveling*, firms never cooperate in competition with a known end.

However, in most oligopolistic markets, e.g. for sugar, automobiles or cement, the firms compete over a long time span with the same rivals. Typically, they have neither a plan to exit the market at a certain point in time nor do they know when the market will disappear due to lack of demand. In such repeated interaction without a known end, the firms have an incentive to soften competition by implicitly or explicitly coordinating their product market behavior. Since there is a direct relationship between price and quantity, the firms can realize supra-competitive profits by specifying either the price or the firm-specific production quotas in such a anticompetitive, collusive agreement.

Naturally, such an agreement is a "hard-core cartel" and is prohibited by antitrust laws in developed countries. In the USA, for example, cartels are illegal since the Sherman Act of 1890. The per se prohibition of cartel agreements between horizontal competitors was recently explicitly reconfirmed by the *Antitrust Guidelines for Collaborations among Competitors* (2000) which state that

Agreements of a type that always or almost always tends to raise price or to reduce output are per se illegal. ... Types of agreements that have been held per se illegal include agreements among competitors to fix

prices or output, rig bids, or share or divide markets by allocating customers, suppliers, territories, or lines of commerce (p.3).

Similarly, the prohibition of such coordination in the Art. 81 (formerly Art. 85) of the *European Community Treaty* of 1957 was recently confirmed by the *Guidelines on the Applicability of Article 81 of the EC Treaty to Horizontal Cooperation Agreements* (henceforth *Horizontal Guidelines*) (2001):¹

In some cases the nature of a cooperation indicates from the outset the applicability of Article 81(1). This is the case for agreements that have as their object a restriction of competition by means of price fixing, output limitation or sharing of markets or customers. These agreements are presumed to have negative market effects. It is therefore not necessary to examine their actual effects on competition and the market in order to establish that they fall within Article 81(1) (p.3).

Simple parallel behavior in the market, however, is not prohibited by competition laws (cf., e.g. Yao, DeSanti 1993, 116/7). In such cases, there is no formal agreement and therefore no scope for legal action against a competitor who deviates from the product market strategy implicitly agreed upon. However, both explicit, written or oral agreements and implicit coordination by parallel behavior might potentially harm consumers and reduce the social welfare by restricting competition in the product market. Since both parallel behavior and legally unenforceable agreements amongst horizontal competitors give rise to the same problems, we treat both cases jointly and use the terms “collusion” and “implicit agreement” interchangeably for both types of agreements.²

Thus, given that the explicit coordination of competitive strategies is illegal and cannot be enforced by legal action against violators, the implicit or tacit agreements must provide an incentive to its participants to abide by it. Members can only choose an agreement that is self-enforcing in the sense that none of them can gain a higher profit by acting individually given the potential punishment for such a defection. This requirement considerably restricts the scope of collusion. Still, firms can tacitly or implicitly coordinate their product market strategies since repeated rivalry offers the possibility to punish a competitor who violates the agreement by aggressive competition

¹ Even in times when antitrust regulation did not prohibit such price or output cartels, enforcement of the agreement in court was explicitly excluded (cf. Symeonidis 2002).

² Very recent work explicitly considers the additional effect of an antitrust authority that detects illegal tacit agreements with a certain probability and offers leniency programs for cooperative offenders (e.g. McCutcheon 1997, Souam 2001, Harrington 2003, Spagnolo 2003, Aubert et al. 2004, Andersson, Wengstrom 2004). However, since this research is still nascent, we abstract from these issues and assume that an antitrust authority has no effect on collusion other than to exclude legally enforceable agreements on prices or outputs.

in the future. Collusion is thus easier, the more severe the punishment for a defection is.

However, the ability to detect a deviation from the implicit agreement depends on the market conditions. In most cases, the output levels of the firms cannot be observed by rivals. If the firms know the demand situation, they can still infer the total market output from the observed price. Consequently, cheating is detected because it results in a lower market price. In other cases however, even the charged price of a good can not be observed, e.g. due to quantity discounts or delivered pricing where the exact transport costs are not known. In both cases, a deviator from an implicit agreement cannot be identified. The participants of an implicit agreement therefore have to resort to a symmetric punishment of all members to make the collusion viable. Such a symmetric strategy may call for a period of low profits achieved by high individual production of all participants that decreases the price. In the extreme, firms may even implement a punishment that yields a profit stream of zero after defection.³ Even if the identity of the offender is known, penalizing this firm alone is possible only if it agrees to it and participates in its own punishment. Since the acceptance of the punishment by the defector gives rise to an additional incentive problem, the scheme that satisfies this additional requirement is considerably more complicated than a symmetric strategy.

Given that price fixing, output restriction and related measures to restrict competition are illegal, the participants in such anticompetitive agreements are well advised to coordinate in a way that leaves no evidence that could lead to detection and prosecution. Complex punishment schemes, for example the asymmetric punishment of the deviator alone, do not fulfill this requirement. If firms explicitly agree on price or quantities, the agreement has to be simple in order to minimize the need for communication and written documentation of the particulars. In the case of implicit cooperation, each participant must infer which competitive strategy realizes the common interest. In both cases, coordination is facilitated if the firms follow straightforward rules. To ease coordination and to avoid prosecution, the participants thus choose a simple scheme that specifies the collusive price or output and the punishment for a violation of the agreement. Since the firms' objective is to realize the highest profits, they maximize their joint profits by colluding.

Since a severe punishment of defection facilitates collusion, additional business strategies that increase its severity may be used strategically to increase the viability of such a tacit or implicit agreement. The concern that some business strategies might be mainly chosen to ease collusion was already expressed very early, e.g. by *Stigler* (1964). Yet the theoretical literature on the pro- or

³ However, a firm chooses a strategy that yields losses in some periods only if these are outweighed by future gains. Thus, zero profits after defection may be implemented only in the case of *Bertrand* competition or by a return to collusion after some time of very harsh punishment that yields losses. In the latter case, the participants in the agreement gain high positive profits again in the periods that follow on the punishment.

anticollusive effect of decisions that carry long-term commitments developed only recently. In parallel, the empirical literature substantiated the commitment value of strategic decisions and derived their effect on competition. Since many decisions, from entry and capacity choice, to financing and management compensation, determine a firm's competitive behavior in the product market for a long time span, business strategies with commitment value abound. Thus, long-run decisions affect competition in all markets, except for the few that are very closely regulated. The customary differentiation between exogenous market conditions, long-term investment and short-term product market strategies however is largely a convenient categorization for the purposes of the theoretical analysis. The criteria for a factor to be subsumed in one of the categories is the level of the sunk cost: If high expenditures are required to change a decision, it carries a high commitment value and binds a firm for a long time. Therefore, exogenous factors are market conditions that were created by sunk, previous investments and can now be changed only at prohibitively high cost. In the long run, the market conditions are the endogenous result of the firms competitive behavior.

Any business strategy that requires investments in a broader sense may either increase or decrease a firm's possibilities to restrict competition by coordinating their competitive strategies. Put differently, a firm may use its long-term business decisions strategically, not only with the "innocuous" objective to maximize its profit, but also to shape the business environment in a way that is conducive to collusion and thus, to maximize the long-term gain from an anticompetitive agreement. However, this motive to facilitate collusion is only one of the possible reasons why firms choose a certain long-run strategy. Should a certain decision be indispensable to enter the market or remain competitive, it might well be taken even if it reduces the scope for collusion. This may apply to expenditures on capital replacement or external financing of an investment project, among others. To assess the viability of an implicit agreement in the market, it is therefore necessary to derive the effect not only of exogenous market conditions, but also of the competitive situation that is created by the firms through their long-term strategic decisions.

Consequently, the detailed analysis of the potential collusive effects of the organization of production, capital investments, financing and the delegation of the management to employees that do not necessarily have a stake in the firm (other than their job and their income) are very important to devise and carry out an appropriate antitrust policy. In particular, the studies of dynamic oligopolistic competition may help to design antitrust regulations that prevent the use of long-term strategic decisions as ancillary devices to facilitate collusion. Thorough analysis however, may show that some product market characteristics or strategic decisions that were previously thought to be procollusive indeed make the coordination of product market strategies more difficult.

The aim of this book is to evaluate whether long-term decisions, for example the organization of the production process, the outside financing of

investment projects and management compensation increase or decrease the scope for collusion in markets with stable and fluctuating demand. Since the theory of infinitely repeated games offers a concise and insightful description of long-term competition and most often yields analytically tractable results, we use such a supergame framework in our theoretical analysis. This approach describes long-term competition as the infinite repetition of a stage game of one-shot interaction. Therefore it can only be applied to markets where the basic conditions remain unchanged. Yet this assumption quite closely describes the situation in mature oligopolies, where the basic competitive situation is stable over time. Furthermore, this approach carries additional advantages: The broad literature on infinitely repeated games demonstrates that the setup can be generalized to account for a large variety of product market characteristics. Moreover, many of these market conditions can be considered simultaneously in such a framework. Since supergames are widely used to study the impact of various market conditions on collusion, our results can be compared to a great number of previous analyses. Henceforth, the model can be integrated in macroeconomic analyses in the line of *Rotemberg, Woodford* (1992, 1999) who show how cyclic collusive pricing affects the aggregate demand and output.

There is a large body of literature on the questions of how firms make an anticompetitive, implicit agreement viable under different market conditions. Examples of factors that affect the inclination to participate in collusion are for example, the number of firms in the market and the degree of product differentiation. These factors are most often treated as exogenous. This literature contributed substantially to the understanding and antitrust assessment of various market conditions. Two caveats are due however: Firstly, these studies largely abstract from changes in demand levels although these are prevalent in many oligopolistic markets. It is especially critical to neglect demand fluctuations since previous work demonstrates that the characteristics of demand development are a decisive determinant of firms' collusive strategy. Secondly, this literature largely abstracts from the fact that competitors take additional long-term decisions that may not have "an independent legitimate business reason" (*Yao, DeSanti* 1993, 118), but serve to facilitate tacit or implicit collusion (cf. also *Correia* 1998, on joint venture formation).

Our study extends the literature on long-term strategic competition in two respects. Firstly, we consider the effect of such decisions in a market with demand fluctuations that quite accurately describe the demand development that is empirically observed in many markets. Thereby, we also analyze situations where the firms cannot implicitly agree on the monopoly price and have to be content with lower profits from a less restrictive agreement. Since in the basic framework of infinite interaction either the most restrictive collusive or the *Nash*-competitive equilibrium is chosen by the firms permanently, the model does not allow for periodic price wars. Such periods of fierce competition however are not uncommon in oligopolistic markets. The integration of demand changes into the basic theoretical framework will quite naturally yield times of high and low prices that may be interpreted as price wars. As previous

work has shown that the effect of demand changes on collusion depends on the pattern of demand development, we consider two types of demand fluctuations, uncorrelated stochastic shocks and recurring cyclic changes in demand. The latter demand pattern is characteristic for markets of input goods that depend on the business cycle in the downstream industries and for markets with strongly seasonal demand changes (e.g. agricultural or transport related products). Furthermore, we offer a brief discussion of the parallel occurrence of a cyclic trend and random shocks. The combination of a deterministic cyclic trend with periodic, stochastic shocks quite closely represents the actual development of demand in many markets. The present study demonstrates that the basic working of collusion in the product market is robust to stochastic and cyclical demand changes.

Secondly, we integrate additional long-term decisions into the model of competition without – a known – end. These often involve interaction with other individuals apart from horizontal competitors. To provide a clear and concise analysis, we abstract from agency problems caused by asymmetric information, e.g. between the firms' owners and investors, bankers or managers, and assume perfect information throughout. Furthermore, we concentrate on three long-term business strategies that are empirically prevalent, but did not receive much attention in the literature so far, namely cooperation in production, outside financing by bonds and management compensation.

The analysis is structured as follows: The next chapter reviews the theoretical literature on the effects of exogenous and endogenous market conditions on collusion. The presentation proceeds from a discussion of the impact of given market conditions, among them the development of the market demand, to a survey of previous findings on the pro- or anticollusive effects of endogenous market conditions which are created by the firms' long-term investments in different business areas. It demonstrates that firms may use various punishment schemes as well as long-term decisions to achieve and facilitate collusion in long-term oligopolistic interaction. Furthermore, this review of previous work will allow to compare our theoretical results with those of related studies.

The third chapter offers an identically structured survey of the empirical evidence on long-term oligopolistic competition, which complements the review of the theoretical literature. We focus on demand fluctuations and the decisions on cooperating in production by coordinating capital reinvestments, on external financing as well as on employing and compensating managers to prepare the ground for the subsequent detailed analysis of their impact on competition. The findings with respect to their pro- or anticollusive effect differ across the industries and are often ambiguous due to data limitations. Still, the empirical observations allow at least for a tentative comparison between the theoretical predictions and the firms' behavior and market performance in the industries considered in the applied literature.

The overview of the literature is followed by the theoretical analysis of different strategic decisions in long-term competition in oligopolies with fluctuating demand. In order to clearly distinguish the effects of the demand

development and the individual long-term decisions we derive and discuss them in turn.

In Chapter 4 we present the basic framework of infinitely repeated oligopolistic competition. Furthermore, we introduce two types of demand fluctuations, namely stochastic periodic shocks and a recurring deterministic cycle. Since the stochastic shocks are uncorrelated over time, the current realization does not affect the future profits. Contrastingly in the case of a cyclic trend the future development depends on the current demand level. Since the punishment for a defection from collusion consists in a loss of future profits, the two demand patterns have polar effects on competition in the market. Consider first the case of periodic, stochastic shocks. If the current demand realization is high due to a large positive shock, the high profit gained by cheating on the colluding competitors makes the tacit or implicit coordination of product market strategies more difficult. The punishment however is always the same irrespective of the present shock. Hence, the incentive to take part in collusion decreases in the current demand level. In the case of a cyclic development of demand, rising demand yields a high inclination to collude since the loss of collusive profits after a defection is then substantial. Since this loss, i.e. the punishment for defection, is small if demand is currently falling, the incentive to participate in collusion is then lower compared to a boom period of rising demand. Since the firms are aware of the impact of demand fluctuations on collusion, they consider these consequences and adjust their price or quota agreement accordingly if they do not value future profits high enough for the continuous monopolization of the market. In the case of uncorrelated shocks, they restrict competition less by reducing the price or expanding production in comparison to the joint monopoly equilibrium if the demand level is currently high. The same is true in times of falling demand, if the demand development is determined by a cyclic trend. Hence, pricing is anticyclic if shocks are the main determinant of the demand development and markedly procyclic if the cyclic trend dominates. These characteristic price movements over time may be used by antitrust authorities to detect anticompetitive behavior. The subsequent analysis of long-term business strategies demonstrates that these basic effects of demand fluctuations on output and pricing always arise irrespective of the firms' other decisions.

However, the integration of such long-term strategies into the basic framework shows that these have an additional pro- or anticollusive impact on competition in the product market. Aside from their empirical prevalence, the three long-term strategies considered here offer examples of decisions that bind a firm over different periods of time. Consequently, they vary in their commitment value. The decision to collaborate in production by coordinating capital reinvestments or by producing in a jointly-owned plant commits a firm for a long time due to high legal cost and reputational damage in case of a termination of cooperation. Whereas reinvestments in physical capital are determined periodically, the financial obligations of a bond issue depend on its face value and cannot be readjusted in the course of competition with-

out dramatically worsening the terms of financing. Compensation contracts in turn may also ultimately be chosen at the time of hiring, given the satisfaction of both the employer and the employee. Yet, especially the contracts of high-level managers who choose the competitive strategy can be terminated or changed on short notice. The present analysis therefore covers the problem of optimal collusion in dynamic competition where the long-term decision is taken either before or repeatedly in the course of product market competition. Consequently, the theoretical framework describes both an action that is followed by a supergame in price or quantity and a supergame with a two-stage basic game.

We start in Chapter 5 with the very common, but rarely considered decision on reinvestments in the stock of physical capital. The depreciation of production equipment necessitates frequent reinvestments: To keep the production process smooth and costs low, firms regularly replace the worn-out equipment. Cooperation in production hence may consist in the coordination of capital reinvestments. Alternatively, firms may produce in a jointly owned plant. The decision to collaborate carries a high commitment value since the dissolution of the cooperation contract entails legal costs and may also damage the reputation of a firm with its suppliers and customers. Since the increase in the number of strategic alliances and joint ventures was dramatic in recent years, the issue of collaboration in production is of great importance for the design of antitrust regulation. Mainly in an effort to increase the competitiveness of domestic firms, the U.S. government as well as the European Commission recently enacted new laws that regulate the horizontal cooperation of competitors and exempt cooperative projects in production from the per se prohibition of the Sherman Act and Article 81 of the EC-Treaty (*Antitrust Guidelines for Collaborations among Competitors 2000* and *Guidelines on the Application of Article 81(3) of the Treaty 2004*, respectively). However, reduced competition in the product market between members of production joint ventures and other types of cooperation in manufacturing might reduce the welfare gains from higher efficiency and competitiveness. As the literature on cooperation in production is scarce, it is to date not clear whether efficiency gains are outweighed by welfare losses which arise from an increase in the market power of the participating firms. The present study shows that non-cooperative capital reinvestments yield low *Nash*-competitive profits, whereas cooperation in the investment stage allows for high *Nash*-competitive profits. The difference between the respective collusive profits is small in comparison. Consequently, the punishment for a defection from the implicit agreement is lower if the firms coordinate the reinvestments in the production process. In contrast to warnings by antitrust experts, horizontal cooperation in manufacturing hence decreases the scope of collusion compared to the benchmark case without reinvestments. The anticollusive effect of cooperation is even higher if collaborating firms realize efficiency gains.

In Chapter 6, we proceed in the same manner and integrate the decision on the external financing into the basic model of long-term competition. As the

decision on collaboration in production, the decision to finance an investment project by a bond issue is taken only once. An adjustment of the resulting financial obligations requires high expenditures on intermediation by banks in the capital market. Furthermore, the issue is observed by investors. A change in the contract terms and even more so a default implies a substantial loss of reputation and restricts future access to the capital market. Consequently, the costs of a change of the conditions of financing are close to prohibitively high. Once the principal of the bond issue is chosen, the consequent financial obligations commit the firms for a long time. If leveraged firms are made bankrupt by unrestrained competition, they cannot make the repayments. In the case of an implicit agreement in contrast, the profits are high enough to meet the obligations. Then, the firms remain solvent and the collusive profits are reduced by the repayments. Therefore, a high level of debt unambiguously reduces the scope of collusion in long-term competition if the firms are protected by limited liability.

In Chapter 7 we discuss a last, wide-spread long-term decision, the effect of delegation of a firm's management. In the context of long-term oligopolistic competition, the design of the managers' compensation schemes proves to be decisive. We derive the effects of the two most prevalent types of incentive compensation, stock-based remuneration that consists either in share-price dependent payments, stock grants or option grants and more traditional payments that depend on current profits. The incentive to collude proves to be higher if the managers receive stock-based instead of profit-based compensation since the former puts a higher value on future profits. If the payments are deferred, their procollusive impact is even stronger because the profit gained by defection is disbursed when the corresponding payment is made. Since a manager with deferred stock-based compensation cannot gain by defection, he always participates in the joint monopolization of the market. However, holding periods for the shares reduce this effect because the managers then receive dividends in addition to their remuneration. Consequently, they put a higher value on the profits in the holding period compared to a situation where an immediate resale of shares is possible. This higher gain from present profits makes collusion more difficult. These conclusions are robust with respect to the firms' dividend policy.

The last chapter summarizes the main results of our study and discusses the advantages as well as the disadvantages of the present theoretical framework. Based on these insights, we conclude with some implications and suggestions for the design and implementation of antitrust policy.

The State of the Research

The literature on the effects of long-term decisions on implicit agreements is rather sparse compared to the work on exogenous market conditions. Still, there are several seminal contributions that shed light on the collusive effect of long-run commitment by some kind of investment. The following short survey of the literature on collusion without and with long-term strategic commitment will prepare the ground for our subsequent detailed analysis of the interplay between strategic competition and collusion in oligopolistic markets.

2.1 Long-Term Competition without Strategic Decisions

The research area of long-term oligopolistic competition is vast. The literature on anticompetitive agreements started with the seminal article by *Chamberlin* (1929). He conjectured that firms might be able to realize monopoly profits in oligopolistic competition even without explicit coordination if they recognized the interdependence of their competitive strategies. *Stigler* (1964) provides another early contribution to the discussion on the feasibility of anticompetitive behavior by oligopolistic firms.¹

2.1.1 Constant Demand

Since the publication of these seminal articles, researchers in this field used theoretical frameworks that fall into two large categories, namely models that describe the adjustment to a steady state over time and models that consist in the infinite repetition of a basic game. The first line of research considers complex frameworks with alternating or simultaneous moves, but restricts attention to *Markov* strategies. Here, the players condition their actions (control variables) only on the current value of a state variable that is determined by

¹ *Salop* (1986) and *Jacquemin, Slade* (1989) survey the early game-theoretic contributions to this literature.

their past play (e.g. *Maskin, Tirole* (1988), *Ericson, Pakes* 1995). In oligopolistic competition for example, the investment decisions of firms are the control variables that change the market conditions (state variables), for example the level of demand or costs in a time-consuming adjustment process. Alternatively, this literature describes competition as a continuous-time differential game. Here, a competitor also sets the control variable that determines the development of the state variable given his information about the past and present market conditions. Most differential games share the *Markov* feature since the authors typically consider open-loop equilibria where only the present state of the world is known. In this situation, the whole path of a control variable is chosen at the beginning of the competition and is executed over the time horizon of the game. Feedback equilibria where the players know the previous state of the world and closed-loop equilibria where the full history of the game is known are rarely considered. Most often they cannot be derived due to their computational complexity. Hence, this literature largely abstracts from the fact that a player may condition his current decisions on his own and his rivals past actions.

The second approach builds on *Friedman's* explanation of non-cooperative coordination. Here, firms set investments at the optimal level either at the beginning of competition or of each period before outputs or prices are chosen. Since the optimal investment level is the same for all periods, the basic market conditions, i.e. the values of the state variables that determine demand and cost, never change. Furthermore, it is assumed that competitors condition current decisions on past actions in the repeated play of the basic simultaneous move game. In addition to the much greater tractability, this is a considerable advantage over the asynchronous-move and differential-game approach described previously.

Aside from these two theoretical approaches, several alternative descriptions of anticompetitive agreements are discussed in the literature. *MacLeod* (1985) for example proposes a stylized model of *conscious parallelism*, that consists in parallel price changes. Deviation from this strategy triggers non-cooperative behavior and results in the non-cooperative equilibrium. Therefore, his model describes a type of implicit coordination of the firms' competitive strategies that is still legal according to current rulings by antitrust law. *MacLeod* requires that the reactions to a rival's price setting are continuous and continuously differentiable and do not depend on the order of labeling. He demonstrates that exact matching of a rival's price changes whenever this is profitable and not changing the own price otherwise is the only strategy that fulfills these restrictions. If firms announce price changes and react as described, there is a single equilibrium in prices. Firms reach this equilibrium by raising their prices in turn up to the profit-maximizing level. If the competitors implicitly agree on this behavior, such consciously parallel behavior also offers an explanation of collusion.

Recently, *Oechssler* (2002) and *Huck et al.* (2004) demonstrated how cooperation in repeated interaction can be achieved by some type of learning.

Oechssler provides an explanation of coordination between players that do not maximize payoffs, but follow a satisficing rule and cooperate in a prisoners' dilemma to achieve their aspiration level. *Huck et al.* (2004), in contrast, model learning by trial and error. Here, the competitors evaluate the effect of small adjustments of their outputs to find the joint-profit-maximizing quantities in a *Cournot* market.

The main body of the literature on tacit collusion, however, builds on the models of simultaneous, infinitely repeated or open-ended oligopolistic competition. *Friedman* (1971) analyzes the basic case of tacit collusion between symmetric firms. He demonstrates how firms can collude tacitly or implicitly by agreeing to punish a defection by infinite *Nash* competition. If they put a high value on future profits, the firms always collude. If not, it pays to cheat on the colluding rivals. Therefore, the firms do not attempt to collude but compete in the market then. In both cases, the rivals choose the same strategy in every period. This description of collusion presupposes that there are no adjustment costs to price changes. Further, it is assumed that there are no capacity restrictions that might prevent a firm from defection or participation in the punishment of a defector.

If, however, the firms know exactly that they will compete only for a certain time span, self-sustaining agreements of the type described above are impossible. Such a situation might arise if production requires a license that is valid only for some number of years or a certain amount of output. In other instances, the introduction of a superior good might be announced that will draw away all demand. Since any game with a finite time horizon can be solved by backward recursion, the *Nash* equilibrium is the only solution of the underlying basic game. This is a restatement of the familiar argument of *backward unraveling*. Note, however, that this is a "knife edge" result that applies only if the probability is zero that competition continues after the presumed last period. If there is any small probability of continuation, it is possible to support an equilibrium that is more cooperative than the *Nash* equilibrium. In this case, firms account for the fact that competition might end by discounting the future profits appropriately (cf., e.g. *Tirole* (1988, 253) for a formal proof). Since situations where firms are certain that they will compete only until a certain date are rare, we will restrict attention to competition without or with unknown end.

Punishment

Since a higher punishment decreases the incentive to defect from collusion, the toughest penalty for deviation supports the most restrictive anticompetitive agreement and yields the highest profits for the participants. At the same time, even the harshest punishment is costless since there will be no defection in equilibrium. The *grim trigger* proposed by *Friedman* (1971) is not the most severe punishment. *Abreu* (1986, 1988) considers a supergame and derives the optimal punishment strategies that maximize the gain from the

implicit agreement. In his first study of a *Cournot* market, he proves that the members' incentive to participate is maximal if a defection triggers an extreme punishment, the "stick", in the next period. Thereafter, the firms return to the collusive equilibrium if all participants took part in this punishment. Otherwise, it is prolonged for another period. The high profits from the continuation of collusion in the second phase of the punishment, the "carrot", is necessary to prevent defection in the *stick* period. Thus, it ensures that firms participate in their own punishment. *Abreu's* subsequent article analyzes the effect of a *stick and carrot* strategy in a more general model and discusses conditions for the existence of such an optimal two-phase punishment. It is shown that this optimal penalty code yields payoffs that are just high enough to keep the participants on their reservation level after a defection. Thus, the firms realize high losses in the *stick* period that are compensated exactly by the subsequent discounted collusive profits. Moreover, oligopolists can implicitly agree on an optimal penalty for defection only if they can produce the high outputs required to realize the *stick*.

Lambson (1987) studies the effect of capacity constraints on implicit price-fixing agreements and shows that firms can compensate such constraints by an extension of the though first phase of the punishment. The number of *stick* periods is then chosen to implement the reservation level of profits after a deviation. However, the optimal punishment can not necessarily be implemented if the firms are asymmetric (*Lambson* 1994, 1995). *Häckner* (1996) points out that the size of losses, and thus the severity of the single-period *stick*, is bounded from below since firms cannot set negative prices. Using a *Hotelling* model of a market for a horizontally differentiated good, he demonstrates that the *stick* phase has to be extended as well if firms are impatient and put a low value on future profits. *Lambertini, Sasaki* (1999) also analyze the effect of non-negativity constraints on price and quantity competition in a market with linear demand for a horizontally differentiated good, but use *Bowley's* (1924) demand function. They, too, conclude that the reservation level cannot be implemented by a *stick and carrot* punishment. If firms compete in quantities, this results holds irrespective of their valuation of future profits. But the restricted applicability that arises from the positivity of prices is not the only disadvantage of the optimal penalty code. Due to its more complicated structure, more effort and negotiations and maybe even a detailed written statement of the implicit agreement are necessary to agree on the details of the collusive scheme. The stronger requirements for communication and documentation are a drawback in markets that are in the focus of vigilant antitrust authorities.

Product Differentiation

The analysis of a market for a heterogeneous good also allows to determine the effect of product differentiation on the firms' inclination to collude. In the literature the degree of product differentiation is treated predominantly

as exogenous. *Deneckere* (1983), *Rothschild* (1992) and *Ross* (1992) focus on the simple case of collusion with *grim trigger* strategy and derive the impact of horizontal differentiation on the firms' inclination to participate in the agreement. *Albaek*, *Lambertini* (1998) summarize the results and conclude that for both price and quantity competition, a greater homogeneity of the good decreases the scope for collusion if the rivals are not driven from the market by a defection from the implicit agreement.² This effect occurs because a greater degree of differentiation reduces the substitutability of the varieties and hence the extent to which a defector can attract the rivals' customers. Consequently, the one-shot gain from defection is smaller the higher the degree of differentiation is. The concomitant decrease of the collusive profits does not offset this effect. If a greater extent of heterogeneity does not require investments, the firms thus choose a higher extent of differentiation the more they discount future profits. *Osterdal* (2003) reconfirms this findings under the assumption of a two-phase *stick and carrot* punishment. There are also studies on the effect of differentiation in address models. *Chang* (1991), *Ross* (1992) and *Häckner* (1996) show that a larger degree of horizontal differentiation in a *Hotelling* model also increases the firms' incentive to take part in collusion. A higher extent of vertical differentiation however makes collusion more difficult (*Häckner* 1994).

The strategic decision on the extent of differentiation is analyzed by *Lambertini et al.* (2002). These authors focus on the question whether R&D cooperation that results in a greater homogeneity of the good facilitates collusion. If differentiation is horizontal, the opposite is shown to be the case. With vertical differentiation, the research effort has no effect on firms' incentive to participate in the implicit agreement.

Asymmetries between the Firms

Moreover, firms may be asymmetric in different respects. In general, asymmetry has two implications for collusion: Firstly, the firms' interests with respect to the collusive quota or price may differ widely. Agreeing on a common collusive strategy is thus more difficult. Secondly, the optimal collusive strategy is more complex and requires a sharing rule for the division of the collusive profit. Therefore, the firms have to agree on a whole schedule of production quotas or a menu of prices.

Differences in the efficiency of production require the allocation of asymmetric market shares to maximize the joint profits of the participating firms. In absence of side payments, coordination and enforcement of such a collusive equilibrium are difficult. By participation in an implicit agreement, a firm gains a higher share of total collusive profits the lower its production cost is. Also, firms with low cost have a higher gain from defection. The effect of cost efficiency on profits in the punishment phase however is ambiguous and

² If the trustful participants are forced to exit the market in the event of defection, the inclination to collude rises in the homogeneity of the good.

depends on the relative cost advantage of a firm. If the cost differential is large, an efficient firm produces a large quantity and is thus hit hard by a decrease from monopoly to the *Nash* price (caused by the increased production of rivals). Then, *Nash* competition imposes a harsh punishment. If, in contrast, the cost differential is small, the punishment is less severe because it affects the smaller individual quantity that is produced by an efficient firm with a moderate cost advantage. Therefore, the viability of collusion depends on the individual production costs as well as on the relative efficiency of the participants. *Rothschild* (1999) considers oligopolists with different quadratic cost functions and demonstrates that even in the case of a reallocation of output that guarantees efficient production, the scope of collusion is smaller than in a symmetric situation. Moreover, he shows that this basic finding is robust to the introduction of uncorrelated, stochastic shocks on demand. *Harrington* (1991a) considers an asymmetric duopoly and models the division of the collusive profits by *Nash* bargaining. As *Rothschild*, he derives a non-monotonic relationship between the inclination to collude and the cost of the less efficient firm. *Mason et al.* (1992) find that cooperation is indeed less likely in asymmetric, experimental duopoly situations.

The situation is very similar if firms are symmetric in all respects except for their discount factors. Such asymmetry between the firms' (effective) discount factors might be due to different capital costs or a different perception of the probability of exit or disappearance of demand. Then, the anticollusive effect of asymmetry is also reduced by the allocation of asymmetric market shares. In the optimal collusive equilibrium, the quotas are assigned according to the ranking of the discount factors. To make the agreement viable, firms with a low valuation of future profits receive a overproportionately large share of the market (*Harrington* 1989a).

Multimarket Contact

There is also some evidence that the extent of asymmetry has additional implications for the firms' incentive to collude if they interact in several markets at the same time. In a well-known study of multimarket competition, *Bernheim, Whinston* (1990) demonstrate that parallel interaction in several markets is likely to facilitate collusion. Intuitively, this seems to be clear since some slack in the sustainability of collusion in one market can be carried over to another market where otherwise the firms' valuation of future profits is not sufficient for collusion. However, this is not true in all cases. In fact, the intuition rests on the notion that firms that are active in several markets may punish a defector in all markets in parallel. This parallel punishment however is insufficient and does not enlarge the scope for collusion, since a participant maximizes its individual profits by defecting in all markets simultaneously. Hence, the incentive to collude in many markets is given by the sum of the incentives to participate in an implicit agreement in each market in isolation.

Bernheim, Whinston (1990) show that the latter argument holds if firms are symmetric competitors that produce with constant marginal costs in all

of the markets. Only if there are asymmetries between the firms is the scope for collusion increased by multimarket contact. This is best illustrated by an example: Consider two duopolies where the market shares are identical but each firm is the larger producer in the one and the smaller in the other market. If the duopolists' valuation of future profits is too low to make collusion viable in the markets in separation, it might be nevertheless possible if they consider participation in the implicit agreement in both markets simultaneously. Then, the incentive for collusion is pooled across both market: Effectively, each of the firms serves 50% of the totals demand. Since the markets are identical in every other respect, the situation is again one of competition between symmetric firms. Collusion in this case requires less patience from the side of the firms. Here, multimarket contact indeed facilitates collusion. Further factors that create such a linkage between different markets and facilitate collusion are asymmetries in production costs, technologies with increasing returns to scale or different growth rates of demand. *Spagnolo* (1999) extends the argument by *Bernheim*, *Whinston* and demonstrates that all factors that yield a strictly concave objective function in the firms' (or their managers') maximization problem give rise to situations where multimarket contact increases the scope of collusion.

The relevance of different demand characteristics is of special interest in the context of the present study. The summation over the incentives to collude over all markets where the firms interact amounts to an averaging of demand levels in the current and each of the future periods. If demand is subject to periodic, uncorrelated stochastic shocks in the line of the *Rotemberg*, *Saloner* (1986), the current demand level alone determines the incentive to collude. Then, high current demand yields a high one-shot gain from defection that makes joint monopolization of the market impossible. If the condition for joint monopolization holds with slack in another market in the same period, the combined incentives to collude may be still sufficient to make perfect collusion viable. For the same reason, collusion might be facilitated by multimarket contact if firms interact in markets where demand changes cyclically as described by *Haltiwanger*, *Harrington* (1991).

So far, we considered the impact of market conditions on collusion in infinitely repeated competition without additional investment decisions. The results of such studies are relevant for the present analysis because the most effects also arise if firms compete in additional long-term decisions. However, the conclusions are subject to qualifications if the firms might be restricted in their decisions if renegotiation of the punishment for defection or the imperfect observability of the competitive behavior, the effects of exogenous market conditions and long-term strategies are not necessarily robust to a renegotiation of the punishment and poor observability of the firms' decisions.

Renegotiation

Irrespective of whether the firms interact and collude in one or many markets, the possibility to renegotiate the penalty code after defection is a factor that

might preclude a severe punishment and make collusion more difficult. Thus, renegotiation is a possible explanation why collusion seems to be less prevalent even in concentrated markets than is predicted by the basic model discussed so far.

Farrell, Maskin (1989) propose *weakly-renegotiation proof* agreements, which require that the average payoffs of the defector and the non-offending players in a punishment period must be sufficiently low to prevent defection from the implicit agreement. At the same time, it must be high enough for the players not to renegotiate the punishment. Moreover, the collusive scheme must be designed to prevent further cheating during punishment. *Farrell, Maskin* (1989) demonstrate that the zero-profit *Nash* equilibrium is the only *weakly renegotiation-proof* punishment in pure strategies in a *Bertrand* duopoly. In the case of larger oligopolies, however, the appropriate punishment scheme is more complex. *Farrell* (2000) builds on *Farrell, Maskin's* analysis and argues that a simple solution is to elect one firm to be the sole producer who blocks renegotiation, while the others including the defector produce nothing. Deviation from this strategy by an innocent firm stops the punishment of the initial defector, while the new offender is punished in turn. Perfect collusion by joint monopolization of the market, however, cannot be achieved even by such a detailed collusive scheme. Thus, the scope of collusion is reduced considerably by the possibility to renegotiate a punishment. *Levenstein* (1997) provides evidence for renegotiations in the pre-World War I bromine industry that seem to have precluded the use of theoretically optimal, but very harsh *stick and carrot* punishment strategies in the line of *Abreu* (1988) and *Abreu et al.* (1986).

Yet, the proposed *weakly renegotiation-proof* implicit agreement is much more complex than the simple *grim trigger* strategy and the *stick and carrot* scheme proposed by *Abreu* (1988). Therefore, this type of *weakly renegotiation-proof* strategy is not likely to be used in markets where other factors, such as asymmetries or demand fluctuations, make the coordination on an appropriate punishment difficult. For the same reason, the negotiations are likely to raise the attention of the competition authorities to the collusive agreement.³

Potential renegotiations reduce the credibility of many collusive strategy. A related and possibly even more important problem is the low commitment value of actions that are not perfectly observable.

Observability

Bolton, Scharfstein (1990) were the first who demonstrated that commitment by unobservable contracts is less effective than by observable contracts

³ Quite to the contrary however, *McCutcheon* (1997) demonstrates that the supervision by an antitrust authority may in fact preclude renegotiation and restore the situation that is described by the basic supergame model. Experimental results by *Andersson, Wengstrom* (2004) confirm her theoretical prediction that antitrust laws might work in the interest of colluding firms.

in the context of financial predation. *Katz* (1991) offers an analysis of the commitment value of delegation contracts. He derives conditions where even observable contracts do not affect the equilibrium. This occurs if the principal and the agent are symmetrically informed, risk neutral and have the same attitude with respect to income and effort. Further, there is no moral hazard problem and all participants know that there is a contract that solves a potential agency problem. A contract tailored to solve moral hazard and risk sharing problems may then possess commitment value and affect the outcome even if this contract is unobservable for other players. The situations considered by *Katz* are so well defined that uninformed outsiders can infer the optimal contract choice of the principal. Observability of the contract itself is therefore unnecessary.

A slightly different situation arises if commitment is not achieved by a contract but by the first move in a sequential game. *Bagwell* (1995) compares the pure-strategy equilibria of a simultaneous game and a sequential game where the first action is only imperfectly observable. He concludes that even the smallest amount of noise in the observation of the action excludes commitment. The focus on pure strategies, however, is criticized by *van Damme, Hurkens* (1997). They show that there exists an equilibrium in mixed strategies that is close to the *Stackelberg* equilibrium without noise if the actions are almost perfectly observable. Moreover, they propose an equilibrium selection criterion that combines approaches of the earlier literature and selects this equilibrium. *Huck, Müller* (2000) test the implications of imperfect observability experimentally. Their conclusions support the results by *van Damme, Hurkens*: The players who acted as the *Stackelberg* followers adapted to the noisy signals and the *Stackelberg* leaders in turn noticed this and took advantage of this adaption. The experimental evidence is thus contradictory to *Bagwell's* theoretical results.

In short, according to the more recent studies, imperfect observability does not eliminate the commitment value of first-mover or first-stage actions. In the context of the present work, however, it is of minor importance since the decisions on cooperation in reinvestments, bond issues and stock-based management compensation are made public in the press or in shareholder meetings. Further, *Bagwell* (1995)'s concern on commitment in a sequential *Stackelberg* game do not apply if firms take their decisions simultaneously.

However, all the above models abstract from demand fluctuations that are common in many oligopolistic markets (cf., e.g. *Johri* 2001, *Marchetti* 2002). Yet, given the structural and business cycle dynamics in markets for goods and services this assumption is a stark abstraction from the empirical evidence on demand development. In fact, the demand for many goods and services, as for example sporting equipment, transport, and fuel oil, follows recurring cyclical pattern. In other markets, the demand development is more complex. Empirical business cycle studies showed that autocorrelated stochastic processes give a quite accurate description of such demand patterns (e.g. *Hamilton* 1989 or *Krolzig, Lütkepohl* 1996). Hence, it is essential to ac-

count for demand fluctuations to derive the implications of strategic decisions in long-term competition.

2.1.2 Demand Fluctuations

As theoretical work starting from *Green, Porter* (1984) and *Rotemberg, Saloner* (1986) has shown, the pattern of demand changes plays an important role in determining the incentive to collude. Fluctuations in the market demand are therefore a plausible explanation for the phenomenon of price wars, i.e. for periods of lower prices that were the main reason for the original interest in price and quota agreements (cf. *Stigler* 1964). Several effects of demand changes on the scope of collusion are discussed in the literature.

In an early work on periods of price wars between members of the *Joint Executive Committee* (JEC), a nineteenth century US-railroad cartel, *Porter* (1983a) and *Green, Porter* (1984) demonstrate that the lack of observability of current demand is a possible explanation for an apparent breakdown of an anticompetitive agreement. In this situation, low sales of a firm might be caused either by a slump in demand or by an event of cheating on the collusive agreement. Due to the unobservability even of current demand, the firms cannot distinguish between these cases. The solution proposed by *Green, Porter* consists in the temporary reversion to oligopolistic competition for some time if the price falls short of a prespecified threshold. The length of this period is chosen to offset the incentive to defect from collusion. Pricing is therefore procyclical. In equilibrium, slack demand is the only reason for low prices since the phase of unrestricted competition prevents defection. Moreover, the temporary return to competition does not constitute a price war in the sense of a breakdown of the collusive agreement, but serves to make the agreement viable. Thus, a period of high output and low prices does not necessarily signal the end of a collusion, but might as well be a consequence of collusion that works by adjusting prices and output in periods of weak demand.

Compared to the simpler situation without demand fluctuations, this agreement is more complex since it specifies the trigger price and the length of the reversionary period in addition to the collusive price or quotas. In the historical case of the *Joint Executive Committee*, the agreement was overt since such cartels were not illegal before the introduction of the Sherman Act in the United States. The use of this *trigger-price* strategy is considerable more difficult if the agreement is illegal, since the coordination on one of the collusive equilibria in the trigger price – competitive period space requires communication and possibly even a written agreement between the firms.

However, even without the additional problem of unobservability, demand fluctuations may force the colluding firms to relax the restriction of competition by setting output quotas above or prices below the monopoly level.

Rotemberg, Saloner (1986) suggested the first model of collusion in the presence of observable demand fluctuations. They consider the effect of uncorrelated stochastic shocks on the demand level in *Friedman's* supergame model

of oligopolistic competition. If shock realizations are uncorrelated over time, future demand is unaffected by its current level. Consequently, the potential loss of profits from collusion in the case of punishment by *Nash* competition is also independent of the current shock realization. The effect of demand changes on an implicit agreement therefore arises only from the higher gain from defection in periods of high demand. To offset this effect colluding firms reduce profits by expanding production and charging a lower price than in the case of joint monopolization of the market. This behavior results in an anti-cyclical development of the price over time that might be taken as evidence of fierce competition. Despite the simplicity of the assumed demand development, the extended supergame framework thus offers a first explanation of periods of low prices and high production levels. These are termed price wars and featured prominently in the title of *Rotemberg, Saloner's* article, although, according to the model, they are part of the collusive agreement, not a signal of its breakdown.

The assumption of non-correlation of demand across the periods however is a rather stark assumption given the evidence on demand development in different industries. *Haltiwanger, Harrington* (1991) tackle this weakness and replace the stochastic shocks by a recurring, single-peaked demand cycle (cf. Figure 4.1). This description captures a development that is characteristic for many markets (e.g. *Ball* 2003, *Cooper et al.* 1999 and the papers discussed in the next chapter). The basic effect of fluctuations that consists in a higher one-shot gain from cheating if the present demand is high is still present in this model. However, the future demand now depends on its present level. The amount of discounted collusive profits that is lost by punishment hence differs across the periods of the cycle. Hence, the incentive to collude is changed compared to a market with stable demand or uncorrelated shocks. The analysis of cyclic demand thus offers an additional insight that helps to interpret empirical evidence on markup development.

Other descriptions of autocorrelated demand development are proposed by *Kandori* (1991) and *Bagwell, Staiger* (1997). *Bagwell, Staiger* describe the development of market demand over time by stochastic changes between periods of high and low growth, termed “booms” and “recessions”, respectively. Strong demand growth is expected to last if the development is positively correlated, but heralds a change to slow growth if the correlation is negative. Since low future demand implies a weak punishment for defection, participants in collusion reduce prices if they expect a recession. If demand is positively correlated this is the case if demand currently grows slowly. Thus, imperfect collusion in recessions implies procyclical pricing. If demand is negatively correlated, high present growth heralds low growth in the future. Then, the firms set low prices in booms to make the implicit agreement feasible. Consequently, the anticyclical pricing found by *Rotemberg, Saloner* (1986) results only in the latter case.

This model is attractive since it derives conditions for both pro- and anticyclical pricing in a single framework. However, the method of proof works

only if punishment profits are zero. The richness of the results is hence bought by the restriction to price competition in a homogeneous market. The model also holds if the firms use an optimal penalty code proposed by *Abreu* (1988) that yields a discounted profit stream of zero after defection. In oligopolistic markets however such a punishment cannot not always be implemented due to the non-negativity of prices and quantities (*Häckner* 1996, *Lambertini*, *Sasaki* 1999).

An alternative explanation of price wars that are triggered by the demand development in a market where prices are observable is proposed by *Slade* (1989). She develops a model of infinitely repeated price competition. The demand for the differentiated good is subject to infrequent, permanent shocks. The setup is conceptually similar to the conjectural-variations approaches in so far as she assumes that each of the competitors holds conjectures on the extent of a rival's reaction to his own price changes. Conversely, a firm adjusts its own price in the same direction, but to a smaller extent in the subsequent period in response to a price change by a competitor. Since the new demand situation is unknown after a shock, the firms use price changes to learn about the demand. These price changes trigger the punishment. The ensuing price adjustment converges to a new equilibrium and the *price war* comes to an end because the extent of punishment for defection from the collusive equilibrium depends on the severity of undercutting. However, the described reaction to a rival's price change is not subgame perfect. It is however ϵ -perfect if the discount factor is sufficiently close to one. In such an equilibrium, the payoffs differ from the subgame perfect ones only by an arbitrarily small amount (cf. *Kalai*, *Stanford* 1985).

A recent contribution by *Martini* (2003) demonstrates that demand fluctuations are not the only possible explanation for price fluctuations in long-term competition. He derives the conditions for the viability of an implicit agreement on non-uniform pricing by duopolists. Here, the firms collude by taking the role of the monopolist in turn for a number of periods. However, the comparatively simple design of the implicit agreement rests on the assumption of *Bertrand* competition. The coordination and implementation of such a collusive strategy would be much more difficult in a market for a heterogeneous product. Hence, collusion by non-uniform pricing is rather unlikely. Other work on price fluctuations does not rely on repeated games but explains periods of low prices as the effort of an incumbent to deter the entry of additional producers into the market or as an action aimed to build a large customer base in a market with switching costs (cf., e.g. *Bils* 1989, *Klemperer* 1995, *Elzinga*, *Mills* 1999).

Aside from exogenous fluctuations of demand, the firms' competitive behavior is an important factor that determines the future market conditions. As is well known from previous work, these long-term business strategies also affect the scope of collusion in a market.

2.2 Long-Term Competition with Strategic Decisions

In addition to the choice of price and quantity, firms have to take a multitude of other decisions in order to run their business profitably and remain competitive in the market. A large body of the industrial-organization literature seeks to clarify, whether firms can use this long-term decisions to solve the problem of coordination of market strategies, i.e. prices or output. A distinction of business strategies that may and may not serve as a facilitating practice allows to assess which – endogenous – market conditions are conducive to collusion. Again, such an assessment offers conclusions in two respects: On the one hand, it facilitates the detection of anticompetitive agreements and allows to devise an effective antitrust legislation. On the other hand, such knowledge can be used by firms to design long-term strategies to facilitate price or quota agreements.

Since the antitrust surveillance in developed countries, among them in the US and the European Union is tight, colluding firms are likely to coordinate on agreements that do not require communication of some kind. Also, institutions, i.e. trade associations, that collect and distribute information on prices, sales, delivery terms and other details that relevant for the competition in the market are seen critically with respect to their antitrust implications. This applies especially if the publication of the information does not imply a commitment vis-à-vis consumers (Kühn 2001). If they are not outrightly prohibited, they will certainly attract the scrutiny of the competition authorities. We therefore abstract from explicit “ancillary” agreements on long-run decisions and do not consider associations of commerce industry in the following discussion of previous work on long-term strategic competition.

Entry

The very first strategic decision of a firm is of course whether to enter a certain market. At the same time, further entry in an established market also changes the conditions of competition between the incumbent firms and hence potentially also their implicit agreement. Collusive markets are especially attractive for entrants because profits are supra-competitively high.

An implicit or explicit *code of conduct* of the given industry is likely to determine how the incumbents react to entry. Such a behavioral norm may depend on an industry’s history and the backgrounds of current owners and managers. In response to entry, the participants might either adhere to their original collusive agreement, admit the newcomer into their agreement or revert to unrestrained competition. Empirically, the incumbent firms use both accommodating and aggressive strategies (e.g. Scott Morton 1997).

In the first case, the incumbents alone continue to collude. Then, they face competition by a competitive fringe of entrants. Collusive quotas are therefore higher and prices and profits lower than in the pre-entry market. The new firms also earn positive profits. Thus, entry is profitable as long as the corresponding costs are lower than the discounted profits of a fringe competitor.

In the second case, the entrant takes part in collusion. Since the number of participants rises, it might become more difficult to reach an agreement. More importantly, each firm's discounted profits decrease since the spoils of collusion must be shared with a larger number of competitors. Furthermore, this accommodating strategy attracts ever more entrants. The group of colluding firms thus gets larger until the cost of entry equals the discount stream of profits from participation. In absence of market barriers, the number of competitors grows without bounds, and the price approaches the marginal cost of production (*Lambson* 1984). Under these circumstances, collusion is not viable. To prevent entry, the incumbents thus set the quotas or the price that yields a negative net collusive profit for a further competitor. Consequently, the joint monopolization of the market may be impossible if the market barriers are moderate. In the third case, colluding firms react to entry by a return to unrestricted competition. *Harrington* (1989b, 1991b) considers joint monopolization and shows that there is then always a finite number of firms in the market that rises in the cost of entry. Similar to the previous case, this is the number of competitors where the stream of discounted *Nash* profits of a new rival does not cover the entry cost.⁴ Since the *Nash* profit is lower than the collusive profit, the perceived market barriers are higher and collusion is easier if potential entrants expect incumbents to abandon collusion after entry.

Vasconcelos (2004) considers the aggressive and the accommodating response to entry and integrates random, unobservable demand shocks to describe the historical case of the *Joint Executive Committee*. The model shows that potential competitors always reduce the scope of collusion. Further, the potential entrants pose a greater problem for colluding incumbents if they are allowed to join the implicit agreement. The data on the transport industry in the area of the Great Lakes to which the *JEC* belonged support the conclusion that the returns to competition were longer and more frequent when the number of firms in the *JEC* was larger. According to *Vasconcelos*, these findings suggest that the members integrated entrants after some time of unrestrained competition and settled on a less restrictive implicit agreement.

Once a firm decided to enter a market, it has to determine the scale of its engagement. Therefore, the production capacity is another important decision that must be taken before a firm competes in the product market. The comparatively large number of analyses devoted to the capacity decision mirrors its prevalence and importance in oligopolistic competition. As will become clear soon, it also has substantial implications for an implicit agreement between the rivals.

⁴ *Klemperer* (1989), *Elzinga*, *Mills* (1999), in contrast, explain a period of low prices that follows entry as an effort to attract consumers who incur switching costs. Having established (or defended) their customer base, the firms return to higher prices.

Capacity

With respect to collusion, the effect of large capacities is ambiguous: Since a large output implies a better utilization of the production facilities, the incentive to defect is especially high if the defector's capacity is large. The punishment of defection however also requires high production and thus likewise increases in the capacities of the firms. Consequently, capacities that exceed the demand at the collusive price make defection both more and less attractive. The detailed theoretical analysis by *Brock, Scheinkman* (1985) demonstrates that excess capacity is needed to enforce collusion by a threat of sufficiently high punishment.⁵ *Benoit, Krishna* (1987) build on their work and allow for flexible capacities that can be adjusted in every period. In this situation, the firms may sustain an agreement on joint monopolization of the market even if the capacities are initially insufficient to make the punishment credible. If capacity choices are irrevocably in contrast, the price that is set by a monopolist cannot be enforced by the colluding firms. *Feuerstein, Gersbach* (2003) compare the effects of irreversible and reversible capital decisions that are taken simultaneously to quantity competition and confirm the conclusions by *Benoit, Krishna*. Recurring capacity setting that amounts to an infinite repetition of the *Kreps, Scheinkman* capacity-price competition is analyzed by *Davidson, Deneckere* (1990). Based on empirical examples for semi-collusion in the market variable only, *Davidson, Deneckere* abstract from the fact that the firms might also tacitly or implicitly coordinate their capacity choices. They demonstrate that the scope of collusion also rises in the participants' excess capacity if productive capital is costly and firms set the capacities in dependence of the cost of capital at the beginning of each period before output is produced and prices are set. Again, the firms build excess capacities that make the threat of punishment credible and are essential to enforce collusion. This is easier and the scale of operation therefore larger if the installation of further capacity is cheap. Moreover, each firm additionally gains from high capacities if the production quotas are allocated according to the relative sizes of the participants' capacities (*Steen, Sørgaard* 1999).

As has been shown recently by *Compte et al.* (2002), the working of collusion

between firms with asymmetric capacities is much the same as in the case of differing production cost. *Compte et al.* demonstrate that the firm with the greatest capacity gains more than the other, smaller competitors by undercutting the collusive price to the same extent. Since the worst punishment consists in production up to full capacity, a producer with low capacity has a limited possibility to discipline its rivals through the threat of a punishment. As a consequence, a firm with large capacity facing a rival with small capacity will have a high incentive to cheat on the collusive agreement. *Vasconcelos*

⁵ Their model is an extension of earlier work by *Kreps, Scheinkman* (1983) who show that the capacity-price equilibrium and the *Cournot*-quantity equilibrium without preceding capacity choice coincide if firms compete in prices only once.

(2005) derives the effect of capacity limits on an implicit agreement that is supported by a *stick and carrot* penalty code. He assumes that the production costs decrease in large capacity. As could be expected on the basis of previous work, collusion is more difficult if the extent of asymmetry is large.

There are also studies that derive the additional effect of demand fluctuations on collusion between capacity-constraint firms. To this end, *Staiger, Wolak* (1992) generalize the setup by *Davidson, Deneckere* to account for uncorrelated stochastic shocks on demand that are observed only after the capacities are chosen. The interplay of demand shocks and excess capacities gives rise to the “price wars during booms” effect demonstrated by *Rotemberg, Saloner* (1986) if demand is so weak that the capacity limits effectively do not restrict the firms’ product market strategies. Then, it is possible to punish a defector effectively by high production that results in a low market price in periods of high demand. Furthermore, a small increase in demand may force the firms to reduce the incentive to defect by setting a lower collusive price. This situation is described by the initial formulation of the model by *Rotemberg, Saloner* who do not consider capacity constraints. If capacity choices restrict the output choices, the firms produce close to their capacity. The unused capacity may then be insufficient to produce the high quantity that would be produced by a defecting firm with sufficient capacity. The additional profit from defection, i.e. the amount gained in excess of the profit from perfect collusion, is then small if the current demand is high. In a period of low demand in contrast, the capacities considerably exceed the output that is produced in the case of joint monopolization of the market. Consequently, defection yields a high additional profit. Thus, capacity constraints reduce the anticyclicity of pricing that results in the market without capacity limits. In short, small excess capacities result in mild price wars, whereas the “price wars during booms” effect is more pronounced if the firms carry high excess capacity.⁶ *Fabra* (2004) considers a description of market demand that describes empirically observed patterns more closely. She explores the interplay between collusive behavior and capacity constraints in a market with recurring demand cycles described by *Haltiwanger, Harrington* (1991). In line with the result of *Staiger, Wolak* (1992), she shows that the effect of demand cycles is also overturned by capacity constraints. During booms, the lack of excess capacity reduces the potential punishment, whereas the higher excess capacities that emerge during a recession increase the possibilities of retaliation. Therefore, the effect of weaker collusion in times of falling demand does not occur if capacities limit the firms’ output choices. As long as the capacities are not extremely small, the conclusions are qualitatively identical to *Halti-*

⁶ *Reynolds, Wilson* (2000) criticize this analysis on the grounds that the authors overlook a discontinuity in the profit function that arises if the firms are symmetric in their capacities, but concede that qualitatively similar results obtain in the case of symmetric optimal punishment in the line of *Abreu* (1988).

wanger, Harrington's and the prediction of largely procyclic pricing remains valid.⁷

Hence according to the literature, the consequence of a credible, high punishment dominates the effect of a large gain from defection and facilitates collusion given sufficiently large excess capacities. This also applies if the market demand fluctuates.

Research

Another decision that affects competition for a long time span is the question of whether to improve the production process or the product quality either by individual research or by participation in a collective research project.⁸

Cooperation by integration of firms' activities in some business area or collaboration in a joint project is subject to antitrust scrutiny if the participants are competitors in the market for the final good. However, many types of cooperation generate efficiency gains. In order to promote the competitiveness of domestic industries by allowing for efficiency gains from cooperation, the *National Cooperative Research and Production Act* was enacted in the USA in 1993. In the European Union horizontal cooperation between competitors is regulated by the articles 81 and 82 of the Treaty of Rome and the new *Commission Regulation (EC) No 2659/2000* known as *R&D Block Exemption Regulation* and the *Horizontal Guidelines* of 2001. This rather lenient regulation of cooperation in R&D, production, and marketing reflects that the implied intensification of dynamic competition, e.g. by development of new products or cost reductions in production, is judged to be more important than the potential costs of collusion.

Several advantages are usually cited by firms that cooperate in research projects. Collaboration is expected to increase firms' internal funds that are available for R&D. Similarly, a group of cooperating firms might have stronger bargaining power in negotiations with investors, and thus obtain additional outside financing faster and under more favorable conditions than any one firm individually (cf. Kukuk, Stadler 2001, for the importance of internal funds as a determinant of R&D activities).⁹ Another way to use cooperative R&D strategically is preemptive patenting that is accelerated by coordination of research efforts and collective setting of standards for new products. Thereby, participating firms aim to close the market against potential entrants (cf. Gilbert, Newbery 1982, and the comments and reply in the same journal in 1984/5).

⁷ It holds as long as firms do not place a very low value on future profits.

⁸ We provide a summary of the related findings for comparison with those regarding reinvestments in physical capital, which are in some respects similar those of R&D expenditures.

⁹ Jensen, Showalter (2004) explore this issue further and demonstrate that the strategic effect of leverage reduces the firms' investment in R&D if they take part in a patent race in parallel to competition in the product market.

However, the most important advantage of cooperation in process innovation is the internalization of the “combined profits externality”, a term introduced by *Kamien et al.* (1992, 1295) for the strategic effect of R&D investments on rivals’ profits. If results are perfectly appropriable, a firm’s cost reduction makes it a more aggressive competitor and hence lowers rivals’ profits. The strategic effect is also negative if less than half of the rival’s knowledge can be costlessly appropriated by its competitors. Hence, it is always negative for the small or zero spillovers that accompany process innovations.¹⁰ If spillovers are very large, the effect of R&D investments on rivals’ profits is positive. Then, the imperfect appropriability of research results outweighs the negative strategic effect of own cost reduction and the concomitant increased aggressiveness in the product market. Moreover, by coordinating research and sharing the results, firms also avoid duplication of R&D efforts. Empirically, there are R&D consortia that share and others that do not share their results (*Foray, Steinmueller* 2003). Yet another technical reason for joint R&D is the access to a larger common knowledge base if all firms disclose the related previously gained insights.

The seminal model on research for standard innovations was developed by *D’Aspremont, Jacquemin* (1988, 1990).¹¹ It describes non-cooperative and cooperative research for a process improvement that reduces production costs. Since the success of the research effort is certain, a firm effectively chooses its unit cost by expending a given amount on R&D. After the research stage, the firms produce at lower costs and compete in quantities in the market. Since the research results are not fully appropriable, the effective cost reduction is determined by a firm’s own R&D results and the part of the rivals’ newly gained knowledge that becomes public. *Kamien et al.* (1992) abstract from the additional coordination of product market strategies and recast *D’Aspremont, Jacquemin*’s analysis to demonstrate the effect of research inputs, i.e. research expenditures. The models thus differ in just one decisive detail and triggered a discussion on the relevance of input and output spillovers. *Amir* (2000) compares both models, relates them to the empirical evidence and shows that their predictions are identical only if the slope of the production function is steeper for output than for input spillovers. For identical investment cost functions, the results are exactly equal only if research results are perfectly appropriable. Therefore, the version with output-spillovers by *D’Aspremont, Jacquemin* (1988) implies a stronger effect of R&D investments and thus a more research-friendly policy than the version with input-spillovers *Kamien et al.* (1992). However, both the input and output formulation yield no un-

¹⁰ *Geroski* (1993, 64) compares the size of spillovers from different types of research projects.

¹¹ The corrigendum by *D’Aspremont, Jacquemin* (1990) corrects the ranking of the equilibria with respect to the output and welfare levels and acknowledges *Henriques* (1990)’s concern that the equilibria are not locally stable if the technological conditions for innovation are extremely favorable (cf. the discussion of the condition for local stability (5.9) in Section 5.1.1 for a more detailed explanation).

ambiguous prediction with respect to the private and social profitability of different types of R&D cooperation. Instead, the conclusions depend on the extent of product differentiation, the amount of knowledge spillovers and on the details of the cooperative agreement.

This model of research with deterministic results by *D'Aspremont, Jacquemin* (1988) proved to be extremely productive and was extended in many directions by the subsequent literature. However, aside from the differences between the versions with input and output spillovers, the assumption of a deterministic research process is an important drawback of this framework. Consequently, much effort has been devoted to consider collective research efforts in a patent race in the line of *Loury* (1979) and *Lee, Wilde* (1980). Since this approach describes research as a contest where R&D investments yield a certain probability for a successful innovation, cooperation stops the race. As the gains from this merger of research activities are highest if all competitors participate, collective research is in essence an investment problem, where the former competitors jointly determine the optimal expenditure path that weighs the cost savings from a slower research process against the losses from the delayed commercialization of the successfully discovered product or implementation of the cost-saving process improvement. The standard patent race by *Loury* (1979) and *Lee, Wilde* (1980) on a single research project and subsequent one-shot competition also provide a basis for the analysis of individual and cooperative research on collusion in the product market.

Since communication is necessary to pursue a collective R&D project, the partner firms also have more opportunities to coordinate other decisions than firms that research individually. Therefore, R&D cooperation might facilitate tacit collusion in the product market. Currently however, the US- and EU-antitrust regulations weigh the beneficial effects of efficiency gains and quality improvements higher than the potential loss due to increased market power of the firm. The more lenient legal treatment of R&D cooperation set forth in the *US-Antitrust Guidelines for Collaborations among Competitors* and the *EU-Guidelines on the Applicability of Article 81 of the EC Treaty to Horizontal Cooperation Agreements* was accompanied by experts' warnings that such law changes could alleviate tacit anticompetitive behavior of the participating firms (e.g. *Jorde, Teece* 1990). Despite such worries, there are no econometric studies and only a small number of theoretical papers that analyze the effect of firms' cooperation in research on the viability of a collusive agreement. Theoretical two-stage models of research and competition, however, are not well suited to analyze the effect of R&D cooperation on collusion. Such a setup neglects the possibility of an implicit agreement that is made viable by the threat to compete more aggressively in response to deviation.

Very few authors consider this dynamic aspect of competition so far. Among those are *Lambertini et al.* (2002) who derive the effect of independent and cooperative development of a new product on the viability of collusion. In their model of a market for a horizontally differentiated good, research

in a joint lab results in a homogeneous product. This lack of heterogeneity destabilizes collusion.

Several other studies, in contrast, analyze process innovations. *Martin* (1995), for example, analyzes the viability of collusion while the firms engage in a patent race for an innovation that reduces production costs. He considers only R&D cooperation that includes sharing of research results. As profits are higher if the firms research jointly, the breakup of the R&D cooperation is a credible additional punishment for defection from the anticompetitive agreement. Hence, collusion is facilitated if the firms collaborate in the research project. However, *Martin* (1995) does not derive the effect of joint research on the viability of collusion after the innovation is made, but assumes that the firms compete in the product market after an R&D success. *Cabral* (2000) also analyzes dynamic competition of researching firms. He assumes full knowledge spillovers and non-contractable R&D, so that there is no scope for research cooperation.

Petit, Tolwinski (1999) take a different approach and describe research as a deterministic process of knowledge accumulation, where periodic investments in R&D lead to a gradual decline of production costs to an exogenous minimal level. Parallel to their research activities, firms compete or collude in the product market. The authors compute the equilibria for a given set of parameter values and show that research expenditures and prices are higher if the symmetric firms collude in the product market, whereas this needs not be true if they are asymmetric. However, the model does not offer general conclusions on the effect of research cooperation on a firm's incentive to participate in a tacit agreement. *Kesteloot, Veugelers* (1995) model competition between firms that research for process improvements as an infinite repetition of a research-quantity setting game in the line of *D'Aspremont, Jacquemin* (1988). They assume that agreements on joint R&D activities are not legally enforceable. Since R&D cooperations are largely exempt from antitrust laws, the assumption that cooperative agreements in R&D cannot be legally enforced at all is a stark abstraction. It is made to analyze the potential instability of research cooperation that arises from the fact that noncompliance with the cooperation contract might be difficult to prove in court. The authors establish by numerical analysis that the viability of an additional implicit quota agreement depends on the extent of knowledge spillovers relative to the degree of product differentiation. According to *Kesteloot, Veugelers*, firms always participate in collusion for the range of low positive spillovers that characterize process improvements. Moreover, the additional sharing of the research results increases the profitability and hence the likeliness of collusion.

The previous theoretical work on the viability of collusion between firms that pursue research individually or cooperatively confirms the conjecture that the effect of R&D on an anticompetitive agreement depends on the details of the market conditions and the organization of the research project.

Production

Following the initial investments in the capital stock that determine the production capacity and possible investments in research for process and product innovation, investments are made to replace worn-out production equipment. These expenditures also play a substantial role for a firm's competitive stance. Again, the investments can be set individually or can be coordinated in a production joint venture.

Many examples of alliances or joint ventures in production can be found in the automobile industry, where firms increasingly often produce the chassis, gearboxes, machines and some times even whole cars jointly in order to reduce production costs, but market the final products independently. Fiat and General Motors for example cooperate in the production of engines and other parts and produce a light commercial van with Peugeot in a jointly owned factory (cf. *The Economist*, April 4th 2002 and June 2nd 2000). Similar projects include the cooperation of several large producers of mobile phones in the production of specialized software (cf. *The Economist*, Feb. 11th, 1999) or the production of chemicals by the firms Sysmex and IRC in a jointly owned plant (Sysmex-Press Release, March 27th, 2001, <http://www.sysmex.co.jp/en/news/press/2001/0327.html>).

To promote the competitiveness of domestic industries by allowing for a wide scope of potential synergies from cooperation, the US-*National Cooperative Research and Production Act* as well as the recent EU-*Block Exemption Regulation* and *Horizontal Guidelines* also cover collaboration in manufacturing. Thereby, production joint ventures are exempt from the per se prohibition of coordination among horizontal competitors, and often from other antitrust regulation as well. The negative effects of the participants' increased market power however may outweigh efficiency gains from cooperation in production. Since the joint-venture firms discuss and coordinate their investment decisions, such collaboration also raises the suspicion of anticompetitive coordination in the product market. The lenient antitrust regulation of cooperation between horizontal competitors therefore has triggered warnings from economists as well as legal scholars that the participants might use the collaboration in production strategically to facilitate collusion in the product market (cf., e.g. Abbott 1989, Jorde, Teece 1990, Correia 1998).

Despite the large number of production joint ventures and strategic alliances, there are only a few studies of horizontal cooperation in manufacturing. Bresnahan, Salop (1986), Reynolds, Snapp (1986) and Kwoka (1992) confine their analyses to joint ventures which differ in ownership structures and distribution of the control rights, but abstract from cooperation outside the managerial and financial sphere. Further, they abstract from coordination of product market strategies and assume *Cournot* competition in the market.¹²

¹² Kwoka (1992) differs from the other authors in so far as he describes the firms' behavior by conjectural variations.

The effect of a firm's endowment with cost-reducing physical capital on one-shot competition is shown by *Farrell, Shapiro* (1990). The authors demonstrate the effect of an exogenous change of a single firm's capital stock on the firms' profits and on the welfare in the market. Further, they consider the effect of an indirect acquisition of new productive assets by investment in a rival and the consequences of a redistribution of the total assets amongst the firms. However, *Farrell, Shapiro* do not derive the optimal investment in the capital stock. Since the model abstracts from capital expenditures, the description of the investment in physical capital is strongly simplified. Similarly, *Yi* (1998) analyzes collaboration by firms that do not invest but realize efficiency gains by sharing the existing capital assets.

Joint production of an input is discussed by *Morasch* (2000) and *Chen, Ross* (2003). The analysis by *Morasch* (2000) is related to the work by *Yi* (1998) in so far as both authors model the alliance as a coalition between *Cournot* competitors. *Morasch* does not consider the problem of optimal investment in production. Instead he analyses the joint venture as a means of strategic commitment by the participant firms. The contract on the provision of the input prohibits the individual production of the input by a member and specifies a certain transfer price. Through the transfer price the cooperation contract indirectly determines the outputs of the participants. A direct quota agreement is thus superfluous. As is well known since the merger analysis by *Salant et al.* (1983), the profitability of a merger (or corresponding cooperation in a strategic alliance) is not necessarily profitable in a *Cournot* oligopoly. If the number of participating firms is too small, the profit increase from the output reduction by the merging (or cooperating) group of firms is outweighed by the negative effect of the non-members' output expansion. The transfer price for the input is therefore set to commit the joint-venture firms to production levels that induce an output reduction of the outsiders. In a market with linear demand for a homogeneous good, the quite complex non-cooperative bargaining process assumed by *Morasch* gives rise to a single alliance and a total production below the *Cournot* market output if the number of firms in the market is smaller than six. If the number of firms in the market is larger, at least two alliances are formed and the total production exceeds the *Cournot* market output. Consequently, the alliance formation gives rise to a welfare loss in tight, but offers a welfare gain in large oligopolies. The model by *Chen, Ross* (2003) is one of the rare efforts to explain cooperation in the physical production process. As *Morasch* (2000), they consider the joint provision of an input good that is essential for the production of a differentiated final good. The two firms hold equal shares in the input-producing joint venture, share the fix costs of production and set the transfer price jointly. In contrast to a vertical relationship between an input producer with only one parent, the transfer price is set above marginal cost by the joint venture firm if the parent firms do not coordinate their product market strategies. If firms cooperate more closely and additionally coordinate their output decisions, the cooperation in production amounts to a merger of the parent firms. Then,

they choose the market prices that maximizes joint profits and realize individual profits that correspond to joint monopolization of the market. However, whether the firms cooperate in the input stage or not does not affect the market price of the final good. Therefore, the individual profits are also the same in both cases: The formation of the input joint venture cartelizes the final goods market and makes a merger redundant. Consequently, the cooperation in input production entails a high welfare loss.¹³

Despite these efforts to derive the impact of cooperation in production, there is still no explanation that describes the effects of collaboration in the physical production process on competition in the market.¹⁴ Moreover, the previous literature does not consider the possibility of an implicit agreement in the product market. These analyses do not take into account that firms usually compete in a market over a long time and thus can credibly threaten to punish a violator of an illegal (tacit or implicit) agreement by aggressive behavior in the future. To date, studies on the additional effect of long-term competition consider only cooperation in R&D. However, there are several decisive differences between research projects and the optimal organization of the production process. As a rule, research results can not be foreseen ex-ante. The return to investments is therefore stochastic. Moreover, R&D is characterized by the involuntary leakage or conscious exchange of newly gained knowledge. In manufacturing, in contrast, the optimal production process is achieved by replacing the worn-out equipment by new and possibly more modern machinery. Thus, the effect of expenditures is known, and investments in one plant have no effect on the efficiency of production in others. The motives for and the effects of cooperation are hence different in R&D and manufacturing.

The most cited motive for cooperation in manufacturing is the potential gain in efficiency (cf., e.g. *Johnson, Houston* 2000). Another very important advantage is the internalization of the “negative externality” that arises from cost reducing investments in the production process. A firm that invests in the replacement of outworn equipment thereby reduces its rivals’ profits since it produces more and competes more aggressively in the market. Thus, such cost-reducing investments are a prime example of a strategy that makes a firm a “tough” competitor in the terminology introduced by *Fudenberg, Tirole* (1984).¹⁵ As this is true for all competitors, the possibility to replace worn-out

¹³ However, the result depends on the assumption of non-substitutability of the input.

¹⁴ The model of production joint ventures by *Roy Chowdhury, Roy Chowdhury* (2001) that explains synergies as a result of mutual learning is probably most closely related to this problem. However, the model describes joint venture formation of a multinational and a domestic firm where the latter has an exogenous disadvantage in learning. Hence, it offers no general conclusion on the private and social profitability of cooperation in production.

¹⁵ With respect to the strategic effect on the rivals, cost-reducing R&D and cost-reducing capital replacement are equivalent.

capital goods results in a prisoners' dilemma. Each firm cuts its own unit costs by high investments in order to keep up with its rivals. This more aggressive competition reduces the profits additionally to the expenditures on capital replacement. If the firms cooperate in manufacturing and coordinate their investments, they are able to mitigate this negative externality and gain higher profits. As in the case of joint research, a larger pool of financial funds and stronger bargaining power in negotiations with banks and financial investors are further advantages of cooperation.

Outside Finance

Often however internal funds are insufficient to cover indispensable investments. But outside finance is not necessarily chosen solely because the own capital is insufficient. In addition, a large number of alternative motives for firms' reliance on debt instead of equity funding are discussed in the literature (cf. *Hellwig* 1991 and *Maksimovic* 1995 for an overview). A given capital structure can be a reaction to informational asymmetries, result from tax advantages of different kinds of outside finance or be set as a commitment to a certain product market strategy. Alternatively, increased leverage can serve as a shield against a hostile takeover (*Dasgupta, Titman* 1998). But there are negative effects of leverage too: A higher debt level reduces managers' opportunities to increase their personal power by acquisitions (*Zwiebel* 1996). Furthermore, high indebtedness reduces the trust of consumers and business partners in the solidity of the firm (*Maksimovic, Titman* 1991).

In addition to the research on reputational and incentive effects of the capital structure, there is a large body of work that analyzes the effect of leverage on competition in the product market. The impact of leverage arises from the high cost of a restructuring of debt that makes financing decisions binding over a long time horizon. This applies to funds sought on the stock or bond market, but also to bank finance. Thus, financial obligations can serve as a credible commitment to a certain competitive strategy in the product market. There is therefore a strong dependency between financing decisions and pricing or production levels. Efforts to explain the different effects of outside capital can roughly be divided as follows: Originating with the seminal article of *Brander, Lewis* (1986), the effect of limited liability is analyzed for different market conditions (e.g. *Glazer* 1994, *Showalter* 1995, *Maksimovic* 1988, *Damania* 1997, *Bagliano, Dalmazzo* 1999). *Chevalier, Scharfstein* (1995, 1996) consider its impact in markets where consumers incur switching costs. Another stream of the literature starting with *Brander, Lewis* (1988) analyzes bankruptcy cost as a factor that determines the degree of competition in the output market. In addition to the direct effect of leverage, the structure of the financial market and the vertical relations between investors and firms affect competition in the product market (*Poitevin* 1989, *Bhattacharya, Chiesa* 1995).

Irrespective of the source of outside funds, the choice of the capital structure influences the market performance. The decisive factor in this respect

proves to be the limited liability of borrowers how cannot be forced to repay debts beyond their wealth, i.e. in the case of firms beyond their profits and assets. *Bagliano, Dalmazzo* (1999) consider the pure liquidation risk (without consideration of repayments and other contract conditions). They show that the risk of bankruptcy reduces the firms' inclination to restrict competition in repeated rivalry. To demonstrate this anticollusive effect, *Bagliano, Dalmazzo* consider the extremely simplified *Rotemberg-Saloner* model presented by *Tirole* (1988) in his text book. In this version of the model, the independently, identically distributed stochastic shock results in either a high or low demand level. The possibility of bankruptcy is described as an exogenous probability of survival in a period of low demand ("recession"). Since a reduced probability of continuation enters the condition for collusion in the same way as the discount factor (cf., e.g. *Tirole* 1988, 253), the liquidation risk raises the critical lower bound of the discount factor for collusion. However, the relative size of profits in periods with low and high demand and thus ultimately the difference between the demand levels also affects the firms' inclination to collude. If the relative size of profits in periods of high and low demand is smaller than the probability to survive a recession, the colluding firms produce a quantity that is higher and gain a price that is lower than in the monopoly equilibrium if demand is high. This adjustment of the implicit agreement is stronger the lower is the probability to survive a recession period. This is the familiar *Rotemberg-Saloner* effect of anticyclical pricing that reduces the incentive to defect in periods of high demand. For a small range of parameter values that correspond to a rather small difference between the two demand levels, and thus profits, the optimal collusive strategy is different. In this case, a procyclical development of prices that is induced by increasing output beyond the monopoly share is shown to be the optimal collusive strategy if demand is low.

In the context of the present study, the main conclusion from this simple model is the finding that a risk of liquidation decreases the firms' incentive to participate in an implicit agreement. Thus, according to this stylized model, leverage can not be used as a facilitating device to increase the scope of collusion in the product market.

The basic effect of bankruptcy however stems from the fact that a firm's owners can not be held liable to meet their financial obligations if these exceed their share in their firm's profits. Their limited liability affects competition in the product market in addition to the costs due to bankruptcy. To demonstrate this effect, *Brander, Lewis* (1986) devise a model of *Cournot* competition between leveraged firms in a market with stochastic shocks on the demand level. The firms are run by equityholders who are claimants of the residual rights, i.e. the profit net financial obligations. Consequently, they produce the outputs that maximize the equity value only, whereas the debt value is not considered. As the current demand is unknown when the quantities are set, unexpectedly slack demand may force them into bankruptcy. Since the marginal return on output is higher in times of high than of low demand, the equityholders set

higher outputs than in the case of full internal finance and realize lower profits. However, a strategic decision typically has opposite effects in two-stage price and quantity competition. Thus, it was only a matter of time until *Brander, Lewis's* work was supplemented by a model on the effect of limited liability in price competition. As was to be expected, the analysis by *Showalter* (1995) that is identical to *Brander, Lewis's* but for the strategic variable yields a positive strategic effect of leverage. The equityholders therefore set higher prices and realize larger profits compared to full equity finance. A subsequent article by *Wanzenried* (2003) extends these models to derive the effect of debt in a market with linear demand for a differentiated product. The reverse results of higher profits in price and lower profits in quantity competition in a market for a substitutive good continue to hold. For a complementary good the reverse conclusion applies. Since leverage makes the firms less aggressive competitors if they compete in strategically complementary variables (e.g. price competition for a substitutive good) and more aggressive competitors if the variables are strategic complements (e.g. quantity competition for a substitutive good), debt reduces social welfare in the former and increases it in the latter case. The endogenous determination of the interest rate is an additional theoretical advantage of *Wanzenried's* model. In equilibrium, it takes a value at which the expected repayment by equityholders covers the principal and interest. Hence, the creditors break even ex-ante. This is a considerable improvement over the previous work where the initial disbursement by creditors was higher than the expected repayment.

In all versions of the model, the strategic effect of leverage results from unobservable demand shocks. If in contrast the demand level is known, it is not rational to take an amount of outside funds that makes a firm bankrupt. Consequently, limited liability and hence leverage does not affect product market competition.

Maksimovic (1988) demonstrates the reduced profitability of leveraged firms in an even simpler, yet appealing analysis of collusion between firms that take outside capital in the financial market. Here, the impact of debt does not depend on the occurrence of demand shocks. He considers three types of outside financing: In the simplest case, the required amount of external funds is raised by a bond issue. If the firms are always solvent, limited liability plays no role and the financial obligations are met irrespective of whether the equityholders who run the firms compete, collude or defect. Conversely, leverage affects the product market strategy if the equityholders are protected by limited liability in case of bankruptcy by unrestrained competition. Then, the periodic repayment is larger than the *Nash*-competitive profit. Since the equityholders lose their rights on the firms' profits in the event of insolvency, they do not obtain profits in the punishment phase that follows a defection. The additional periodic gain from the implicit agreement, namely the net collusive profit less the net *Nash*-competitive profit, is thus given by the per-period profit from collusion net the repayment alone if unrestrained competition makes the firms bankrupt. The gain from the implicit

agreement therefore decreases in the repayment. Further, the financial obligations have to be met whether the firms collude or defect. The additional gain from defection, i.e. the one-shot profit realized by deviation net the alternative collusive profit, is hence independent of the amount that has to be repaid in every period. Consequently, bankruptcy in connection with limited liability reduces the equityholders' incentive to participate in an implicit agreement. *Hege* (1998) extends this basic finding by *Maksimovic* and demonstrates that the anticollusive effect of leverage makes financing by banks relatively more attractive than public debt because it can be paid back faster. The value of a colluding firm is thus higher if it takes outside funds from banks instead from the capital market.

Instead of a bond issue, the competitors might raise funds by issuing convertible debt. Then, the right to receive repayments can be exchanged for equity. The conversion of debt into equity reduces the financial obligations of the firm. Since a creditor gives up the discounted stream of repayments only if it is smaller than his corresponding share in the equity value of the firm, the original equityholders may prevent conversion in times of working collusion by issuing the appropriate amount of convertible debt. *Maksimovic* (1988) shows that convertible debt can be used to maintain an implicit agreement if the need for outside funding arises, but cannot be used to restrict competition more than in the case of full internal finance. Therefore, convertible debt is not a suitable device to facilitate collusion.

Alternatively, a firm might issue warrants. The holder of a warrant can acquire a newly issued share of equity for a specified price. Given an appropriately chosen exercise price, its owner will acquire new shares only in the case of defection, but not in the case of continued collusion if the discounted profit stream starting in the period of defection is higher than the corresponding stream of the discounted collusive profits. Due to the dilution of capital the previous owners then gain less from cheating on the implicit agreement compared to a situation with full internal financing, whereas the discounted stream of collusive profits remains unchanged. Consequently, the incentive to continue collusion is higher if the firms issue such securities. As *Maksimovic* (1988) demonstrates, the management of a firm may use warrants strategically to make even an implicit agreement on joint monopolization of the market viable. In contrast to bonds and convertible debt, warrants thus facilitate collusion.

Since several previous contributions on one-shot competition between leveraged firms demonstrate the decisive impact of stochastic demand development on the product market strategies, it is important to derive the effect of such shocks in long-term competition. *Stenbacka* (1994) takes up this question and integrates *i.i.d.* demand shocks into *Maksimovic's* model of financing by bonds. He shows, that the basic effect of an anticyclical development of the market price derived by *Rotemberg, Saloner* (1986) is robust to the introduction of debt. However, as in the original model without outside capital, the applicability of his analysis is limited by the focus on a homogeneous

good. In this case, the profits from unrestrained price competition are zero. Thus, the additional gain from the implicit agreement, i.e. the net periodic collusive profit, is not diminished by the alternative net periodic profit from unrestrained competition that is gained after defection. Therefore, the net collusive profit is smaller the higher the repayment is. The additional gain from defection in contrast remains unchanged by a firm's financial obligations because the repayment has to be made whether a firm defects or continues to collude. Since the repayment reduces the gain from collusion alone, the incentive to participate decreases in the debt level. As in the basic model by *Maksimovic* (1988), leverage reduces the scope of collusion and hence the profitability of the firms.

To the best knowledge of the author, *Damania* (1997) is the only researcher who concludes that debt increases the scope of collusion. He analyzes a market with *i.i.d.* demand shocks where leveraged firms chose the capital structure before they compete in infinitely repeated quantity competition. In contrast to the model by *Stenbacka* (1994), the current demand level remains unknown to the competitors. Hence, *Damania* develops a dynamic version of the model by *Brander, Lewis* (1986) that rests on the assumption that the firms' capital structure remains constant over time. The most important effect in the *Brander, Lewis*'s framework arises from the equityholders' inability to repay the debt if low demand makes their firm bankrupt. Consequently, they produce larger quantities that are optimal for states of demand in which the firm is solvent, but too high if all states of demand are taken into account. *Damania* (1997) uses this variant of the prisoners' dilemma to prove that the discounted profits gained by defection and during the following infinite punishment are lower the higher is the level of debt. However, he abstracts from the fact that the limited liability of equityholders (i.e. the loss of profits in the case of bankruptcy) reduces the value of future profits and thus an equityholder's effective discount factor in the similar manner as in the model by *Bagliano, Dalmazzo* (1999). Furthermore, when stating the incentive to collude, *Damania* implicitly assumes that the level of indebtedness is the same whether the firms collude or defect and take part in the subsequent punishment. However, since there is a one-to-one relationship between output and debt, the amount of outside capital that corresponds to the collusive output cannot be optimal for the production of the much larger quantities in the punishment phase or in the period of defection. Both points of criticism cast doubts on *Damania*'s result of debt as a facilitating device. Most likely, the integration of the two neglected effects of limited liability yields the opposite result that debt reduces the scope of collusion. This basic tendency of leverage to decrease the profitability of an anticompetitive agreement is supported by the supergame studies by *Maksimovic* (1988), *Stenbacka* (1994), *Hege* (1998), and *Bagliano, Dalmazzo* (1999) discussed above.

The previous theoretical work points to the fact that leverage increases competition in long-run interaction. This finding is opposed to the conclusions by *Showalter* (1995) and *Wanzenried* (2003) that leverage can be used

to commit to less aggressive behavior if firms compete only once in strategically complementary variables. A comparison of these results highlights the differences between both approaches: In the model of one-shot competition, leverage is held for purely strategic reasons and affects the firms' strategies through bankruptcy caused by unexpectedly low demand. In the repeated-game framework in contrast leverage is not used strategically but is assumed to be indispensable for participation in competition. If not, the competitors would choose internal finance unless debt yields a tax advantage that offsets its negative effect on profits.

Contractual Relationships between Competitors

Similar to the procollusive effect of a concentrated banking sector, cross-ownership between competing firms or mutual silent financial interests in a subsidiary decreases competition in the market. Abstracting from the additional effect of repeated interaction, *Reynolds, Snapp* (1986), *Bresnahan, Salop* (1986) and *Chen, Ross* (2003) demonstrate that cross holdings by firms as well as the merging of some lines of business amount to a noncollusive coordination of the partners' market strategies. Since irrespective of the details of the cross interests, a firm partly benefits from its partners profits, such contractual relations yield a certain extent of joint-profit maximization in a similar way as collusion even without an coordination of the product market strategies. *Flath* (1991, 1992) finds the same effect in an analysis of symmetrical cross shareholdings. The robustness of the "cartelizing effect" to product differentiation and asymmetries in the production technology is shown by *Merlone* (2001).

However, the negligence of repeated interaction ignores an important feature of oligopolistic markets. *Makueg* (1992) considers this additional effect in a supergame model of competition between firms that hold a stake in their rivals. At first glance, cross ownership is likely to increase the interlocked firms' inclination to collude since their interests should be more similar. However, since an increase in cross holdings raises the *Nash*-competitive profits, it also reduces the scope for retaliation. Consequently, the firms' inclination to collude may be decreased by interlocking interests in such a situation of competition over a long time horizon. If the demand function is concave or linear, this effect causes the firms' inclination to collude to fall in the extent of cross holding. If demand is convex, the negative effect of cheating that reduces the return from the investment in rivals dominates if the stake in the rivals is high. Consequently, the inclination to collude first falls, but then rises again in the investment in the rivals.

Delegation

Today, a large part of compensation packages consists of a firm's shares or stock options, but their use is obviously confined to joint-stock companies, i.e. very large firms. In industries consisting of small and medium sized firms,

the owners themselves often run the firms. If, however, smaller firms are run by managers, their compensation contains more traditional incentive components, predominantly boni dependent on short-run success (*Murphy* 1999).

The pioneers in the theoretical analysis of strategic effects of management compensation are *Vickers* (1985), *Fershtman, Judd* (1987) and *Sklivas* (1987), who consider a linear compensation contract linked to the sales and profits of a firm. Their analysis demonstrates that the weight of sales and profits changes the manager's perceived marginal cost of production and therefore his competitive behavior. By the design of the compensation, the owner indirectly chooses the product market strategy. Since any strategy that reduces the marginal costs makes a firm "tough", overinvestment by weighting sales heavily is optimal in the case of strategically substitutive variables. In the case of strategic complements however, underinvestment is optimal and implies a negative weight on sales in the compensation (cf. *Fudenberg, Tirole* 1984). Hence, in one-shot competition, the long-term decision on management compensation has the same strategic effect as the choice of investments in production and the level of outside capital. *Lambertini, Trombetta* (2002) analyze the impact of such a linear contract on the pricing by managers in a supergame model of a duopoly market with constant demand. They show that the managers' incentives to collude are independent of the weight given to sales and profits as long as the owners compete in the compensation contracts.

Boni and stock-based payments are other typical compensation components (*Murphy* 1999). *Reitman* (1993) assumes that managers compete in quantities and extends the linear contract by replacing the profit-dependent component by a stock option grant. In effect, this grant is a bonus which a manager only receives if the current profits exceeds some strike level. Any other bonus that depends on reaching the same profit level has an identical effect on the competitive strategy of the manager. *Reitman* demonstrates that the profits in a symmetric equilibrium are always higher than in the case of a traditional, sales- and profit-dependent contract, but do not exceed the *Cournot* profits. *Spagnolo* (2000), in contrast, derives the effect of share-price-dependent compensation on managers' pricing behavior in infinitely repeated competition. He shows that such payments increases a manager's inclination to collude. Thus, managers with stock-based compensation compete less aggressively than those with a traditional, *Fershtman-Judd-Sklivas*-type of contract.

Aside from the conclusions on the strategic behavior of firms and the resulting market performance, the comparison of previous results on one-shot and long-run interaction yields insights with respect to the *topsy-turvy principle* of the supergame theory by *Shapiro* (1989). According to this principle, any factor that makes competition more aggressive facilitates collusion since it enlarges the possibilities of punishment.

As *Fudenberg, Tirole* (1984) demonstrate, the profitability of one-shot two-stage competition depends on the strategic substitutability or complementarity of the product market variables. If the investments make the firm a "tough" competitor, their strategic substitutability gives rise to a prison-

ers' dilemma, where the strategic investments reduce the firms' profits. Only if the product market variables are strategic complements, can the long-run commitment be used to raise the profits. However, this strategic use of the long-run investment does not amount to a non-cooperative coordination of the firms' product market strategies. Long-run decisions on capacities considered by *Kreps, Scheinkman* (1983), on process investments in the line of *D'Aspremont, Jacquemin* (1988), on capital structure as introduced by *Brander, Lewis* (1986, 1988) and *Showalter* (1995) and on management compensation analyzed by *Fershtman, Judd* (1987), *Sklivas* (1987) and *Reitman* (1993) are examples for such strategic competition. If the investments make the firm a "soft" competitor instead, the strategic complementarity and substitutability of the product market variable have converse effects.

According to the *topsy-turvy principle*, a basic game of two-stage competition that yields a low *Nash* profit implies a small scope of collusion. If the firms set investments that make them "tough", the scope of collusion is therefore small if the firms compete in strategic complements, but large if they compete in strategic substitutes.

The analysis of capacity-price competition provides a good example: If the decisions are taken only once, the competitors build small capacities to commit themselves to low production. By producing up to capacity, they realize *Cournot* profits even if they compete in price in a market for a homogeneous good (*Kreps, Scheinkman* 1983). In the case of unlimited capacities in contrast, the profits are zero. If the decisions are taken repeatedly however, the firms set up excess capacities to make the punishment of defection from the implicit agreement credible. As shown by *Benoit, Krishna* (1987) and *Davidson, Deneckere* (1990) respectively, this result applies both to collusion in capacities and price and to semi-collusion in price, irrespective of whether capacities are chosen once or periodically. The models of competition with exogenous capacity limits by *Brock, Scheinkman* (1985) and one-time irreversible capacity choice by *Benoit, Krishna* (1987) confirm the robustness of these results. Thus capacity limits as a factor that increases the profitability of one-shot competition, indeed constrains collusion as predicted by the *topsy-turvy principle*.

Yet, the literature on repeated games also offers counter-examples as for instance the case of mutual shareholdings analyzed by *Malueg* (1992). In one-shot interaction, the firms weight rivals' profits more heavily in their own objective function the larger the interlocking financial interests are. Consequently, competition in the market comes closer to joint profit maximization if the investments in the rivals increase. In repeated interaction in contrast, mutual investments make collusion difficult only if the demand function is concave or linear, but may facilitate collusion if the demand function is convex. *Malueg* considers exogenous shareholdings that correspond to the study of given capacity limits by *Brock, Scheinkman* (1985). To date, there is no analysis of the strategic choice of interlocking financial interests that are analogous to the analysis by *Benoit, Krishna* (1987) and *Davidson, Deneckere* (1990).

However, the counter-example by *Malueg* is sufficient to show that “[O]ne must exercise extreme caution is (sic) using counterintuitive results of this sort that are based on the *topsy-turvy principle* (*Shapiro* 1989, 365).” Hence, the fact that a certain market condition or strategic decision reduces the *Nash* profits does not allow for conclusions on the profitability of long-term competition.

Empirical Evidence on Long-Term Competition

Empirical evidence on collusion and price fluctuations in oligopolistic markets can be found both in descriptive and econometric studies. In order to establish the basic stylized facts, we will briefly survey the previous research in this area. As the present work seeks to explain collusion in long-term competition in a theoretical framework, we restrict attention to a limited number of empirical studies that exemplify the methods and the most important findings of the applied literature.

As the theoretical literature, the empirical research on collusion can be divided into papers that analyze the types and restrictiveness of implicit agreements and those that determine which exogenous and endogenous market conditions are conducive to collusion. To show the effect of given market characteristics, we review the studies on the *Joint Executive Committee*, a railroad cartel, and on collusion in cement markets. Cross-industry studies provide further evidence, in particular on the relationship of demand and markup development. To illustrate the impact of long-run decisions, we report the findings on capital reinvestments, financing of investment projects and management compensation which serve as examples of long-term decisions in our subsequent theoretical analysis.

3.1 Long-Term Competition without Strategic Decisions

The applied literature on collusion uses different methodological approaches. Some studies rely on the narrative evidence from antitrust cases or individual markets (e.g. *MacAvoy* 1965, *Genesove, Mullin* 2001), others analyze data from one or several industries using econometric methods. As in the theoretical research, some empirical analyses abstract from demand fluctuations, whereas others focus on the effect of the demand development on collusion. We will consider both lines of the literature in turn.

3.1.1 Constant Demand

There are a number of studies that analyze the working of collusion based on documents and case filings of competition authorities. Since they do not account for demand changes, we will discuss them together with the econometric methods that were developed to derive the extent of market power in imperfect competition.

Descriptive Studies

Evidence on the correlation between explicit collusion and individual market conditions can be found in the descriptive studies of antitrust cases by *Posner* (1970), *Hay, Kelley* (1974) and their followers. *Posner* (1970) pioneered the analysis of the characteristics of price fixing. He collects information on 989 cases that were recorded by the U.S. Department of Justice and the Federal Trade Commission between 1890 and 1969. To a very large part, they occurred in highly concentrated industries. On average, these price-fixing conspiracies were of long duration and affected rather large sales volumes. Two-thirds of the agreements had ten or less, slightly more than a third even less than six participants. These were typically the most important sellers in the market. Moreover, a large number of agreements was not confined to joint price setting, but included ancillary clauses on quotas, audits and fines, patent pools and many other issues. The latter fact may either indicate that additional restraints are commonly used to facilitate collusion or that they are especially prone to draw the attention of the antitrust authorities. Very similar conclusions arise from the much cited study by *Hay, Kelley* (1974), who rely on evidence from case filings and work documents of the U.S. Antitrust Division. The authors consider 49 investigations into price fixing amongst horizontal competitors in the years from 1963 to 1972. These incidents of explicit collusion occurred predominantly in highly concentrated industries that produced a homogeneous product. Moreover, only a small number of firms participated in the anticompetitive agreements. If there were non-participant rivals, these were typically smaller firms. The analysis of these judicial cases therefore lends support to the theoretical prediction of an anticollusive effect of product differentiation. The evidence is also consistent with the theoretical conclusion that a large number of participants makes collusion difficult. Similar studies of antitrust cases followed (e.g. *Asch, Seneca* 1975, *Fraas, Greer* 1977).

In a recent survey of judicial cases of explicit collusion at the U.S. Department of Justice and the European Commission, *Evenett et al.* (2001) report the characteristics of more than 40 international agreements between horizontal competitors. Aside from a smaller number of legal export cartels, the participating firms most often jointly determined the prices or market shares and sometimes also the regional division of the markets. The collusive agreements lasted from one year to over twenty years. In several cases, the offenders belonged to the industries' major producers. The affected sales vol-

ume amounts to well over U.S. \$30 billion. Unfortunately, the authors do not provide information on the number of the participants in the agreements.

A problem of these studies is that there are prone to sample selection bias. Since the evidence is obtained from judicial investigations, it remains unclear whether the features of these anticompetitive agreements are characteristic for collusion in general or only for types of agreements that are susceptible to detection and prosecution. Furthermore, the theoretical studies of collusion in markets with demand uncertainty demonstrate that periods of low prices do not necessarily indicate a breakdown of an agreement. To determine whether an illegal agreement was dissolved or only adjusted to unfavorable circumstances is therefore difficult unless it is ended by antitrust prosecution.

Econometric Studies

These descriptive studies are complemented by analyses of repeated oligopolistic interaction that rely on econometric methods to evaluate the extent of market power. Starting from the very first efforts by *Porter* (1983b) and *Rotemberg, Saloner* to implement their models of price wars caused by demand fluctuations, several econometric approaches were developed to estimate models of long-term oligopolistic competition. We will briefly describe the two most prevalent underlying specifications that were extended to study dynamic competition in markets with fluctuating demand. However, since we aim to provide a detailed theoretical analysis of strategic behavior in long-term oligopolistic competition, the proceeding discussion is meant to illustrate the types of collusive strategies and the use of strategic decisions as well as their impact on the market outcome by citing examples from the empirical research. A thorough discussion and assessment of the econometric methods used in the respective market and cross-industry studies however is beyond the scope of the present work.¹

Basic Estimation Methods

One of the most widely used econometric frameworks is the conjectural-variations approach that is based on an extension of the *Cournot* model. In the modern game-theoretic interpretation, the *Cournot* model is a static game of simultaneous, one-time quantity setting. According to the early interpretation however, the competing producers react to each other's decisions over time and hold beliefs about the rivals' reaction to their own output choice. Extended to account for such conjectures, the theoretical model can be collapsed into an equation that lends itself to econometric implementation. This "dynamic" version is often used in empirical studies of oligopolistic interaction over a longer time horizon.

¹ *Hyde, Perloff* (1995) provide an extensive comparison of the structural estimation of conjectural-variations models, *Hall's* (1988) method and *Panzar, Rosse's* (1987) statistic. *Bresnahan* (1989) and *Martin* (2002) discuss extensions of the conjectural-variations approach and provide surveys of the applied literature.

Formally, a duopolist i maximizes the profit

$$\pi_i(q_i, q_j) = p(q_i + q_j)q_i - C(q_i), \quad (3.1)$$

where q_i is the individual output, $Q = q_i + q_j$ the market output and $C(q_i)$ the cost function that is identical for both firms. If he expects a reaction of his rival, he produces the quantity that satisfies the first order condition

$$p(q_i + q_j) + q_i \frac{\partial p(q_i + q_j)}{\partial Q} \left(1 + \frac{\partial q_j}{\partial q_i}\right) = C'(q_i). \quad (3.2)$$

Given a constant conjecture about the rival's reaction (cf., e.g. *Bowley* 1924)

$$\lambda_i \equiv \frac{\partial q_j}{\partial q_i}, \quad (3.3)$$

it can be rearranged to determine the markup

$$\frac{p(q_i + q_j) - C'(q_i)}{p(q_i + q_j)} = \frac{(1 + \lambda_i)s_i}{\eta}. \quad (3.4)$$

Here, $s_i = q_i/Q$ indicates the market share of firm i and $\eta = \partial p(\cdot)/\partial Q Q/p$ is the price elasticity of the market demand. This concise description of the equilibrium is convenient for the empirical analysis since the equation (3.4) nests all market outcomes from monopoly, $\lambda_i = 1$, *Cournot* duopoly, $\lambda_i = 0$, to *Bertrand* pricing at marginal cost for $\lambda_i = -1$, $i = 1, 2$. With respect to the conjecture λ_i , the *Bertrand* case is identical to perfect competition. In a corresponding structural econometric model, a variant of the markup (3.4) is estimated simultaneously with a demand function. The empirical implementation of the equation (3.4) allows to determine the conjectural derivative and thereby the extent of market power. However, the model does not explain how the firms coordinate on the observed equilibrium. A number of empirical studies address this question and extend this approach in order to discriminate between the different strategies that might be used to achieve an implicit agreement (e.g. *Ellison* 1994, *Briggs* 1996). Still, these studies are not able to distinguish between explicit agreements and implicit coordination on parallel behavior in the product market.

Hall (1988) proposes a different approach to test for market power that relies on the *Solow* residual (*Solow* 1957). This measure of technological progress indicates the increase in the aggregate output that is not explained by changes in the input factors labor and capital. It is constructed to assess the contribution of technological progress to the growth of output under the assumption of a competitive market and constant returns to scale. Hence, it measures all sources of growth that either change the productivity or are caused by shifts in the productivity. Technically, the *Solow* residual is determined by the growth rate of the output-capital ratio, the capital-labor ratio and the income share of labor.

Hall shows that any factor that has an effect on the growth of output and employment, but does not cause productivity shifts or results from such shifts is uncorrelated with the *Solow* residual under the mentioned assumptions. However, it will be correlated with the *Solow* residual under imperfect competition. Moreover, he argues that the covariance will be negative or zero in the case of competition and positive only in the presence of market power. As data on the output-capital ratio and the capital-labor ratio are available, the value of the markup measured by the ratio of price over marginal cost can be determined empirically with help of his method.

Hall (1988) analyzes highly aggregated U.S. data on 7 one-digit and on 26 two-digit SIC industries over the time span from 1948 to 1978.² He uses military spending, the world oil price and the political party of the U.S. president as instruments to test for market power. The oil price generates the greatest number of rejections of the hypotheses of perfect competition: In five of the one-digit and in nine of the two-digit industries the covariance of the instrument and the *Solow* residual is positive and significant. The other instruments provide less evidence against competition, but the results are qualitatively similar. As *Hall* does not report the corresponding elasticities of demand, the estimates of the markup cannot be used to assess the extent of market power.

3.1.2 Demand Fluctuations

Most of the applied studies of oligopolistic markets use different versions of the conjectural-variations approach. Many of them assume that the implied markup is constant over time and report the extent of market power in one or more industries (early examples are *Iwata* 1974, *Gollop, Roberts* 1979 and *Appelbaum* 1982). As the approach as well as the conclusions with respect to market power are very similar to the studies of time-varying markups, we will not review the individual contributions. Instead, we discuss the studies of the markets for railroad freight and cement that served as examples in the research on whether colluding firms restrict competition less in booms or in recessions.

Joint Executive Committee

The probably most prominent and controversial case of collusion is the *Joint Executive Committee* (JEC). It is described in detail by *MacAvoy* (1965). The participating railroad companies operated on the shore of the Great Lakes from 1879 to 1887 and jointly determined the freight rate for shipments from Chicago to the Atlantic. During its existence two firms entered into the JEC and were integrated without resistance of the established members. Since the

² SIC stands for the Standard Industrial Classification of the U.S. Bureau of the Census.

agreement preceded the passage of anti-cartel legislation in the United States, the participants made no effort to cover its existence.

The first econometric study of this case by *Porter* (1983a) implements the model by *Green, Porter* (1984). The author tests whether phases of low freight rates can be explained by an adjustment of the JEC agreement to unobservable demand shocks. As the members of the *Joint Executive Committee* indeed used a kind of trigger strategy and set low prices for a certain time if they suspected an incident of cheating, *Porter* models such changes in the collusive regime by a simultaneous-equation switching-regression model. More precisely, he estimates a version of the markup (3.4) weighted by the market shares and added up over the firms in the industry. The periods are classified as collusive or reversionary based on information from the contemporary business press.³ Alternatively, the probability of a change between cooperation and reversion is estimated using a *Bernoulli* distribution of the dummy for collusion. This method imposes no restriction on the length of the punishment. The resulting categorization of the periods is in line with the reports on price wars in the contemporary press. According to the data on the *JEC*, the reversionary periods lasted on average ten weeks. Moreover, in cooperative periods the indicator of market power is close to the value that corresponds to *Cournot* behavior. The resulting price is far higher (66%) than in the punishment periods, but much lower than in the case of joint monopolization of the market. Expected decreases in demand during the shipping season due to competition by sail and steam boats in contrast caused only small reductions of the price for rail shipments. Hence, the results of the estimation are consistent with the *Green, Porter's* theory of collusion in markets with unobservable pricing and demand.

In a subsequent study, *Porter* (1985) seeks to determine the cause and the structure of the price wars. He shows that high aggregate demand is a likely trigger of a reversion to a low price, whereas deviations from the preagreed market shares as a possible trigger are statistically significant only at the 10% level. The first finding can be explained by *Green, Porter's* theory: A chiseling of the price indeed increases the freight volume of the defecting firm and therefore the total volume of rail shipments if the demand is at least somewhat price elastic. In addition, the studies by *Porter* (1983b, 1985) provide evidence that collusion is more difficult the larger the number of participants is: The prices in cooperative periods were lower and the frequency of punishment phases higher when the JEC had more members.

Compared to *Porter* (1983b), *Ellison* (1994) finds much stronger support for *Green, Porter's* theory insofar as he reports a much higher value of market power in collusive periods. He uses the same data set, but allows for serial correlation in the error terms and considers other indicators of reversions to the

³ The terms reversionary period and punishment are used synonymously although a reversion is part of the collusive strategy that makes the agreement viable in the presence of unobservable demand shocks.

low-profit equilibrium. Moreover, he determines the probability of a transition between cooperation and reversion endogenously by assuming a *Markov* process.⁴ Thus, the probability to remain in a cooperative or reversionary phase depends on whether the members of the JEC had cooperated in the previous period or not. In essence, the analysis compares the performance of *Green, Porter's* hypothesis of price wars during slumps and *Rotemberg, Saloner's* (1986) prediction of price wars during booms. To assess the applicability of *Green, Porter's* model to the JEC, *Ellison* includes four additional variables that account for a very uneven distribution of the market shares that may have served as indicators of a potential defection. An alternative variant of the model tests whether large residuals in aggregate demand, which mirror an unexpectedly high market demand, served as trigger. The inclusion of the latter variable is motivated by *Porter's* (1995) findings on the potential trigger that might have been used by the JEC. It allows to distinguish the effects of an expectedly high level and an unforeseen positive shock on demand. The results suggest that either an asymmetric distribution of the market shares in favor of a single member or a high unexpected increase in the aggregate demand may have served as a trigger. Alternatively, another unknown variable that is strongly correlated to the previous two indicators may have been used. Based on the large and statistically significant negative effect of unanticipated high levels of the market demand, *Ellison* rejects *Rotemberg, Saloner's* explanation of low prices as an adjustment to observable high demand levels as a reason for the price-war phenomenon in the JEC. Instead, the result is consistent with *Green, Porter's* model of collusion in markets with unobservable demand shocks. It lends stronger support to this latter explanation than the finding of switches between periods of high and low prices by *Porter* (1983b, 1985) alone. However, there are two caveats to this conclusion: Firstly, contrary to the theory by *Green, Porter* price cutting seems to have occurred in the JEC although only infrequently. Secondly, the poor observability of demand for rail shipments from Chicago to the Atlantic violates one of the fundamental assumption of the model by *Rotemberg, Saloner*. As *Ellison* concedes, the JEC data therefore do not allow for a true comparison of both theories.

The data set is explored further by *Vasconcelos* (2004) who extends on the model by *Green, Porter* to derive the effect of entry on the extent of collusion and the duration of reversionary phases in a market with unobservable demand. He considers a return to aggressive, unrestrained competition as well as an accommodation of entrants into the implicit agreement as possible reactions by the incumbent firms. According to the theoretical model, the incumbents set a price that makes entry unprofitable at the given level of market barriers. Therefore, it is not observed in equilibrium. Furthermore, *Vasconcelos* shows that the length of a reversion increases in the number of

⁴ *Briggs* (1996) demonstrates that a *Markov* process of order one describes the JEC data well. He interprets this finding as evidence in favor of *Abreu et al.'s* (1986) extension of *Green, Porter's* model to an optimal penalty code.

participants in collusion both in the initial formulation of the model without entry by *Green, Porter* and in the extended version with entry at considerable fix costs. The results of the logit estimation confirm this conclusion: The duration of reversionary phases is indeed larger in times where more firms participated in the *Joint Executive Committee*.⁵ Both the theoretical analysis and empirical evidence from the JEC confirm the robustness of the conclusion from earlier work that collusion is facilitated if the number of participants is small. Furthermore, the estimation shows that the onset of a price war was more likely after periods of low shipments. This result is consistent with the main prediction of the theory by *Green, Porter* that price wars are caused by unexpected slumps in demand that cannot be distinguished from cheating. However, as the author himself remarks, there is a contradiction between theory and evidence. The theoretical model predicts that entry will never occur, whereas there were several episodes of entry into the market for railroad shipment in the sample period.

According to the descriptions of the institutional detail, the members of the *Joint Executive Committee* had access to price data from surveys amongst the participants. However, as the railroad companies sometimes agreed on the rate for shipments in negotiations with individual customers, there were periods where several rates were charged by one firm. Due to the impossibility to verify the price information, members also may have deliberately misstated the freight rates in the surveys. Price data hence was not fully reliable. In addition, demand was volatile and difficult to predict. These market conditions are very similar to the assumptions in *Green, Porter*. Their explanation of price wars triggered by unexpectedly low demand therefore seems to be a quite accurate description of the rail freight market in these years. However, this conclusion does not imply that the explanation by *Rotemberg, Saloner*, who argue that firms align the incentive to collude by setting the price anticyclically, is not likewise an appropriate theory of collusion. Since both models are plausible and internally consistent it depends on the institutional detail of the collusive agreement and the market conditions which explanation of “price wars” is more appropriate. The previous discussion demonstrates that it is particularly the observability of the current demand level that determines the choice of the collusive strategy. The JEC is therefore an inappropriate example for *Rotemberg, Saloner*’s theory.

Cement

A further example is the market for cement that is a prime example for a homogeneous good. Since its value in relation to transport costs is low, cement is sold in regional markets. The number of competitors in each market is relatively small. Therefore, cement has several characteristics that are conducive

⁵ The classification of the periods as cooperative or reversionary relies on information from the press.

to illegal anticompetitive agreements between producers. Indeed, the industry has a history of collusion in many countries, e.g. in Norway, the U.S. and Germany (*Steen, Sørsgard* 1999, *Jans, Rosenbaum* 1996 and *Bundeskartellamt* 2003, respectively). Furthermore, the market for Portland cement is chosen by *Rotemberg, Saloner* (1986) as a suitable example to demonstrate their finding of countercyclical, low prices in periods of high demand. Thus, we will review their findings and discuss the subsequent work on competition in this specific market.

Using U.S. data for the period from 1947 to 1981, *Rotemberg, Saloner* regress the real price for cement on the growth rate of the gross national product that is taken as a measure of changes in demand. This estimation does not exactly implement their model since the levels of the gross national product are to some extent correlated over the years. Their theoretical results however rely on the assumption that the demand levels are uncorrelated over time. The authors themselves see their empirical analysis “not [as] a direct empirical test, but only a cursory analysis of its most striking implication (p.398)”. The estimation shows that the cement price rose in the recessions in 1954 and 1958 and fell in the boom years 1955 and 1959 relatively to the producer price index and a construction price index. On average, an increase in the GNP resulted in a 0.5 or 0.9% fall in the relative price of cement. The first percentage states the change of the price relative to the producer price index, the second to the construction price index. However, with respect to the accuracy of the description of the U.S. cement industry several additional comments are in order: In the empirical part of their analysis *Rotemberg, Saloner* neglect the regional structure of the cement market as well as potential capacity limits. The latter abstraction however is rather problematic, since the extent of excess capacity determines the scope of collusion.

Increasing returns to scale and capacity limits that depend on the number of cement kilns in the market are considered by *Jans, Rosenbaum* (1996). They use a structural model with a supply relationship analogous to (3.4) to determine the effect of multimarket contact on collusion between cement producers. However, the extent of the markup is assumed to remain constant over time. Thus, the potential effect of demand fluctuations is not taken into account. *Jans, Rosenbaum* examine data on 25 regional cement markets in the United States during the period from 1974 to 1989. The results of their estimation support the hypothesis that multimarket contact increases the scope of collusion. A firm’s markup in its home market increases in the market share and in the concentration in the non-home markets where firms interact with the same rivals. This finding can be explained by the theoretical model by *Bernheim, Whinston* (1990). They show that under increasing returns to scale a slack in the condition for collusion in some market allows for a more restrictive collusive agreement in another market where firms have to confine themselves with imperfect collusion.

Aside from the effect of multimarket contact, *Jans, Rosenbaum*’s results demonstrate the robustness of the procollusive effect of market concentration.

However, conclusions on the effect of demand changes on the viability of collusion cannot be drawn since the authors estimate the markup as an average over all the periods.

The effect of demand fluctuations is determined in a subsequent analysis of the same data by *Rosenbaum, Sukharomana* (2001). Here, the authors devise a structural model to test both *Rotemberg, Saloner's* prediction that high current demand makes collusion more difficult (level effect of demand) and *Haltiwanger, Harrington's* (1991) conclusion that high future demand facilitates collusion (slope effect of demand). To separate the stochastic component of the demand development from the deterministic trend they employ the polynomial trend method and alternatively the *Hodrick-Prescott* filter. The demand for cement is proxied either by the state constructions expenditures or by the output calculated from the value added to construction activities. However, the predicted trends in the two proxies differ from each other irrespective of the method used. More importantly, the trends extracted from the same data series by the two methods are not similar to each other. Therefore, *Rosenbaum, Sukharomana* report the results for all four alternative demand trends. The estimations support the theory of *Haltiwanger, Harrington*: *Ceteris paribus*, the markup is lower in the recessionary phases of falling demand than in the boom phases of rising demand. Furthermore, it increases in the *Herfindahl* index. As predicted by the theory of collusion, a small number of firms as well as a symmetric distribution of the market shares facilitates collusion. However, the positive impact of a larger variance in the size of the cement kilns is at odds with the latter finding. The authors interpret this result as a possible effect of collusion with a fringe of much smaller rivals.

In two related papers, *Rosenbaum* (1994) and *Azzam, Rosenbaum* (2001) test whether the market power in the U.S. cement industry is caused by collusion or efficiency advantages of large producers. Market concentration may yield efficiency gains in the cement industry due to increasing returns to scale in production. In their analysis of data from 1978 to 1982 *Azzam, Rosenbaum* (2001) confirm that an increase in market concentration raises the market power and thereby the price, but at the same time increases the average efficiency. The latter effect lowers the price. The market power effect however is approximately twice as large as the efficiency effect. In sum, a 1% increase in concentration measured by the *Herfindahl* index increase the price by circa 4.5%. Hence, the market-power increasing effect of concentration is robust even if higher concentration yields efficiency gains.⁶

⁶ The only study on market power in the cement market of countries other than the USA published so far is the model of semi-collusion in the Norwegian cement industry by *Steen, Sjørgard* (1999). However, the cement producers cooperated in a legal common sales agency that set the domestic price and allocated the market shares according to the relative size of the capacities of each producer. Therefore, this analysis does not offer conclusions on the working of collusion or of an explicit agreement that cannot be judicially enforced.

Cross-Industry Studies

Other authors use aggregated industry-level data to determine the average market power. *Lee* (2001) provides a recent example that is methodologically related to the study by *Rosenbaum, Sukharomana* (2001) insofar as he also decomposes the industry demand into a trend and a stochastic component. In contrast to the former he uses an autoregressive moving average model (ARIMA). In a sample of 180 U.S. four-digit SIC-industries that covers the period from 1963-1987, each industry is characterized by a different autoregressive pattern and lag structure. Using weighted ordinary least squares, *Lee* shows that the price-cost margins move in parallel to industry demand growth. This finding confirms *Haltiwanger, Harrington's* (1991) prediction that collusion is facilitated if the future expected demand is high. In addition, the relationship between the unexpected component of demand and the margin proves to be negative. This effect is in line with the *Rotemberg-Saloner* theory of anticyclical pricing caused by stochastic shocks on demand. Hence, the empirical evidence supports the theories of collusion in markets where the firms observe the current demand level before they decide on price or output levels. As in other studies, concentration proves to be conducive to collusion. Whereas the deterministic component in the demand data used by *Rosenbaum, Sukharomana* (2001) often exhibits a full cycle or at least a peak or trough, the demand trend derived by the ARIMA procedure has a more complex structure. The study is therefore closer to a test of the model of collusion in a market with a stochastically autocorrelated demand development by *Bagwell, Staiger* (1997). According to their analysis, prices are higher in booms than in recessions if the correlation of the demand is positive. However, *Lee* does not relate his empirical findings to their theoretical results.

A considerable number of studies seeks to determine the cyclicity of markups in comparison to the development of the GNP or the aggregate demand in the manufacturing sector.

Among the first efforts in this direction is the work by *Domowitz et al.* (1987, 1988). *Domowitz et al.* (1988) test for market power using *Hall's* (1988) insight that any instrument of the capital-output or the capital-labor ratio in a market with constant returns to scale is correlated with the *Solow* residual only if the market is imperfectly competitive. The instruments used in this study are the GNP and a combination of military purchases and the relative price of imports. The model is estimated using panel data on 284 U.S. four-digit industries over the period from 1958 to 1981. *Domowitz et al.* estimate an equation similar to *Hall's* (1988), but consider materials as a third input factor. Due to large costs of materials relative to output that are wrongly attributed to the markup in *Hall's* initial formulation, they report a much lower extent of market power. Yet, according to their estimation results there is a considerable amount of market power in several industries.

In an extension of the initial estimation, the authors account for the import-adjusted concentration in the industries and find that it raises the

markup to a small, but statistically significant extent. Furthermore, the markup is procyclical in a sense that it increases in the aggregate capacity utilization in manufacturing in all but the concentrated durable-goods industries. The market power hence typically increases in the current demand level proxied by capacity utilization. This result is roughly in line with *Green, Porter's* theory. However, the results can not be interpreted as a true test of the models of collusion in oligopolies because the capacity utilization does not allow to distinguish between the deterministic and the stochastic component of demand. Further, the estimation does not account for the effect of the future demand development on the markup. Without such information a comparison of the empirical evidence with *Haltiwanger, Harrington's* (1991) prediction of more intense collusion in times of rising demand is impossible. Apart from that, the finding of high market power in times of high capacity utilization is also consistent with models of collusion between firms that set capacity before they enter into competition in the product market. In this case, the lack of excess capacity may preclude profitable defection if the current demand is high, whereas it may be still sufficient to carry out the punishment (*Staiger, Wolak* 1992).

In a closely related article, *Domowitz et al.* (1987) analyze the same panel data set. However, as they aim to compare the explanatory power of *Green, Porter's* and *Rotemberg, Saloner's* models, they restrict attention to 57 industries that are structurally similar to the market characteristics assumed in these models. In contrast to the previous study, they do not use *Hall's* method, but develop a conjectural-variations model. To estimate the conjectural derivative in the supply relationship (3.4) they approximate marginal by average costs and use data on the price-cost margins from the U.S. Bureau of the Census. Due to lack of data, they replace the *Herfindahl* index by the four-firm concentration ratio. Judging by the relatively low values of the industries' average price-cost margins, they conclude that the firms are indeed constrained to imperfect collusion.

Based on their finding of differences in the cyclicity of prices across the industries in *Domowitz et al.* (1988), they decompose the sample and report the results for highly concentrated consumer-goods industries and two groups of highly concentrated producer-goods industries with price-cost margins above and below the average in addition to the results for the full sample. Capacity utilization in manufacturing is included in the regression as a proxy of aggregate demand. The relationship between capacity utilization and price-cost margins is positive in all industries in the sample. Hence, the markup is procyclical. The cyclicity is negligible in the unconcentrated, but pronounced in the concentrated industries. Further, the markups are more procyclical in producer-goods industries with low than with high price-cost margins. Sharp price declines as they would occur in the case of a reversion to punishment in *Green, Porter's* model are extremely rare however. Further analysis of the data demonstrates that the increase in capacity utilization from period to period is negatively related to price differ-

ences in the full sample, but the effect is statistically not very significant. The split sample yields stronger conclusions with respect to the price development over time. In concentrated producer-goods industries with low markups, the price develops procyclically over time. In concentrated producer-goods industries with high markups in contrast, the pricing is strongly anticyclical at a low level of statistical significance. Given the procyclic development of the price-cost margins, the production costs must be very strongly anticyclical in the concentrated producer-goods industries with high price-cost margins. The absence of sharp price declines and the countercyclic development of price in the latter industries lead *Domowitz et al.* to favor the *Rotemberg, Saloner's* over the *Green, Porter's* explanation of the price movement over time. However, the findings of *Domowitz et al.* (1987, 1988) hinge on the assumption that the average capacity utilization in manufacturing is a good proxy for the current demand level in the individual consumer- and producer-goods industries.

Several recent articles develop empirical models that are similar to the approach used by *Domowitz et al.* (1988) to analyze the relationship between demand and markup fluctuations. In the following we will discuss those that refer to theories of oligopolistic competition.

Beccarello (1996) builds on *Hall's* method to analyze highly aggregate panel data for nine one-digit SIC industries from the G-7 countries during decade from 1979 to 1989. In contrast to *Domowitz et al.* (1988), he does not account for materials cost. A statistical test demonstrates that the *Solow* residual is identical across the manufacturing branches in all countries except for Italy. Consequently, the technological progress affects the industries of one country in the same way. On average, the market power is substantial in all industries and countries. Most interesting in relation to the present work is the movement of the markup over time. To detrend the data, the gross domestic product is regressed on a trend up to the fifth order. The residuals of this estimation are used as a proxy of the cyclic demand development. The relationship between the markup and the demand proxy however is assumed to be identical across the industries. The corresponding parameter estimates are positive for all countries and statistically insignificant only for the USA. Furthermore, the results are robust to the introduction of an additional explanatory variable that accounts for import competition. As the demand proxy measures the stochastic part of the development over time, the findings are consistent with *Green, Porter's* theory. Although *Beccarello* quotes the predictions by *Green, Porter* and *Rotemberg, Saloner* in the introduction, studies of such highly aggregated data are not conclusive with respect to the explanatory power of microeconomic models of collusion in oligopolistic markets.

The finding of a procyclical development of the markup is confirmed by *Johri* (2001) who also analyzes highly aggregated data on 17 U.S. two-digit manufacturing industries and uses an extension of *Hall's* approach to estimate the markups. He splits the development of the industries' markups and output levels into a deterministic trend and a stochastic component by regressing the

percentage changes in both series on monthly dummies. The outputs indeed exhibit a marked, seasonal pattern that allows to apply *Haltiwanger, Harrington's* theory to explain the pricing in these industries. The regression of the markup on the discounted expected aggregate manufacturing output of the following three month, the industry's current output level and the discounted expected industry output of the next twelve month shows the effect of expected future market demand on collusion. The relationship between the markup and expected future profits is positive and statistically significant in eleven and negative in only three of 17 industries. The markup is therefore predominantly procyclical. This finding supports *Haltiwanger, Harrington's* prediction that collusion is easier in times where the market demand increases.

The analysis of time-varying markups is further extended by *Bloch, Olive* (2001) who additionally account for inflation and a cyclic component in the development of production costs over time. However, they do not use *Hall's* method, but assume that the change in the price depends on the change in aggregate demand, the aggregate price and marginal cost. The assumed cost function yields marginal costs that are directly proportional to average costs. The rate of change of marginal and average costs is hence the same. The model is estimated on data of 21 U.S. two-digit industries from 1948 to 1979. According to the estimation results, the relationship between a change of price and a change of cost is statistically significantly positive, but smaller than one in all but one industries. Hence, the markup over marginal cost decreases in response to an increase in the marginal cost. In this specification the cyclic development of the price in each industry is captured by its relationship to the growth of the aggregate demand. The estimated coefficient of the growth rate of aggregate demand is statistically significantly negative in five and positive in two industries.

To determine the effect of industry concentration, the sample is split in a group of 11 high- and 10 low-concentration industries according to their four-firm concentration ratios. The coefficient of demand growth is now negative and larger in absolute value for the high- than for the low-concentration subsample (-0.34 and -0.01, respectively). Therefore, an increase in the aggregate demand results in a decrease in the price that is stronger if the industry is more concentrated. If one is willing to overlook the fact that *Rotemberg, Saloner* derive the effect of the current demand level on the collusive price, whereas the authors consider demand growth, the results of the estimation may be taken as evidence in favor of their theoretical model. However, if interpreted along these lines, the empirical results imply that collusion is more difficult in concentrated industries. This conclusion however is counterintuitive and, more importantly, contradictory both to previous empirical findings and the results of the theoretical literature. The model by *Haltiwanger, Harrington* is closer to the econometric specification. However, their conclusion that collusion is facilitated by demand growth stands in contrast to the empirical evidence. The only theoretical model that gives rise to low prices in times of rising demand is *Bagwell, Staiger's* (1997) analysis of a market with stochastic

changes between high and low growth of demand. Since booms are most likely followed by recessions if the demand development is negatively correlated, the resulting small possibilities of punishment indeed require price cuts in periods of rising demand to make collusion viable.

The work by *Nishimura et al.* (1999) offers a more promising assessment of theories of collusion since it relies on disaggregated data. The empirical model accounts for dissimilarities between the firms that are caused by differences in the managers' abilities and in the costs of adjustments of the production process. The authors use the identity of the short-run elasticity of output to the inputs that is calculated from the production function to the one calculated from definition of production cost. Thereby they assume that the input markets are perfectly competitive. Hence, the factors are paid by their marginal products. Further, they assume that the firm-specific markup depends on the market conditions that are proxied by the firm's net cash flow in relation to its asset value. In contrast to *Hall's* method, the technology parameter of the production function is taken as given. The markup estimation is therefore independent from technological change and from characteristics of demand.⁷ The approach requires relatively few information on factor shares, output levels, the capital stock that proxies a firm's scale of operation and a proxy of the market condition. Notably, it avoids the use of cost and price data. The model is estimated on panel data for 1276 large Japanese firms in the period from 1971 to 1994. The results of the estimation indicate that the effect of fixed costs for the adjustment of the production capacities and the levels of the firm-specific markups indeed differ across the firms, whereas the effect of managerial ability and the sensitivity of the markup of a firm to the market conditions is identical within an industry. Since we are interested in the markup development, the finding that the price reaction to a change in the market conditions is the same for the firms of an industry is the most important conclusion from the analysis. It demonstrates that industry-specific effects affect the firms within an industry in the same manner as it is implicitly assumed in the models of collusion in oligopolies. Furthermore, the estimated markups are moderate. In 13 of 21 industries, the estimates differ more within than across the industries. Using the firm-specific market conditions as a proxy for the industry-wide situation, *Nishimura et al.* also draw conclusions on the cyclicity of the markup movement over time. As the relationship between the market conditions and the markup is statistically significantly positive for all industries except for "Other Manufacturing", they conclude that markups are strongly procyclical in Japanese industries. However, changes in the proxy of the market conditions, i.e. a firm's net cash flow in relation to its asset value, are not necessarily caused by changes in the market demand. It is therefore difficult to compare the finding of a procyclical markup with the develop-

⁷ Instrument variable estimation accounts for a possible correlation between explanatory variables that might be caused by transitory productivity shocks.

ment of the markup that is predicted by theoretical models of collusion in the presence of demand fluctuations.

Critique of these Methods

This short survey of some examples from the extant literature on the cyclic development of markups and its determinants demonstrates the variety of approaches used in these analyses. As far as they aim to assess the predictive power of the different theories on collusion in oligopolies, all of them are to some extent open to criticism.

The above description of competition by a conjectural-variations model is open to fundamental criticism. From a theoretical perspective, the approach is not justified since the rivals cannot react to each others' choices in one-shot competition. Therefore, it is irrational to hold beliefs about the relationship between the own and a competitor's quantity as it is implied by the conjectural derivative (3.3). The modern interpretation of the *Cournot* model is consistent only with the expectation of no reaction, $\lambda_i = \lambda_j = 0$. Nevertheless, the "dynamic" extension is widely used in the empirical studies of market power in oligopolies. Aside from the problem of identification that arises in simultaneous-equation models, the estimation requires a comparatively large amount of data. As is shown by *Hyde, Perloff* (1995), the estimation results of the conjectural-variations model are very sensitive to specification errors. Therefore, the market power is misrepresented unless all equations are correctly specified. However, in contrast to alternative econometric models that test only for the existence of market power, the conjectural derivative or a related parameter of conduct offers a direct measure of its extent.

In addition, a part of the studies relies on the *New Empirical Industrial Organization* (NEIO) approach to avoid the use of cost data. The authors estimate the parameters of the cost function and the conduct parameter simultaneously from the supply relation. The cost data from financial statements may be distorted away from the true economic costs due to accounting standards on the treatment of depreciation and to incentives generated by tax laws. The estimation of the cost function within the conjectural-variations approach however introduces another source of potential misspecification. *Genesove, Mullin* (1998) analyze data from the sugar-refining industry and demonstrate that the use of cost information indeed improves the predictive power, but the difference between the predictions of the different variants of the estimation are small. *Corts* (1999) raises attention to the fact that the NEIO-conjectural-variations parameter may be a poor predictor of market power if the firms collude imperfectly and coordinate on an equilibrium between the *Nash*- and the monopoly solution. He considers a duopoly with linear demand and constant marginal cost and estimates the cost parameters as a part of the supply relation. The stochastic development of demand and cost is described by discrete random variables. The demand shock follows a *Markov* process and may be to a greater or lesser extent permanent. The cost shocks

are assumed to be uniformly and identically, independently distributed. Simulation results for different parameters of the stochastic process of demand development demonstrate that a specific estimate of the conduct parameter is consistent with different values in the true model depending on the degree of the persistence of the demand shock. Therefore, changes in the conjectural-variations parameter over time are not necessarily caused by more or less competitive behavior of the firms in the product market, but might as well arise from changes in the structure of the stochastic demand development. *Corts'* analysis hence uncovers another potential source of misspecification in the NEIO framework that arises if the econometrician misjudges the demand conditions in the market. In this sense, it confirms *Hyde, Perloff's* (1995) finding that the predictive power of the conjectural-variations approach is indeed very susceptible to specification errors.

As they show, a similar criticism applies to *Hall's* method that critically depends on the assumption of constant returns to scale. Moreover, the extent of market power cannot be assessed from the estimated values of the markup unless additional information on the market, as for example the price elasticity of demand, can be obtained. In addition, *Hyde, Perloff's* comparative study casts some doubt on the reliability of the estimated results. In the simulation study summarized in their Table II, the method fails to reject the hypotheses of competition in almost all cases where the error is large. Moreover, in an analysis of twelve U.S. markets of tobacco, beverages and food products, the results from the instrument test partly depend on the instrument used. Only few of the estimates are statistically significantly different from zero at the 5% level (two for the oil price and three for the M1 money supply as instruments, respectively). Further, the results are not fully consistent with the values of the markup gained from the estimation. Therefore, *Hyde, Perloff* conclude that the method is indeed very sensitive to deviations from constant returns to scale. In comparison to the estimation of the structural model however, *Hall's* method requires a smaller amount of data.

Aside from these methodological considerations, it is highly doubtful whether the existence and extent of market power in oligopolies can be assessed by the analysis of highly aggregated data. The one- or two-digit SIC industries consist of numerous markets for diverse goods with very different numbers of participants. The industry No. 26 "Paper and Allied Products" for example that is considered by *Hall* comprises seventeen four-digit industries that produce goods as dissimilar as No. 2653 "Corrugated and Solid Fiber Boxes", No. 2676 "Sanitary Paper Products" and No. 2677 "Envelops" to name just a few. The latter, four-digit classifications are much closer approximations of economic markets that allow for conclusions on competitive and collusive strategies. This criticism also applies to several other studies that build on *Hall's* approach.

Given the sensitivity of the estimation approaches to violations of the underlying assumptions the value of their application to aggregated data seems all the more doubtful. Across a number of markets that constitute a composite

aggregate “industry” the conditions are most likely dissimilar. The conclusions with respect to the collusive or competitive strategies of the firms are hence of limited reliability. Furthermore, it seems rather unlikely that the assumptions of a particular theoretical model are fulfilled in all of these markets. Therefore, the estimated conduct parameter most likely misrepresents the extent of market power in many of the disaggregate industries.

If the demand and cost equations are correctly specified, the estimated conduct parameter indicates the existence, and in the conjectural-variations model, also the extent of market power and collusion. However, it remains to explain how the firms achieve the inferred extent of collusion. Unfortunately, the econometric models proposed so far are unable to discriminate precisely between the different theoretical models of collusion. Often, periods of aggressive competition may be interpreted in different ways. In the case of demand uncertainty, firms may react to low demand with some periods of competitive behavior to maintain the incentive to abide by the implicit agreement. Alternatively, the apparent *price war* might be an adjustment to observable demand fluctuations that require less intense collusion in a period of high demand to offset the incentive to defect. The distinction of different collusive behavior is even more difficult if the two-phased optimal penal code by *Abreu* (1986) is taken into account (*Briggs* 1996). Then, a close analysis of the price wars is required to determine whether the reversionary phase indeed ends after the predetermined number of periods as proposed by *Green, Porter* or because the price reaches a second critical value that ends a reversion as in the extension to optimal punishments by *Abreu et al.* (1986). Furthermore, the small number and limited duration of price wars might even preclude an econometric analysis. Therefore, a particular empirical framework can often be interpreted as an implementation of the *Porter* (1983a) *Green, Porter* (1984)-demand uncertainty model as well as of the models of observable demand fluctuations by *Rotemberg, Saloner* (1986), *Haltiwanger, Harrington* (1991) or *Bagwell, Staiger*. This ambiguity is a problem since these theories predict a very different development of collusive prices and outputs over time that depends on the details of the demand pattern. The different descriptions of the *Joint Executive Committee* in the studies by *Porter* (1983b), *Ellison* (1994), *Briggs* (1996) and *Vasconcelos* (2004) provide examples of this equivocality of the empirical research on collusion. Only the main finding of procyclical pricing is robust across these analyses, whereas the conclusions on the underlying reasons for the observed behavior differ.

Aside from the problems of specification, a further reason for the very different predictions of the empirical studies on collusion may be the negligence of strategic decisions that may increase or decrease the scope of collusion in the product market. Therefore, these long-term investments affect the restrictiveness of a collusive agreement as well as the cyclicity of the markup.

3.2 Long-Term Competition with Strategic Decisions

To complement our survey of the theoretical literature on long-term strategic competition we also provide a summary of the results that are reported in the empirical literature so far. To keep the present work well focused and concise, we concentrate on the examples of the most prevalent long-run decisions that will be discussed in detail in the subsequent theoretical analysis.

3.2.1 Investment in Physical Capital

Judging by the empirical work, it seems to be much easier to distinguish theoretically between the initial decision on capacity and the replacement investments that are made to keep the capital stock in good working condition and the production process efficient. In the empirical literature, investments in physical capital are often treated summarily as capacity choices.

Brander, Zhang (1993) and *Röller, Sickles* (2000) consider competition in the airline industry. In contrast to the former, *Röller, Sickles* explicitly account for the strategic effect of capacity choices in their analysis of the European market for passenger flights. The study is based on detailed data on the fleet characteristics, as the number of aircraft, aircraft size and age and the expenditures on the fleet. The latter most likely include significant replacement investments. The empirical analysis implements a two-stage capacity-price game in the line of *Kreps, Scheinkman* (1983) where the firms' competitive strategy is assumed to remain unchanged over time. Since the estimated markup is 13% higher than the one that corresponds to *Nash* competition there is some collusion in the market. Furthermore, the estimation results demonstrate that capacity has a negative strategic effect on the rivals' profit which is consistent with a *puppy dog* strategy of non-aggressive underinvestment.⁸ In one-shot competition, this accommodating strategy is optimal if the firms share the market and do not aim to squeeze out rivals. The authors compare the estimates for capacity-price competition with estimates for a single-stage basic game that does not account for capacity choices and conclude that the single-stage specification overstates the market power of the firms. Therefore, *Röller, Sickles's* analysis documents that the market result depends in a decisive way on the firms' long-term business strategies that are chosen in addition to price or quantity.

The small degree of market power can also be explained by capacity-constrained collusion in repeated interaction. The airlines' load factors between 53.5 and 72.7% imply unused capacities of 46.5 to 27.3%. These excess capacities might have been insufficient for profitable defection even if the potential punishment might have been lower than in the case of unlimited

⁸ Repeated reinvestment in the capital stock is also an aggressive strategy that reduces the rivals' profits. Therefore, this finding cannot be used to distinguish capacity choices from reinvestments.

capacities as well.⁹ However, this study tests a two-stage model of strategic competition and does not explicitly account for the possibility of anticompetitive coordination of product market strategies. *Brander, Zhang* (1993), in contrast, test supergame models of collusion using data for flight connections between Chicago and other U.S. cities. They describe changes between periods of more and less intense collusion by a regime switching model. Although the prices were regularly lower in the second and third quarters of a year, the authors do not consider the possibility of seasonal demand changes, but model demand fluctuations as a result of independently, identically distributed stochastic shocks. Moreover, they abstract from the possible use of *stick and carrot* punishment strategies that might be an alternative explanation of changes between periods of high and low prices. The assumed constancy of marginal costs per passenger-mile is an other source of misspecification since it implies unlimited capacities or operation far below the capacity limit. The estimated conduct parameter in periods of collusion is similar to the value reported by *Röller, Sickles* for the European market for passenger flights. In sum, the studies provide evidence of some market power in the U.S. and European airline industries but do not allow to discriminate between the different theoretical explanations of the strategic use of capacity in competition and collusion.

An empirical analysis of competition between firms that make investments in physical capital is presented by *Galeotti, Schiantarelli* (1998). It is closely related to our theoretical framework since the authors assume that firms invest to adjust their physical capital.¹⁰ The estimated markups and thus the extent of market power differs between the nineteen U.S. two-digit industries under consideration. Furthermore, the econometric specification allows for both level and slope effects of demand fluctuations. The authors estimate the effect of the current demand level and the expected future demand on the scope of collusion that is proxied by the markup over marginal costs. In the sample, the markup decreases in the current demand level and increases in future expected demand. Hence, the empirical evidence supports the theoretical conclusions by *Rotemberg, Saloner* and *Haltiwanger, Harrington*. Their robustness to the integration of repeated investments in the capital stock is demonstrated by our theoretical analysis in Chapter 5 below.¹¹ It shows that the markup changes anticyclically over time if the level effect of demand dom-

⁹ *Evans, Kessides* (1994) also analyze the airline industry and demonstrate that multimarket contact may be an alternative explanation for profits that are higher than in the *Nash* equilibrium.

¹⁰ Since time is continuous in their model, it is technically similar to differential game.

¹¹ *Morrison* (1993, 1994) uses a similar production theoretic approach with capital adjustment to explain the markup fluctuations in U.S. and Canadian industries. Since she assumes monopolistic competition, there is no scope for strategic interaction between the firms. The model is hence unsuitable as a description of repeated oligopolistic interaction.

inates, but procyclically if the slope effect dominates as it is predicted by the models without investments. *Chirinko, Fazzari* (1994) analyze data on eleven U.S. four-digit industries. As *Galeotti, Schiantarelli*, they account for the adjustment of the physical capital and find significant differences across the industries with respect to the degree of market power. However, according to their estimation results, the capital investments do not affect the markups. *Chirinko, Fazzari* use changes in the output levels of the industry instead of data on the production levels to estimate the effect of demand fluctuations on competition. They find a positive relationship between markups measured by the *Lerner* index and demand growth in seven and a negative link in only one of the industries. (The parameters for the other three industries are not statistically significant.) Their analysis is hence largely consistent with a positive slope effect of demand and confirms our theoretical result on the regular replacement of production equipment in markets with cyclic demand fluctuations.

In short, the few empirical studies of market power of firms that repeatedly invest in physical capital demonstrate the robustness of the results by *Rotemberg, Saloner* and *Haltiwanger, Harrington* to the integration of capital investments.

3.2.2 Financing

The empirical evidence on the effect of leverage on the price level and profits to date is sparse and inconclusive. *Phillips* (1995) for example analyzes four highly concentrated industries where the largest competitors significantly increased their leverage, namely the U.S. fiberglass, polyethylene, tractor trailer and gypsum industries. In all but the last one, an increase in outside capital led to a higher market price and a contraction of quantities, often by closing facilities. In the gypsum industry, the interrelation between debt and market performance is reversed, probably due to low average leverage and low entry barriers. The fiberglass, polyethylene and tractor trailer industries in contrast are both highly leveraged and protected by considerable barriers to entry. The poorer market performance after recapitalization in these three industries is consistent with *Showalter's* (1995) model of limited liability in price competition, whereas the improved performance in the gypsum industry is in line with *Brander, Lewis's* (1986) analysis of quantity competition as well as with *Maksimovic's* (1988) model of collusion between leveraged firms.

Several other contributions are also concerned with the effect of debt on product market competition. *Chevalier* (1995a,b) reports a positive relationship between price and debt in a study of recapitalizations in the supermarket industry. In particular, prices were higher after a leveraged buyout in markets where competitors also held high amounts of outside capital. Based on these findings she concludes that the evidence from the supermarket retailing contradicts *Brander, Lewis's* prediction that debt toughens competition. It is however consistent with *Showalter's* model of softer price competition

among leveraged firms. Price not quantity setting however seems to be the appropriate description of competition between supermarkets. Thus, the evidence provided by *Chevalier* does not disprove the two-stage models of the limited-liability effect on product market competition. *Showalter* (1999) tests his theoretical model on U.S. data on 1641 firms from two-digit manufacturing industries. His study supports the theory that demand uncertainty makes debt holding as a strategic commitment device in price competition more attractive, whereas it reduces profitability in the case of cost uncertainty. In his sample, the firms' reliance on outside capital indeed increases in the volatility of demand and decreases in the volatility of cost. In contrast to the theoretical prediction of a higher expected profit of a leveraged firm in price competition however, the relationship between debt and profitability in the estimation is negative.

Chevalier, Scharfstein (1995) analyze the joint effect of leverage and demand fluctuations on competition. Based on data on 20 two-digit manufacturing industries, they report that debt softens competition during recessions and gives rise to anticyclical pricing. Their analysis of supermarket retailing yields the same negative relationship between indebtedness and market performance (*Chevalier, Scharfstein* 1996). The authors conclude that higher prices are attractive in recessions if the probability of bankruptcy is high. Then, the future is less important to highly leveraged firms because their expected profit from future sales to a large customer base is smaller. Consequently, the competitors' inclination to set low prices initially to attract customers is lower if they are highly indebted. Since bankruptcy is more likely in times of slack demand, a recession further reduces the incentive to build a large customer base by making introductory offers. Thus, the anticyclicity of pricing increases in leverage. However, this pricing is also optimal in a market with stochastic demand shocks if the firms face a certain risk of bankruptcy. To offset the high gain from defection the participants make the implicit agreement viable by lowering the collusive price if demand is currently high. Reliance on outside funds reduces the incentive to collude because the probability to receive future profits is decreased by the risk of insolvency. Therefore, the price cuts in booms are more pronounced the higher the leverage is. The limited-liability effect of debt hence magnifies the anticyclicity of pricing in markets with uncorrelated shocks on demand (*Rotemberg, Saloner* 1986, *Stenbacka* 1994).

Interestingly, the impact of the development of demand can be negligible if the empirical model additionally accounts for the decision to defect and start a price war. This is shown by *Busse* (2002) who tests the hypothesis that firms with high financial obligations are more likely to initiate price wars on data of the U.S. passenger flight market. The individual episodes of tough price competition are identified by evaluating reports in the business press. With respect to the effect of demand fluctuations the conclusions are mixed: Price wars are more likely if the total number of sold seats is low, but also if enplanements on the firm level are high. However, demand changes have no statistically significant effect on the decision to initiate a price war. The

empirical results suggest that a firm is more likely to start a price war if it strongly relies on outside capital and still more if it is highly leveraged compared to its competitors. This finding supports the theoretical analyses that show the anticollusive effect of asymmetries between the firms. Furthermore, it can be interpreted as a confirmation of a negative impact of outside capital on the viability of collusion that is derived by *Maksimovic* (1988) in his model of bond finance. Since equityholders do not longer receive profits in the event of insolvency, they value present profits more the higher their financial obligations and hence the probability of bankruptcy are. Consequently, the scope of collusion is smaller, the higher the leverage is. However, in this interpretation the price wars are not due to a breakdown of the implicit agreement, but to an adjustment to an increase in outside funds. However, it is difficult to relate the empirical findings on the competitive behavior of the airlines to the models of collusion between leveraged firms since *Busse* (2002) does not provide evidence on the decision to end a price war.

Lord, Farr (2003) in turn provide evidence in favor of *Maksimovic's* (1988) conclusion that leveraged firms may strategically increase the viability of collusion by issuing convertible debt. Using data on the U.S. steel market, they show that after the demise of basing point pricing in 1959 the participants implicitly agreed to retain this price scheme. Furthermore, the firms changed their capital structure after the end of the formal system of price fixing and took more outside capital. Since they raised funds predominantly by issuing convertibles, it is likely that the adjustment of the debt-equity ratio was used to facilitate the implicit continuation of the price agreement. Moreover, *Lord, Farr* argue that the firms chose their capital structure to signal their willingness to participate in collusion.

In sum however, the applied work on the interrelation of financing decisions and product market competition is inconclusive. The findings of these studies may be interpreted as support for one or several of the theories on the competitive effects of outside capital, but the econometric models proposed so far can not discriminate precisely between the different explanations. Most often they are unsuitable to exclude competing alternatives. To date, the empirical findings are robust only in so far, as they provide overwhelming evidence for the linkage between financial decisions and product market competition.

3.2.3 Management Compensation

Although there are countless empirical studies on management compensation, there is hardly any evidence on the effect of incentive schemes on product market competition. Except for the work by *Aggarwal, Samwick* (1999) and *Joh* (1999) on incentive compensation that depends on the relative performance of a manager, the econometric models are concerned with the incentive effect or the pay-performance relation of different types of compensation.

Joh (1999) considers a case of relative performance evaluation where a manager's compensation is tied to industry profit. In her sample of Japanese

firms during the period from 1968 to 1992, management compensation has a positive effect on industry profit. Based on this finding, she concludes that the sustainability of collusion increases when compensation is positively linked to performance. However, since the econometric analysis does not discriminate between different types of compensation, the positive link between management compensation and profits may also stem from stock-based compensation components.

A closely related study of relative performance evaluation by *Aggarwal, Samwick* (1999) yields similar results. The authors consider a model of one-shot competition in the tradition of the literature on strategic delegation that ranges from *Vickers* (1985) to *Miller, Pazgal* (2002). The prediction of the theoretical model is tested using U.S. data on the compensation and the stock-market value of firms from the manufacturing industries during the period from 1992 to 1995. *Aggarwal, Samwick* distinguish short- and long-term incentive payments. Short-term payments that are composed of salary, bonuses and other perquisites. Long-term components make up about half of the total remuneration and predominantly consist of unrestricted stock options. A smaller part is made up of grants of restricted stock and of long-term incentive plan payouts. Severance payments and contributions to benefit payments also fall into this category, but do not account for a significant part. In the empirical part of their analysis, *Aggarwal, Samwick* estimate the sensitivity of the managers' short-term and long-term compensation payments to the own firm's and the rival firms' performance. The link between a manager's compensation and its rival's performance is positive in most specifications. (The same is true for the own firm's performance, as could be expected.) This effect is more pronounced for total than for short-term payments alone suggesting a overproportionate impact of long-term components, namely stock grants and stock options.

In the opinion of the author, the empirical variables describe the parameters of the relative-performance incentive contract only imprecisely. The sensitivity of the remuneration to a measure of the own and the competitors' profits is therefore not necessarily due to incentive compensation that depends on a firm's relative performance. As a consequence, the empirical studies published so far are not able to discriminate between the different theoretical models that predict higher firm profits and thus higher markups. The theoretical analyses however propose very different underlying relationships between compensation and performance. In models of one-shot competition and strategic delegation to managers with a linear contract (e.g. *Fershtman, Judd* 1987, *Sklivas* 1987 and *Aggarwal, Samwick* 1999, *Miller, Pazgal* 2001, *Miller, Pazgal* 2002), the firms are highly profitable only if they compete in strategic complements, whereas in repeated competition between managers with a linear-contract considered by *Lambertini, Trombetta* (2002), high profits are due to collusion between managers or coordination of their compensation schemes by the firms' owners.

The above review of empirical work on long-term competition in oligopolies yields few univocal results. The conclusions with respect to the pro- or countercyclicality of the markup in contrast differ widely. There are studies that indeed find an anticyclical development of markups over time and confirm that is more difficult to maintain an implicit agreement during a boom. Others however find evidence of procyclical markup development, that is interpreted as response to a cyclical decline in demand. Often the cyclic development differs between a number of manufacturing branches even if the same empirical method is used in the analyses.

These wide discrepancies in the predictions of the econometric models may be due to the technical problems of implementation and specification discussed above. Yet it might also reflect differences in the market conditions as for example in the observability of demand and pricing, scale economies and capacities. Moreover, an other reason for these disaccords in the empirical studies of collusion may be the negligence of long-run decisions that may increase or decrease the scope of collusion in the product market and the fact that their impact depends on other market characteristics. The number of studies on the effect of long-run decisions on competition however is sparse. Furthermore, the econometric models are often only loosely related to the theoretical models and do not offer a reliable test that might support or reject a certain explanation of collusive behavior.

However, several robust results emerge from the empirical studies on long-term oligopolistic competition: Firstly, the procollusive effect of product homogeneity and market concentration is a robust finding of the descriptive and the econometric work on anticompetitive agreements between horizontal competitors. Secondly, long-run decisions prove to be an important factor that determines the scope of collusion in a market. More importantly, their effect depends on other market conditions as for example the development of demand. Consequently, an assessment of the scope of collusion requires a thorough analysis that is based on a precise description of the market conditions. Therefore, the present work analyzes the scope of collusion in long-term oligopolistic competition in a theoretical framework that accounts for different types of demand development and allows to integrate different long-run decisions.

Competition with Fluctuating Demand

4.1 Product Market

In oligopolistic markets firms typically compete over a long time span with the same rivals and have neither a plan to exit from competition at a certain point in time nor do they know when the market will disappear due to lack of demand. Throughout the exposition, we describe such a market by assuming that competition takes place over an infinite number of periods. In every period, the firms produce the good with constant unit costs c and zero fix costs. The profit functions are concave and twice continuously differentiable. The demand function is continuous, bounded from above and falling in the price. Further, we assume that the price rises in the demand level. Thus, a higher demand level implies a higher monopoly price, i.e. the demand function in periods of high demand is not extremely price elastic. The value of future profits is identical for all market participants. It is determined by the market discount factor δ that is *common knowledge*. Moreover, we assume that the price as well as the current realization of demand for the good are observable by all market participants. Such an infinitely repeated game can also be interpreted as a model of finitely repeated competition with uncertain end (cf. *Tirole* 1988, 253). In this case, the firms' valuation of future profits accounts for the uncertainty of continuation of the competition. The competitors then use the probability of the continuation of the competition θ and the market discount factor to determine the present value of future profits, i.e. $\delta_{\text{effective}} = \theta\delta$. The assumption of an infinite time horizon is hence a convenient simplification that is not as restrictive as it might seem at first glance.

The assumptions that we stated so far apply to all variants of the model developed below. To illustrate the effects of strategic decisions and demand fluctuations on the market results in the simplest possible framework, we use a *Cournot* duopoly with linear demand throughout. The inverse demand for the homogeneous good is given by

$$p(Q) = a_t - q_i - q_j, \quad a_t > c \tag{4.1}$$

where p is the market price, a_t the current size of the market in period t , Q is the market output, q_i is the individual quantity produced by firm i and c is the constant marginal cost, which is identical for both firms. Beyond its analytical clarity, this setup carries the advantage that the strategic effect is most pronounced in a duopolistic market.

Possible extensions to markets for a differentiated product or more general demand functions will be discussed additionally to explore the applicability as well as the limits of the present framework. The sensitivity of the results to the number of firms and the size of the market is especially important for the assessment of market power in markets with changing demand. We will discuss these factors separately in order to clearly distinguish their impact on the viability of collusion. Since the effects do not depend on the type of demand fluctuations, we postpone the detailed analysis until we derived the firms' collusive strategies for the three demand patterns. In the subsequent chapters, we will reconsider these factors only where the robustness of the present results to the integration of long-run business decisions is not obvious.

In long-term interaction, firms have an incentive to restrain competition by implicitly agreeing to choose product market strategies that maximize their joint profits. If they compete in price, they will participate in such perfect collusion by setting the monopoly price. In the case of quantity competition, they will produce their share of the monopoly output. In a market for a differentiated product, the firms jointly act as a multiproduct monopolist in both cases. Such perfect collusion by joint monopolization of the market however is only possible if firms place a high value on future profits. Otherwise, the high one-shot gain from cheating on the trustful competitors who abide by the agreement creates a forceful incentive for a firm to deviate. In order to maximize their joint profits the firms will thus set either the lowest quantity or the highest price that just not destabilizes collusion given their low valuation of future profits. By reducing the price or expanding their output they decrease the current profit and therefore also the one-shot gain from defection just as much as is necessary to make the implicit agreement viable. Technically speaking, we assume that firms coordinate on the *Pareto*-frontier by choosing the equilibrium that yields the highest profit. Such an implicit agreement solves the problem of which price or quantity to set in the continuum of possible solutions of such a supgame that ranges from the *Nash* to the most restrictive collusive equilibrium. In a market with profit-maximizing firms, the *Pareto*-efficient solution is a plausible *focal point* (Schelling 1960) for the coordination of product market behavior because it offers the highest profits. The above assumptions guarantee the existence and uniqueness of the *Nash* and the collusive equilibrium.

If a participant deviates from the implicit agreement and produces a larger quantity or charges a lower price, he realizes an even higher profit compared to adherence to the agreement. Despite this temptation to cheat, the implicit agreement can be enforced because firms can credibly threaten to punish a deviator by playing the noncooperative *Nash* equilibrium forever. A deviation

is noticed immediately since it results in a higher market output and a lower price. If the market price of the good can be observed, but individual outputs are not known, the colluding firms can not determine which participant violated the agreement. It is hence impossible to punish only the defecting firm. In a duopoly, in contrast, the identity of the deviator is obvious. Individual punishment by setting the price or quantity outside the one-shot *Nash* equilibrium however is also excluded since it requires the participation of the violator in his own punishment.¹ Most likely, the firms will loose trust in the other participants after a violation of the implicit agreement. We describe this situation by the assumption of an unrelenting punishment that consists in the reversion to infinitely repeated *Nash* competition. Actually, a punishment is never carried out in equilibrium because the firms anticipate whether cheating will take place and participate in collusion only if it the resulting profits outweigh the incentive to deviate.

Since the threat of a harsh punishment facilitates collusion, shorter periods of more severe punishments could be used to implement an optimal punishment that yields higher collusive profits (cf. *Abreu* 1986). The proposed simpler collusive mechanism is attractive though since it requires no extensive negotiations or written arrangements. Thus, potential evidence of anticompetitive behavior is minimized or even avoided. The fact that the firms' strategies are identical in equilibrium is an additional appealing feature in a model of a symmetric market. From a technical point of view, the unrelenting punishment simplifies the analysis and yields qualitatively identical conclusions. By considering a grim *trigger strategy*, we hence abide by the precept of Ockham's razor and avoid complications that are not necessary to demonstrate the central results. In short, we analyze variants of *Friedman's* (1971) supergame to demonstrate the workings of collusion of long-term competition in markets with demand fluctuations without and with additional long-term decisions. In static models of competition in contrast, there is no second period where a firm could react on a rival's decision or demand could change. Therefore, the analysis of a kinked demand curve proposed by *Hall, Hitch* (1939) and *Sweezy* (1939) or the models of conjectural variations introduced by *Bowley* (1924) are not suited for the analysis of collusion or fluctuating demand.

The empirical evidence on pricing in markets with changing demand that is presented in Chapter 3 documents the decisive impact of demand fluctuations on firms' strategies. In order to predict the effect of strategic decisions that have commitment value on firms' short-run product market strategies and

¹ For an oligopoly, such an asymmetric punishment of the cheating firm alone is analyzed by *Farrell* (2000). This type of collusive agreement requires the cooperation of offender in his own punishment. The corresponding penalty code is quite complex and necessitates communication to coordinate on the required collusive behavior. Despite the fact that it offers higher profits it is less attractive in the presence of a vigilant antitrust authority since detection and prosecution of the anticompetitive agreement are more likely. Further, it is even more difficult to coordinate on a complicated collusive scheme by simple parallel behavior.

thus on market results it is therefore necessary to account for such changes in market demand.

In the following analysis we consider three alternative types of demand development over time to describe such fluctuations. A market with demand that does not change serves as the benchmark case. The subsequent introduction of uncorrelated, transitory shocks on the demand level offers a simple description of a time-varying demand. In many markets however the pattern is more complicated. Demand for a large number of consumer goods, as for example sporting equipment, transport, fuel and heating oil, or sugar used for preservation of fruits varies strongly according to the season. The empirical studies of price fluctuations discussed in Chapter 3 offer examples of markets with cyclic demand development. *Cook* (1999) takes a broader perspective and documents the strong cyclicity of the aggregate demand for durable consumption goods in the United States that is more pronounced than the fluctuations in the demand of non-durable goods. The changes of the demand for many capital goods that arises from sporadic reinvestments are another prime example for a recurring cyclic pattern (cf. *Cooper et al.* 1999 and the literature cited therein). In our theoretical analysis, we therefore also consider a market with demand cycles. If the demand for a good is subject to cyclical changes, future demand levels can be easily predicted. Hence, we assume that the demand development is known in advance to all market participants. As an extension, we also discuss the occurrence of uncorrelated stochastic shocks during a cycle. In this case, the demand fluctuations are due to a superimposition of independently, identically distributed shocks on the demand level and the underlying deterministic, cyclic trend. This modification allows for a stylized representation of a rather irregular pattern.

In the model we describe the development of demand level over time by the changes in the market size a_t , where the index t indicates the current period.² Therefore, the terms market size and demand level are used synonymously. In the benchmark case of unchanged demand, a_t remains constant over time. In the case of stochastic, transitory shocks, the realization of the demand level in each period is determined by an independent draw from the identical cumulative probability distribution, whereas in the case of recurring cyclic fluctuations, the market size a_t describes the development of the demand level during a single peaked cycle. As mentioned above, the current demand level a_t is observable at the beginning of every period.

In order to clearly distinguish the effects of different demand patterns on the strategies of the firms, we firstly analyze the cases of constant demand, uncorrelated stochastic shocks and recurring cyclic changes of demand sep-

² The model can also be reformulated in order to cover correlated fluctuations of costs. In this case $-a_t$ is interpreted as a parameter that reduces the unit costs. Then, a change of the parameter value has the same effect on the profit for both demand and cost fluctuations. Since the firms' inclination to collude and thus their product market strategies are determined by the size of per-period profits, the results of the proceeding analysis also hold for fluctuating unit costs.

arately. Secondly, we briefly discuss the simultaneous occurrence of the two latter types of demand development.

4.2 Constant Demand

The analysis of participation in an anticompetitive agreement in a market where demand is constant over time clarifies the basic working of implicit collusion. Furthermore, the resulting market behavior serves as a reference case for the comparison with the firms' strategies in markets where the demand level is subject to uncorrelated stochastic shocks or a recurrent cyclic development.

In the simplest case of a market with stable demand, the market size remains constant over time, $a_t = a = \text{const.} \forall t$. *Friedman* (1971) analyzes this basic case of tacit collusion between symmetric firms. We briefly review a part of his results that will serve as a benchmark for comparison with the three cases where firms take additional strategic decisions and compete in markets with alternative demand development.

In general, a firm takes part in an implicit agreement if the resulting discounted stream of current and future collusive profits is at least as large as the one-time gain from cheating and the profit stream in the ensuing infinite punishment phase. Due to the discounting of future profits it is never optimal to defer the unilateral defection from the agreement. So if a firm cheats, it does so in the present period. If market demand is constant, the implicit agreement is hence feasible if

$$\sum_{i=0}^{\infty} \delta^i \pi_A \geq \pi_D + \sum_{i=1}^{\infty} \delta^i \pi_N$$

holds, where π denotes the per-period profit of the firm. Index A stands for a collusive "agreement", D for "defection", and N for "*Nash*"-*Cournot* competition. If necessary we distinguish the case of perfect collusion by joint monopolization of the market by a bar on the index $\bar{A}$. Since the firms have to agree on the allocation of the roles if they use asymmetric strategies, these require more efforts of coordination. A symmetric solution avoids this problem. Therefore, we focus on symmetric collusive strategies that are also more plausible given the symmetry of the competitors. Hence, the firms' per-period profits are equal in the cases of collusion or *Nash* competition. Furthermore, the above condition for collusion applies to each firm.³ The reformulation of the preceding inequality demonstrates that the firms have an incentive to collude if the difference of these discounted additional profits gained by collusion compared to *Nash* competition and the additional profits gained by defection

$$V(\pi_A, \delta) \equiv \frac{\delta}{1 - \delta} (\pi_A - \pi_N) - \pi_D + \pi_A \geq 0 \quad (4.2)$$

³ In the following, a firm index is omitted where no information is lost.

is positive. Therefore, the inequality (4.2) states the condition for collusion that yields periodic profits π_A . The discounted additional profit stream from the participation in the collusive agreement, given by the first term on the right hand side above, increases in the discount factor δ . The additional profit from defection, $\pi_D - \pi_A$, is independent of δ . A firm's incentive to collude, $V(\pi_A, \delta)$, thus increases in its valuation of future profits. If it places a low value on future profits, corresponding to a low value of the discount factor, perfect collusion by joint monopolization of the market is impossible. Then, the firms must decrease the incentive to defect, given by the last two terms above. As the one-shot gain from cheating on an implicit agreement is smaller, the lower the current profit from collusion is, the firms then restrict competition to a lesser extent. In the case of quantity competition, the participants in the implicit agreement produce a larger output and realize a lower market price than in the monopoly equilibrium. In order to gain the highest possible profits from such imperfect collusion they set the smallest output that makes the implicit agreement viable. To the same end, they set the highest price that yields a nonnegative incentive to collude (4.2) and produce the corresponding quantity if they compete in prices instead.

In principle, per-period profits could also be reduced by agreeing on a collusive output that is even smaller than the share monopoly output or a collusive price above the monopoly price. Since an extreme output restriction or very high market price rises suspicion in the competition authorities, colluding firms will not use this strategy.

By solving for the threshold of the discount factor, that fulfills condition (4.2) with equality, we obtain

$$\delta \geq \delta_{\text{crit.}} \equiv \frac{\pi_D - \pi_A}{\pi_D - \pi_N} \quad (4.3)$$

as an alternative formulation of the condition for collusion that yields a periodic profit of π_A for each participant. It shows that a firm takes part in the implicit agreement if it values future profits more than is indicated by the threshold $\delta_{\text{crit.}}$. Since the level of collusive profits may be any amount between the *Nash*-competitive and the share of the monopoly profit, the condition (4.3) applies to all collusive equilibria between the *Nash* and the monopoly equilibrium and indicates the extent of "patience" $\delta_{\text{crit.}}$ that is necessary to maintain a certain agreement.

We denote the critical threshold of the discount factor for the special case of maximal restriction of competition by joint monopolization of the market (perfect collusion) by

$$\delta \geq \underline{\delta} \equiv \frac{\pi_D - \pi_A}{\pi_D - \pi_N}. \quad (4.4)$$

These considerations demonstrate that a firm's valuation of future profits measured by δ is a convenient indicator of its inclination to collude. *Ceteris paribus*, a higher value of future profits always increases the firms's incentive

to collude irrespective of the development of demand. This conclusion is especially important in the present context since the collusive potential of certain market conditions or of a strategic, long-term decision can be identified by evaluating its effect on the critical threshold for collusion $\underline{\delta}$.

So far we did not make use of any special assumptions on the market conditions. Hence the above conclusions apply to both quantity and price competition with a fairly general demand function irrespective of the extent of product differentiation. The following analysis of a *Cournot* duopoly with linear demand illustrates a firm's consideration whether to participate in an implicit agreement.

In this case, firms gain the maximal profit from the quota agreement by setting the market quantity that maximizes their joint market profits and does not violate the condition for collusion (4.3). They share the market profit by producing equal shares of the market output. Thus, they solve the following optimization problem

$$\max_Q \pi_i + \pi_j = (a - Q - c)Q \quad \text{s.t. } V(\pi_A, \delta) \geq 0. \quad (4.5)$$

If firms value future profits highly, $\delta \geq \underline{\delta}$, the condition for collusion does not bind. Then, perfect collusion is possible and the optimization problem simplifies to

$$\max_Q \pi_i + \pi_j = (a - Q - c)Q. \quad (4.6)$$

In the symmetric equilibrium each firm produces half of the monopoly output

$$q_A = (a - c)/4. \quad (4.7)$$

Thereby, it realizes a per-period profit

$$\pi_A = (a - c)^2/8, \quad (4.8)$$

i.e. each firm obtains an equal share of the monopoly profit.

If a firm violates this implicit agreement, it maximizes its individual profit, while the faithful rival continues to produce the collusive quantity q_A . The deviator solves the optimization problem

$$\max_{q_i} \pi_i = (a - q_i - q_A - c)q_i \quad (4.9)$$

by setting the quantity

$$q_D = 3(a - c)/8 \quad (4.10)$$

in response to the rival's collusive output and realizes a one-shot profit that amounts to

$$\pi_D = 9(a - c)^2/64. \quad (4.11)$$

The defection triggers the punishment by *Cournot* competition, where both firms maximize individual profits. The corresponding individual quantity solves

$$\max_{q_i} \pi_i = (a - q_i - q_j - c) q_i \quad (4.12)$$

By the first order condition

$$a - c - 2q_i - q_j = 0$$

the optimal quantity given the rival's output is given by

$$q_i = (a - c - q_j) / 2. \quad (4.13)$$

Therefore, each firm produces the equilibrium output

$$q_N = (a - c) / 3 \quad (4.14)$$

and gains the *Cournot* profit of

$$\pi_N = (a - c)^2 / 9. \quad (4.15)$$

The per-period profits in a *Cournot* duopoly in the cases of collusion, defection and competition (4.8), (4.11) and (4.15) determine the firms' incentive to participate in joint monopolization of the market. Inserting the per-period profits in the condition for perfect collusion (4.4) yields the critical lower bound of the values of the discount factor that are consistent with perfect collusion in the *Cournot* duopoly $\underline{\delta} = 9/17 \simeq 0.593$. If firms are at least as patient, and thus, $\delta \geq 9/17$ holds, they can tacitly agree to set any quota between the *Nash*-competitive and the joint-profit-maximizing level. Hence, $q_A \in [q_{\bar{A}}, q_N]$ are the possible collusive equilibria. Since the firms maximize their profits, they set the smallest collusive quantity that make the implicit agreement viable and realize the highest possible gain from collusion.

Note that the additional periodic gain from perfect collusion

$$\pi_{\bar{A}} - \pi_N = (a - c)^2 / 72 \quad (4.16)$$

and the additional one-shot profit from cheating

$$\pi_D - \pi_A = (a - c)^2 / 64 \quad (4.17)$$

increase in the market size. The firms' inclination to collude however is independent of the market size because the relative lower periodic gain from the implicit agreement is offset by the fact that it accrues to infinity, whereas the additional gain from deviating is realized only once. The critical threshold $\underline{\delta} = 9/17$ documents that the likeliness of perfect collusion is independent of the market size. The size of the market however determines the amount of discounted profits that a participant gains from the agreement.

If the firms value future profits less, i.e. if the discount factor is lower than $\underline{\delta} = 9/17$, they can sustain only imperfect collusion. As argued above, the competitors then increase production and reduce the per-period profit just

enough to make the agreement feasible by satisfying the condition (4.3). Each duopolist thus sets the collusive quantity that reduces the incentive to collude

$$V(\pi_A, \delta) = \frac{\delta}{1-\delta} \left[(a - 2q_A - c) q_A - \frac{(a-c)^2}{9} \right] - \frac{(a - q_A - c)^2}{4} + (a - 2q_A - c) q_A \quad (4.18)$$

to zero. The profit from defection, given by the last but one expression, is calculated using the best-reply (4.13) to the rival's collusive output. The quadratic equation has two roots. The first one is the *Cournot* quantity q_N that yields additional profits from collusion and defection that amount to zero. The second root is

$$q_A = \frac{(a-c)(9-5\delta)}{3(9-\delta)}. \quad (4.19)$$

The collusive output given by (4.19) is larger than the symmetric share of the monopoly output (4.7) for all values of the discount factor that correspond to imperfect collusion $\delta < 9/17$. Moreover, its derivative with respect to the discount factor δ

$$\frac{\partial q_A}{\partial \delta} = -\frac{12(a-c)}{(9-\delta)^2}$$

is negative. A colluding firm restricts its output and thereby competition to a greater extent if it places a high value on future profits. Thus, this consideration is another way to demonstrate that the scope for collusion increases in the firms' valuation of future profits. The incentive to collude (4.2) shows that this relationship is also valid in the general oligopoly case discussed above.

The following numerical example further illustrates the working of collusion and provides a benchmark for the comparison with the collusive strategy in markets with demand fluctuations.

Consider a market of the constant size $a = 1$, unit cost of $c = 0.5$ and a value of the discount factor of $\delta = 0.25$ that certainly excludes joint monopolization. By (4.19), the collusive output $q_A = 0.148$ maximizes the gain from imperfect collusion.⁴ It results in the market price $p_A = 0.704$. (Due to rounding the incentive to collude is still positive, but very small. It amounts to $V(0.030, 0.25) = 0.207 \cdot 10^{-4}$.) The periodic profit from the production of $q_A = 0.148$ amounts to $\pi_A = 0.030$. Thus, imperfect collusion is indeed preferable to *Cournot* competition that yields the profit $\pi_N = 0.028$ per period, but much less profitable than perfect collusion that offers a periodic profit of $\pi_A = 0.125$.

Needless to say that both in the general oligopoly market discussed first and in the *Cournot* duopoly just analyzed, the market price is constant

⁴ The first root $q_N = 0.167$ is the *Cournot* output.

over time at the level that is determined by the firms' incentive to collude. The corresponding prices for the *Cournot* duopoly $p_{\bar{A}} = (a + c)/2$ and $p_N = (a + 2c)/3$ are easily calculated by inserting the equilibrium quantities (4.7) and (4.14) in the inverse demand function (4.1). Therefore, the price can be used as an indicator of market power only if the market conditions are known. Especially with respect to the unit costs, however, this requirement is unlikely to be met because firms are usually very reluctant to disclose their production costs. In the case of an antitrust investigation a firm might even deliberately misrepresent its cost condition in a way that an econometric analysis indicates low market power (*Philps* 1995, Chap. 8). In a market with fluctuating demand, the price will prove to be a meaningful indicator of the scope of collusion in the product market because its development over time depends on the firms' inclination to collude. The only informational requirement then is the constancy of marginal cost, whereas its level needs not be known.

The preceding analysis demonstrates that repeated interaction enables the firms to conclude self-enforcing anticompetitive agreements.

Integration of demand fluctuations in this framework provides further insights into collusive market behavior. To avoid an overtly technical exposition and tedious repetitions, we slightly abuse the terminology. In the case of uncorrelated shocks, we use the word "boom" to describe periods with a high demand level, and "recession" for periods of low demand. In the analysis of demand cycle a "boom" period is characterized by an even higher demand level in the following period, whereas in a "recessionary" period demand will be lower in the subsequent period. In short, the phase of the cycle where demand rises is called a "boom", the phase of falling demand a "recession". This description is used although the terms "boom" and "recession" are usually applied to describe the development of the gross national product, i.e. the development of the aggregate demand level, but not of the demand in individual markets. Moreover, we will use the same notation δ for the critical threshold of the discount factors that correspond to perfect collusion although the precise values differ depending on the details of the demand development. Progressing from the simpler to the more complex pattern, we will first consider a periodic, uncorrelated stochastic shocks on the demand levels.

4.3 Demand Shocks

Following *Rotemberg, Saloner* (1986), we assume that the demand level is subject to a stochastic shock that yields a market demand level $a_t \in [\underline{a}, \bar{a}]$, $\underline{a} > 0$. Thus, the market size is a random variable with the realization a_t in each period t . The realizations in the different periods are independent and identically distributed (*i.i.d.*) according to the density function $f(a)$ with the cumulative distribution function $F(a)$. This assumption also implies that each shock is transitory and affects only the market size of the current period. The main

difference to the model proposed by *Rotemberg, Saloner* (1986) consists in the fact that in the original formulation per-period profits are zero in the punishment phase since the firms compete in prices. In the case of *Cournot*-quantity competition, in contrast, punishment profits are positive. The latter fact was shown above for a duopoly, but is also true for any number of firms in the market. The results of this section thus confirm *Martin's* (2002, 321) conjecture that the conclusions also hold for price and quantity competition between producers of a horizontally differentiated good.⁵

The uncertainty about the future demand affects a firm's inclination to collude in addition to the value of future profits that is determined by the discount factor. The latter effect was derived in the previous section. Hence, we now focus on the realization of the market size. Since the current profit increases in demand, a firm gains a high additional profit by defection from the collusive agreement if the realization of the shock is high. The future demand however is independent of the current level because the shock realizations are uncorrelated across the periods. Therefore, the discounted stream of additional profits from participation in collusion is independent of the current realization of the demand shock. If demand is currently strong, the temptation to defect is large and makes collusion difficult. Consequently, continual monopolization of the market is possible only if the realization of the market size is rather low. Then, an adjustment of the implicit agreement is not necessary and the price mirrors the development of demand exactly: The higher the current level of demand the higher are the monopoly price and quantity. However, since the additional gain from defection from the agreement rises in the demand level, there is a critical upper bound of the market size $\tilde{a}$ where monopoly profits are no longer sustainable because the incentive to cheat is too large. If perfect collusion is not feasible for the whole range of shock realizations, the firms agree on a highest price or lowest production quota that makes the implicit agreement viable given any currently observed high level of demand. To cover perfect and imperfect collusion in our analysis we assume that perfect collusion is possible for the lowest level of demand $\underline{a}$, but not for the highest $\tilde{a}$. Then, the firms have to agree on the collusive quantity conditionally upon the current market size to prevent a breakdown of their implicit agreement in periods of high demand.

We demonstrate the effect of the *i.i.d.* shocks on the demand level both in the general setting and in the *Cournot* duopoly introduced before. Note, however that the basic working of collusion in a market with fluctuating demand depends neither on the number of market participants nor on the decision variable of the firms. Thus, the theoretical analysis that is carried out below also applies to oligopolies with price or quantity competition and a general demand function for a differentiated good. Only the levels per-period profits have to be changed to account for the generalization. As a consequence, an-

⁵ To the best of our knowledge, the framework of *Rotemberg, Saloner* (1986) was never generalized to the case of product differentiation before.

other critical threshold of the shock realization results, but the conclusions continue to hold qualitatively.

In a market with demand shocks, the firms' basic consideration remains unchanged: Again, they participate in collusion if the resulting discounted profits are higher than those gained by cheating and the subsequent infinite punishment phase. The incentive to collude $V(\pi_A, a_t, \delta)$ now depends not only on firms' valuation of future profits δ , but also on the current realization of the market size a_t . Consequently, the condition for collusion (4.2) must be modified if the demand is subject to *i.i.d.* shocks. Since the current profits depend on the realization of the market size, we denote the per-period profits from competition (index N), collusion (index A) and defection (index D) by $\pi_R(a_t)$, $R = N, A, D$. Collusion is feasible if

$$V(\pi_A, a_t, \delta) \equiv \frac{\delta}{1-\delta} \left\{ \int_{\underline{a}}^{\tilde{a}} \pi_{\bar{A}}(a) f(a) da + [1 - F(\tilde{a})] \pi_A(\tilde{a}) - \int_{\underline{a}}^{\tilde{a}} \pi_N(a) f(a) da \right\} - \pi_D(a_t) + \pi_A(a_t) \geq 0. \quad (4.20)$$

holds. The product on the right hand side states the discounted stream of future collusive profits net the alternative profits from the punishment phase, whereas the last two terms deduct the one-shot gain from defection. Since joint monopolization of the market is possible only if demand is currently low, the firms realize their share in the monopoly profit given by the first integral if the realization of the market size takes a value in the range $[\underline{a}, \tilde{a}]$. If the demand level is higher however they are forced to settle for the lower profits from a less restrictive implicit agreement. The resulting collusive profits are given by the subsequent term. The second integral states the profit of *Cournot* competition. This more complex expression mirrors the fact that firms can no longer monopolize the market in a period of high demand even if they are very patient.

The uniqueness of the upper bound of the market size can be shown as follows: Under the assumptions on the shock detailed above, the firms can jointly monopolize the market if the demand is currently at its lowest level $V(\pi_{\bar{A}}, \underline{a}, \delta) > 0$, but not if it is on its highest level, $V(\pi_{\bar{A}}, \bar{a}, \delta) < 0$. In the *Cournot* duopoly, the gain from defection $\pi_D(a_t) - \pi_{\bar{A}}(a_t) = (a_t - c)^2 / 64$ strictly increases in the realization of the market size a_t .⁶ As the shock realizations are independent from each other, the expected discounted streams of

⁶ In a *Cournot* oligopoly, the same holds true since the additional gain from defection amounts to $(a_t - c)^2 [1 + 4n(n-2)] / (16n^2)$. The argument also applies to price competition between producers of a homogeneous good because $\pi_D(a_t) - \pi_{\bar{A}}(a_t) = (n-1)\pi_{\bar{A}}(a_t)$. The same can be shown to hold in an oligopoly with linear demand for a horizontally differentiated good. Since the derivations are tedious and not instructive, we do not go into the proof (cf., e.g. *Martin* 2002, 312). In the general case, the result holds if $\pi_D(a_t) - \pi_{\bar{A}}(a_t)$ monotonously rises in the realization of the market size.

future *Nash*-competitive and monopoly profits do not depend on the current level of demand. Consequently, the incentive to participate in perfect collusion strictly decreases in the current value of the shock, $\partial V(\pi_{\bar{A}}, a_t, \delta) / \partial a_t < 0$. By the intermediate value theorem, there is indeed a critical upper bound of the market size $\tilde{a}$ in the range $[\underline{a}, \bar{a}]$ up to which the firms can jointly monopolize the market given their valuation of future profits δ as claimed.

In a recession that is characterized by slack demand ($a_t \leq \tilde{a}$), the firm jointly monopolize the market. Since both the shares in the monopoly output and the monopoly price increase in demand, the market price then rises in the shock realization a_t . Pricing is exactly procyclical and mirrors the development of the demand level over time. However, the quantity that firms produce if they participate in imperfect collusion increases and the market price thus decreases in the market size: As the future additional discounted collusive profits given by the term with the curly brackets in the condition for collusion (4.20) is constant over time, the additional gain from deviation that fulfills the condition with equality must also be held constant over time. Since it increases in the market size, the participants in the implicit agreement have to expand their output more and realize a lower market price the higher the current demand level is. In boom periods, corresponding to values of the market size $a_t \in (\tilde{a}, \bar{a}]$, pricing is therefore anticyclical. Thus, our analysis extends the result of *Rotemberg, Saloner* (1986) who derived this effect in a *Bertrand* oligopoly. If the firms cannot collude at all due to extreme impatience, they compete in the market. The resulting price also increases in the size of the market. Noncollusive pricing is hence procyclical.

Consequently, anticyclical pricing in a market with uncorrelated demand shocks indicates an implicit anticompetitive agreement in the product market if the marginal costs of the firms are indeed constant as it is assumed here.

The general model illustrates the collusive strategy in a market with i.i.d. shocks on the demand level. The anticollusive effect of high demand realizations becomes even more obvious if we consider a numerical example of the *Cournot* duopoly. We assume that there are three possible realizations of the market size $a_1 = 1$, $a_2 = 3$ and $a_3 = 2$ that are observed with equal probability.⁷ As in the example of a market with constant demand, the level of unit cost is $c = 0.5$. By (4.20) the condition for perfect collusion in this case is

$$V(\pi_{\bar{A}}, a_t, \delta) = \frac{\delta}{3(1-\delta)} \left[\frac{(a_1 - c)^2}{72} + \frac{(a_2 - c)^2}{72} + \frac{(a_3 - c)^2}{72} \right] - \frac{(a_t - c)^2}{64} \geq 0, \quad a_t = a_1, a_2, a_3 \quad (4.21)$$

⁷ The values $a_1 = 1$, $a_2 = 3$ and $a_3 = 2$ are chosen in anticipation of the discussion of cyclic demand in the following section.

because by (4.16) and (4.17) $(a_t - c)^2 / 72$ is the additional gain from collusion and $(a_t - c)^2 / 64$ the additional gain from defection in a period with a market size a_t . For the assumed parameter values, the critical values of the discount factor for perfect collusion are $\underline{\delta}_{a_1} = 0.0879$, $\underline{\delta}_{a_2} = 0.7068$, $\underline{\delta}_{a_3} = 0.4646$, where the index indicates the market size in the present period t . The values of the discount factor demonstrate that collusion is most difficult if the demand is at its highest level a_2 . Further, joint monopolization of the market is impossible only in the periods of peak demand a_2 if firms valuation of future profits corresponds to a value of the discount factor $\delta \in [0.4646, 0.7068)$. As argued above, the firms will then expand their output in these periods to satisfy the condition for collusion which then requires

$$V(\pi_A, a_2, \delta) = \frac{\delta}{3(1-\delta)} \left[\frac{(a_1 - c)^2}{72} + (a_2 - c - 2q_{A,a_2}) q_{A,a_2} - \frac{(a_2 - c)^2}{9} + \frac{(a_3 - c)^2}{72} \right] - \frac{(a_2 - c - q_{A,a_2})^2}{4} + (a_2 - c - 2q_{A,a_2}) q_{A,a_2} \geq 0$$

to hold. If for example the market discount factor is $\delta = 0.6$, the collusive quantities $q_{\bar{A},a_1} = 0.125$, $q_{A,a_2} = 0.6721$ and $q_{\bar{A},a_3} = 0.375$ yield the maximal discounted profit stream from collusion that amounts to 1.3215.⁸ The corresponding intertemporal gain from *Cournot* competition is 1.1806. Since analogous considerations determine the collusive strategy for discount factors that prevent joint monopolization of the market in periods with an intermediate or a high market size of a_3 or a_2 , $\delta \in [0.0879, 0.4646)$, and values that exclude it for all demand realizations, $\delta < 0.0879$, we skip the details of the derivations. Tables 4.1 and 4.2 summarize the rounded results for exemplary values of the discount factor δ in the different intervals. The last line states the *Cournot* quantities and prices.

The numerical example shows that firms indeed expand output and induce prices to fall for a greater range of demand realizations the lower is the value that they place on future profits. Hence pricing is anticyclical if perfect collusion is impossible at all levels of demand. This effect of “price wars during booms” can be read off from the collusive prices stated in Table 4.2. It arises although, in contrast to the *Bertrand* supergame considered by *Rotemberg, Saloner* (1986), the firms set quantities and gain positive punishment profits in a *Cournot* market.

⁸ The equilibria are calculated with help of Mathematica 4.1. Due to rounding the corresponding incentive to collude $V(\pi_A, a_2, 0.6) = 0.5406 \cdot 10^{-4}$ is positive, but very small.

Table 4.1. Collusive Quantities in Markets with Demand Shocks

δ	a_1	a_2	a_3
0.71	$q_{\bar{A}} = 0.13, q_A = 0.63, q_{\bar{A}} = 0.38$		
0.6	$q_{\bar{A}} = 0.13, q_A = 0.67, q_{\bar{A}} = 0.38$		
0.25	$q_{\bar{A}} = 0.13, q_A = 0.78, q_A = 0.44$		
0.05	$q_A = 0.15, q_A = 0.82, q_A = 0.49$		
0.09	$q_N = 0.17, q_N = 0.83, q_N = 0.5$		

Table 4.2. Collusive Prices in Markets with Demand Shocks

δ	a_1	a_2	a_3
0.71	$p_{\bar{A}} = 0.75, p_{\bar{A}} = 1.75, p_{\bar{A}} = 1.25$		
0.6	$p_{\bar{A}} = 0.75, p_A = 1.66, p_{\bar{A}} = 1.25$		
0.25	$p_{\bar{A}} = 0.75, p_A = 1.45, p_A = 1.11$		
0.05	$p_A = 0.69, p_A = 1.36, p_A = 1.02$		
0.09	$p_N = 0.67, p_N = 1.33, p_N = 1$		

The preceding theoretical analysis shows that the same collusive strategy is optimal regardless whether the firms compete in quantities or prices. Since the extent of horizontal product differentiation, the number of firms in the market, and a change from quantity to price competition affect only the amount of per-period profits gained by collusion, defection and unrestricted *Nash* competition, but not the general consideration on whether to collude or not, this anticyclicity of pricing is stable across these various specifications. The model thus offers an explanation for alternating phases of pro- and anticyclical pricing in oligopoly.

The anticyclicity of prices that arises from demand shocks is the basic finding of *Rotemberg, Saloner* (1986). Their catch phrase of “price wars during booms” however misses the crux of the matter. A price war in the sense of a breakdown of the implicit agreement does not occur because the firms enter only into agreements that are self-sustaining given the infinite punishment of a defection by *Nash* competition. It is therefore never necessary to mete out the punishment. As we discussed in Chapter 3, some of the empirical studies find such a countercyclical reaction of markups to changes in the market demand. *Rotemberg, Saloner* (1986) themselves provide evidence using data for the US-cement market after the second world war. *Rosenbaum* (1986) also analyzes US-data for cement and confirms the pricing behavior that is derived in the theoretical framework. *Scherer, Ross* (1990, 306ff) cite examples for price reductions in response to bulk orders that induce a boom. The studies by *Domowitz et al.* (1986, 1987) however offer a counter-example. He analyzes the price-cost margins in 284 US-manufacturing industries and finds a procyclical development of markups. Moreover, the margins are more sensitive to demand fluctuations if the industry is more concentrated. This

discrepancy may be explained by capacity restrictions that preclude the production of the defection output and hence overturn the results of the present model where constant unit costs imply unlimited capacities (cf. the discussion of capacity limits in the Introduction). The above setup with *i.i.d.* demand shocks suggests that anticyclical pricing is only observed in markets where the firms have considerable excess capacities in times of high demand, since the punishment threat is not credible otherwise.

However, capacity constraints are not the only possible explanation for different pricing across markets. Another reason might be the sensitivity of the markups to the exact pattern of demand development over time. Therefore, we next turn to another type of demand fluctuations and consider a cyclic development instead of uncorrelated, transitory shocks.

4.4 Demand Cycles

In the market with identically, independently distributed period shocks discussed previously, the demand level of each period is unaffected by the past or future shock realizations. Actually, the current market size offers some information on the quantity that will be demanded by consumers in the future. The analysis of the US-business cycle by *Hamilton* (1989) establishes the interrelation between actual and past demand levels empirically. If the demand realizations of subsequent periods are in some way correlated, the current market size will influence the firms' conjectures on future profits. Then, their incentive to collude depends on the underlying trend of the demand development. The resulting price and its development over time hence differs from the pattern that is observed in a market with uncorrelated shocks on the demand level.

If the demand level is subject to cyclic fluctuations, the same pattern recurs time after time. Thus, future demand levels can be easily predicted. Hence, we assume that the demand development is known to all firms in the market. In order to reflect such a cyclical pattern, we use the setup developed by *Haltiwanger, Harrington* (1991) for the special case of *Bertrand* competition. For the sake of concreteness, we consider again a *Cournot* duopoly. However, the important result that the firms' inclination to participate in perfect collusion is lower in recessions also applies to an oligopolistic market for a differentiated good if the per-period profits are reinterpreted as the corresponding oligopoly profits.

Most of the results that are derived by *Haltiwanger, Harrington* (1991) hold only in the case of extremely severe punishment by zero profits. Given the assumption of a *grim trigger* punishment, the applicability of the model is limited to *Bertrand* price competition, i.e. a market with a homogeneous good. A one-to-one application of the argument to the analysis of markets where

the profits from *Nash* competition are positive is impossible.⁹ The cases of quantity competition (irrespective of the degree of product differentiation) and price competition between producers of a heterogeneous good are hence not covered by the original model by *Haltiwanger, Harrington* (1991). Their assumption of a homogeneous good is a limitation especially for the empirical analysis. In their study of the US-gasoline market, *Borenstein, Shepard* (1996, 433) comment on the practical relevance of zero punishment profits: "If punishment means a reversion to a noncooperative equilibrium so that 'punishment' and 'noncollusive' profits are equal, this assumption might be violated in gasoline markets. On the demand side, there is reason to believe that noncollusive margins would be changed with demand." Most likely, firms make costly investments that constitute a long-term commitment only if the profits are positive even in the case of unrestricted competition. In the case of *Bertrand* competition in contrast, profits net investment cost would be negative. In such a situation, an antitrust authority that observes investments has strong reasons to believe that firms make their business viable by restricting competition in the market. The probability of an investigation and a detection of the implicit agreement is then high. The long-run strategic decision would most likely be prosecuted as an antitrust offence since the (costly) investment has no independent business reason, in a *Bertrand* market, but may serve as a facilitating device. By US-antitrust law, for example, an "agreement among competitors to adopt conduct that constitutes a facilitating practice may be attacked either as an anticompetitive agreement in and of itself or as circumstantial evidence of price fixing. In addition, unilateral adoption of facilitating practices may be scrutinized under the Federal Trade Commission Act." (*Yao, DeSanti* 1993, 120). In the European Community, horizontal coordination among competitors of all types of business strategies are prohibited by the Art.81(1a) of the *EC-Treaty* except if they yield efficiency gains. It is thus sufficient that the firms use a certain incriminating strategy, an agreement on the adoption among the competitors is not required. Since firms will hardly use business strategies that may be judged illegal if they compete in prices in a homogeneous market, we demonstrate the effect of cyclic demand fluctuations in markets where the noncollusive punishment profits are positive. To show the decisive impact of the positivity of the *Nash*-competitive profits, we then rederive the results for *Bertrand* competition.

The demand development is again determined by changes in the market size a_t . It now describes the cyclical pattern that is repeated infinitely over time. a_t changes according to

⁹ Although the continuation profits after defection may be pushed down to zero by a *stick and carrot* punishment, the requirement of non-negative prices and outputs still considerably restricts the applicability of the model (cf. *Lambertini, Sasaki* 1999).

$$a_t = \begin{cases} a_1 & \text{for } t = 1, \bar{t} + 1, 2\bar{t} + 1, 3\bar{t} + 1, \dots \\ a_2 & \text{for } t = 2, \bar{t} + 2, 2\bar{t} + 2, 3\bar{t} + 2, \dots \\ \vdots & \vdots \\ a_{\hat{t}} & \text{for } t = \hat{t}, \hat{t} + \bar{t}, \hat{t} + 2\bar{t}, \hat{t} + 3\bar{t}, \dots \\ \vdots & \vdots \\ a_{\bar{t}} & \text{for } t = \bar{t}, 2\bar{t}, 3\bar{t}, \dots \end{cases} \quad (4.22)$$

where $a_1 < a_2 < \dots < a_{\hat{t}} > \dots > a_{\bar{t}-1} > a_{\bar{t}}, a_{\bar{t}} > a_1$.

Thus, the market size increases from period 1 until the peak of a cycle in $\hat{t}$ and falls afterwards until it reaches the initial level again in period $\bar{t} + 1$. Figure 4.1 illustrates this “single-peaked” pattern that need not be symmetric around the period with the demand peak $\hat{t}$. Also, boom and recession might be of different length. In the following, we refer to a sequence of periods $t, t + 1, \dots, t + \bar{t} - 1, t = 1, 2, \dots, \bar{t}$ as a (full) cycle.

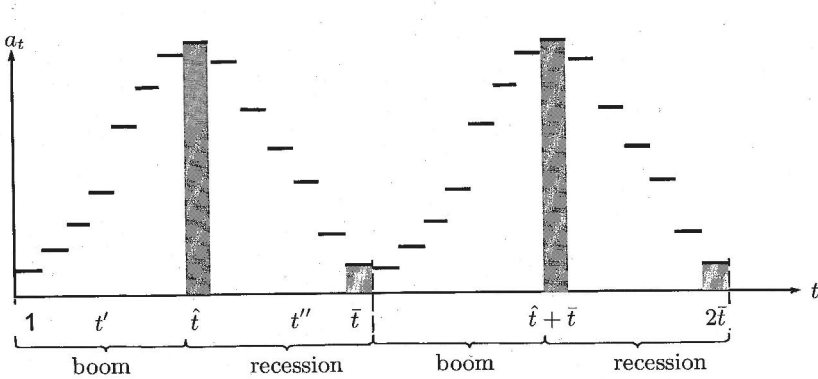


Figure 4.1. Cyclic Demand

Note, that a market of constant size is a special case of this setup. It arises from the specification $a_t = a \forall t = 1, \dots, \bar{t}$ from the cycle given by (4.22). Already at this stage, it is rather obvious that the firms will react differently to the cyclic changes in demand than to the uncorrelated shocks discussed before. The basic effect of demand fluctuations on the incentive to collude that consists in a high one-shot gain from cheating in a period of strong demand is of course still present. In addition, the periods of the cycle are characterized by a different development of future demand. Therefore, the periods $1 + k\bar{t}$ to $\bar{t}(1 + k\bar{t}), k = 0, 1, 2, \dots$ differ with respect to the discounted collusive profits that are lost due to the punishment of defection. The latter fact also affects a firm's inclination to collude. It does not arise in the framework with uncorrelated, transitory shocks on the demand level since there current and future levels of demand are independent. Then, the expected loss that results from punishment is always the same.

The ability to collude depends on the discounted profit stream from an indefinitely repeated cycle starting in the current period t . To shorten notation we denote this profit stream by

$$R(t, \delta) \equiv \left[\pi_R(a_t) + \delta \pi_R(a_{t+1}) + \dots + \delta^{\bar{t}-t} \pi_R(a_{\bar{t}}) + \delta^{\bar{t}-t+1} \pi_R(a_1) + \dots + \delta^{\bar{t}-1} \pi_R(a_{t-1}) \right] / (1 - \delta^{\bar{t}}), \quad R = \bar{A}, A, N. \quad (4.23)$$

where R indicates whether the firms collude perfectly (index $\bar{A}$), imperfectly (index A), or compete in quantities (index N).

If the stream of collusive profits exceeds the discounted profits attainable by deviation, the firms participate in collusion. In a market with cyclic demand changes this condition for collusion in the present period t amounts to

$$V(t, \pi_A(a_1), \dots, \pi_A(a_{\bar{t}}), \delta) \equiv \delta [A(t+1, \delta) - N(t+1, \delta)] - \pi_D(a_t) + \pi_A(a_t) \geq 0. \quad (4.24)$$

The above inequality demonstrates that the incentive to collude in period t $V(t, \pi_A(a_1), \dots, \pi_A(a_{\bar{t}}), \delta)$ depends on the development of the market size over the cycle that determines the per-period profits. If the demand develops according to the deterministic pattern described by (4.22), the future demand is determined by the position of the current period in the cycle. As in the case for *i.i.d.* shocks, continuous perfect collusion is possible if the firms place a very high value on future profits. If they are less patient, the firms expand the output beyond their share in the monopoly output and reduce the incentive to defect just enough to make the agreement feasible given their valuation of future profits δ .¹⁰ In the case of imperfect collusion, their incentive to participate in this collusive agreement (4.24) is zero. This adjustment of the implicit agreement results in a lower market price and yields a lower periodic profit than joint monopolization of the market. Since the discounted gain from collusion depends on the firms' valuation of future profits and thus on the market discount factor, there is a critical value of the future below which even imperfect collusion is impossible.

The incentive to defect, $\pi_D(a_t) - \pi_A(a_t)$, is determined by the current demand level alone. Thus, it is identical in a market with and without cyclically fluctuations, if the current market size is the same in both cases. The incentive to collude, in contrast, depends on the additional gain from participation in the agreement, $\pi_A(a_\tau) - \pi_N(a_\tau)$, $\tau = t+1, t+2, \dots$, that will be realized in each of the future periods. In a market of constant size a_t however the additional profit from collusion $\pi_A(a_t) - \pi_N(a_t)$ accrues in every period. Therefore, the incentive to collude is lower in a market with cyclic than with constant demand if the discounted stream of additional future profits that are realized over the infinitely repeated cycle that starts in $t+1$ falls short of the one gained in the situation without demand fluctuations. This is the case if the average

¹⁰ In the case of price competition, they reduce the price instead and produce the corresponding higher quantity.

level of additional collusive profits over the cycle is smaller than the per-period profit gained in a market with constant demand, $A(t+1, \delta)/\bar{t} < \pi_A(a_t)$. If the average additional periodic profit over the cycle is higher than in the market with constant demand the converse statement holds. Thus, any threshold of the discount factor that corresponds to a certain extent of collusion is higher in the former and lower in the latter case if demand fluctuates cyclically,

$$\delta_{\text{crit.}} \geq \delta_{t,\text{crit.}} \quad \text{for} \quad [A(t+1, \delta) - N(t+1, \delta)](1 - \delta^{\bar{t}})/\bar{t} \leq \pi_A(a_t) - \pi_N(a_t). \quad (4.25)$$

The critical value of the discount factor for constant demand is obtained by inserting the per-period profits in a market of size a_t in the condition for collusion (4.3). This threshold is hence given by

$$\delta_{t,\text{crit.}} \equiv [\pi_D(a_t) - \pi_A(a_t)] / [\pi_D(a_t) - \pi_N(a_t)],$$

where the index t indicates that the demand is constant at the level of the period t .

For the *Cournot* market, more detailed results on the collusive behavior of the firms can be derived.

If the firms implicitly agree on low production quotas, they gain a higher collusive profit, but also increase the one-shot gain from cheating. A very restrictive quota agreement thus does not violate the condition for collusion (4.24) only if the firms place a high value on future profits. This corresponds to a high value of the market discount factor and in turn to a high profit stream that is realized by collusion.

According to (4.24) the incentive to participate in perfect collusion is

$$V(t, \pi_A(a_1), \dots, \pi_{\bar{A}}(a_{\bar{t}}), \delta) \equiv \delta [\bar{A}(t+1, \delta) - N(t+1, \delta)] - \pi_D(a_t) + \pi_{\bar{A}}(a_t) \quad (4.26)$$

The value of the additional gain from perfect collusion given by the expression in square brackets is zero if the firms do not value future profits, $\delta = 0$. It increases continuously in the discount factor and approaches infinity if the discount factor approaches its maximal value, $\delta \rightarrow 1$. The additional gain from defection $\pi_D(a_t) - \pi_{\bar{A}}(a_t)$, in contrast, is positive and does not depend on the discount factor. By the intermediate value theorem, the threshold of the discount factor that corresponds to an incentive to collude (4.26) of zero must be smaller than 1. Further, by (4.25) this critical value is smaller than in a market of a constant, maximal size $a_{\bar{t}}$ since the incentive to defect is the same, but the additional stream of future collusive profits is larger than in a market with cyclical demand fluctuations. If the discounting of future profits prevents the firms from monopolizing the market even if the demand is constant at the peak level of the cycle, their incentive to do so is even smaller if demand is lower in most of the future periods due to cyclical fluctuations. Then, the corresponding condition for collusion (4.24) is certainly violated.¹¹ If demand

¹¹ The proof generalizes the finding by *Haltiwanger, Harrington* (1991, Theorem 2), who derive a similar result for the special case of price competition in a homogeneous market.

fluctuates cyclically, the threshold for perfect collusion is therefore higher than the threshold in a market where the demand is stable at the peak level $a_{\bar{t}}$, $\underline{\delta} \in (\underline{\delta}_{\bar{t}}, 1]$. By (4.2), we have $\underline{\delta}_{\bar{t}} = [\pi_D(a_{\bar{t}}) - \pi_{\bar{A}}(a_{\bar{t}})] / [\pi_D(a_{\bar{t}}) - \pi_N(a_{\bar{t}})]$.

For the values of the discount factor that enable the firms to jointly monopolize the market, $\delta \geq \underline{\delta}$, the development of the production quantities and the resulting market price is again exactly parallel to the development of the demand level. In the *Cournot* duopoly the firms produce their share in the monopoly output $q_{\bar{A}} = (a_t - c)/4$ and realize the price $p_{\bar{A}} = (a_t + c)/2$. Since the monopoly price always rises in demand, the conclusion also applies in the general model. The development of the market price is described by the chain of inequalities given by

$$p_R(a_{1+k\bar{t}}) < \dots < p_R(a_{i+k\bar{t}}) > \dots > p_R(a_{(k+1)\bar{t}}), \quad \forall k \in \mathbb{N}_0, \quad (4.27)$$

with the index changed to $R = \bar{A}$ to account for the joint monopolization of the market. The markup therefore changes procyclically.

If the discount factor takes a value in the interval $\delta \in [\bar{\delta}, \underline{\delta})$, the firms' valuation of future profits is in the intermediate range. Then, collusion is possible, but the firms are forced to produce more than their share in the monopoly output to reduce the incentive to defect. They set the collusive quantity just high enough to fulfill the condition for collusion (4.24) given their degree of patience δ .

For values of the discount factor just below the critical threshold of perfect collusion, $\underline{\delta}$, there is a period t^* , where the firms can only realize a profit below the monopoly profit, whereas perfect collusion is still possible in all other periods of the cycle. If the firms are slightly less patient than is necessary for joint monopolization of the market over the whole cycle, they can implicitly agree on such production quotas by setting the quantities above their share in the monopoly output in this most critical period t^* . Thus, a price below the monopoly price is observed in only one of the periods of the cycle. The development of the price therefore differs from the one of demand only in this period. In all other periods of the cycle price and demand move in parallel.

As Figure 4.1 demonstrates, for every period t' in boom phase of a single-peaked cycle there is always a period t'' , where demand is as high or lower and falls in the following period(s). Hence, the period t'' is part of a recession.¹² Again, the additional discounted profit stream from joint monopolization of the market is higher in period t' than in t'' due to the discounting of future profits. The incentive to defect however is the same in both periods. The incentive to participate in the implicit agreement $V(\cdot)$ in (4.24) is therefore higher in a boom period t' than in a recession period t'' . The period that is most critical for perfect collusion falls in a phase of falling demand (recession).

Analytically, this can be demonstrated as follows: The period $m(t)$ is defined as the last recession period of the cycle where the market size is at least

¹² *Haltiwanger, Harrington* (1991, Theorem 4) prove this result for the special case of *Bertrand* competition.

as high as in a boom period t .

$$m(t) \equiv \max\{\tau | a_\tau > a_t, \tau \in \{t+1, \dots, \bar{t}\}\}, t \in \{1, \dots, \hat{t}-1\}. \quad (4.28)$$

Figure 4.1 illustrates such a situation with $t = t'$ as the boom period that corresponds to the recessionary period $m(t) = t''$.¹³ Since the additional periodic gain from perfect collusion (4.16) increases in the market size, $m(t)$ is at the same time the last recessionary period of the cycle where this additional profit is higher than the corresponding amount in the boom period t , $\pi_{\bar{A}}(a_{m(t)}) - \pi_N(a_{m(t)}) \geq \pi_{\bar{A}}(a_t) - \pi_N(a_t)$.

Further, we define H to be the part of the additional discounted profit stream that is realized in the “high” part of the cycle in the periods from $t+1$ to $m(t)$ and L as the part that is realized in the “low” part, i.e. in periods $m(t)+1$ to t .

$$\begin{aligned} H &\equiv \delta [\pi_{\bar{A}}(a_{t+1}) - \pi_N(a_{t+1})] + \dots + \delta^{m(t)-t} [\pi_{\bar{A}}(a_{m(t)}) - \pi_N(a_{m(t)})], \\ L &\equiv \delta [\pi_{\bar{A}}(a_{m(t)+1}) - \pi_N(a_{m(t)+1})] + \dots + \delta^{\bar{t}-m(t)+t} [\pi_{\bar{A}}(a_t) - \pi_N(a_t)], \\ &\quad \forall t \in \{1, \dots, \hat{t}-1\}. \end{aligned}$$

Thus, the period t' in Figure 4.1 is a boom period that corresponds to a recession period $t'' = m(t')$. Our aim is to show that the incentive to participate in perfect collusion is always higher in a boom period $t \in \{1, \dots, \hat{t}-1\}$ than in the recessionary period $m(t)$,

$$V(t, \pi_{\bar{A}}(a_1), \dots, \pi_{\bar{A}}(a_{\bar{t}}), \delta) > V(m(t), \pi_{\bar{A}}(a_1), \dots, \pi_{\bar{A}}(a_{\bar{t}}), \delta), \forall t \in \{1, \dots, \hat{t}-1\}. \quad (4.29)$$

The additional gain from defection (4.17) is higher the larger the market is.¹⁴ By the definition of $m(t)$ in (4.28) the additional gain from defection is hence larger in period $m(t)$ than in t , $\pi_D(a_{m(t)}) - \pi_{\bar{A}}(a_{m(t)}) \geq \pi_D(a_t) - \pi_{\bar{A}}(a_t)$. The inequality (4.29) therefore holds if

$$\bar{A}(t+1, \delta) - N(t+1, \delta) > \bar{A}(m(t)+1, \delta) - N(m(t)+1, \delta) \quad (4.30)$$

is true. With the definitions in (4.29) this simplifies to

$$H + \delta^{m(t)-t} L > L + \delta^{\bar{t}-m(t)+t} H \quad (4.31)$$

and hence to

$$H / (1 - \delta^{m(t)-t}) > L / (1 - \delta^{\bar{t}-m(t)+t}). \quad (4.32)$$

¹³ We assume that the monopoly price is not too elastic in periods of high demand. It can be shown that the additional gain from perfect collusion increases in demand in price competition (e.g. *Martin* 2002, 312). In a *Cournot* oligopoly, the corresponding gain $(a-c)^2 (n-1)^2 / [4n(n+1)^2]$ rises in the market size as well. In the general case, the result holds if $\pi_{\bar{A}}(a_t) - \pi_N(a_t)$ monotonously increases in the demand level.

¹⁴ The validity of these results in a more general setup is discussed in footnote 6.

The last inequality demonstrates that the share of the discounted profit stream H that is realized in the infinitely recurring “high” part of cycle (left hand side) is larger than the share L that is gained infinitely often in the “low” parts (right hand side). According to the definition of $m(t)$, the additional profit from perfect collusion in any period $\tau' \in \{t+1, \dots, m(t)\}$ is larger than in the corresponding period $\tau'' \in \{m(t)+1, \dots, t\}$, $\pi_A(a_{\tau'}) - \pi_N(a_{\tau'}) > \pi_A(a_{\tau''}) - \pi_N(a_{\tau''})$. The inequalities (4.31) and (4.29) therefore hold, as claimed.

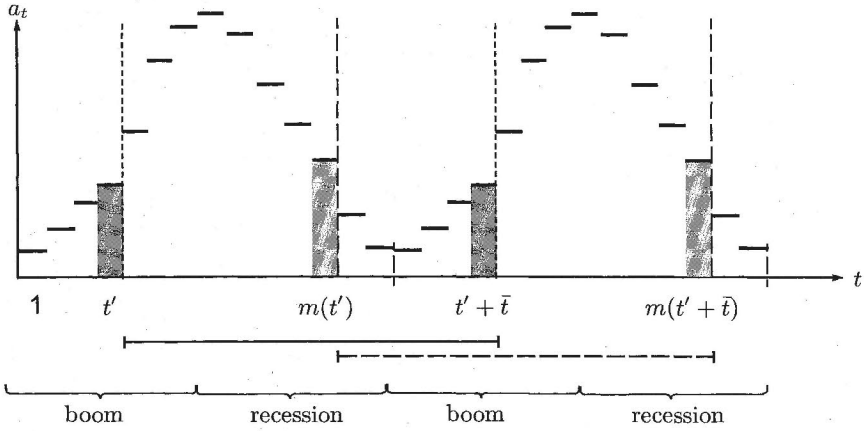


Figure 4.2. Critical Period for Perfect Collusion with Cyclic Demand

Figure 4.2 illustrates that the discounted profits from a full cycle that starts in a boom period t (solid horizontal line) is indeed larger than the corresponding discounted profit stream from a full cycle that starts in period $m(t)$ (dashed horizontal line). This is true since the higher per-period profits accrue earlier and are discounted less if the current period falls in a phase of rising instead of falling demand. Consequently, the discounted profits from the infinite repetition of the cycle that starts in a boom is also larger than the infinite discounted profit stream that starts in the recession.

The lower the firms' valuation of future profits the larger is the number of periods of the cycle where production must be increased above a firm's share in the monopoly output. The resulting lower collusive profits reduce the incentive to cheat on the implicit agreement and make collusion viable. Moreover, the development of the market price of the good diverges from the development of the demand level in a larger number of periods if the firms discount future profits highly.

In the same way as for the case of the joint monopolization of the market, it can be shown that the firms' inclination to participate in imperfect collusion is always higher in a boom than in a recessionary period if the market demand

level is at least as high in the former than in the latter. Analogously to the case of joint monopolization of the market, both the additional periodic gain from imperfect collusion and from defection increase in the market size. In every period of collusion, the firms realize the additional profit

$$\pi_A(a_t) - \pi_N(a_t) = (a_t - c - 2q_A) q_A - (a_t - c)^2 / 9. \quad (4.33)$$

Its derivative with respect to the market size

$$\partial [\pi_A(a_t) - \pi_N(a_t)] / \partial a_{t+2} = q_A - 2(a_t - c) / 9 \quad (4.34)$$

is positive because they never restrict the output more than in the case of perfect collusion, $q_A > q_{\bar{A}} = (a_t - c)/4 > 2(a_t - c)/9$. The additional one-shot gain from defection

$$\pi_D(a_t) - \pi_A(a_t) = (a_t - c - q_A)^2 / 4 - (a_t - c - 2q_A) q_A \quad (4.35)$$

also increases in the market size because the derivative

$$\partial [\pi_D(a_t) - \pi_A(a_t)] / \partial a_t = (a_t - c - 3q_A) / 2 \quad (4.36)$$

is positive for all production quotas that are smaller than the *Nash* output $q_N = (a_t - c)/3$. Due to the latter fact, the additional profit gained by deviation from imperfect collusion is higher in the recessionary period $m(t)$ than in the respective boom period t . Thus, the inequality

$$V(t, \pi_A(a_1), \dots, \pi_A(a_{\hat{t}}), \delta) > V(m(t), \pi_A(a_1), \dots, \pi_A(a_{\hat{t}}), \delta), \forall t \in \{1, \dots, \hat{t} - 1\} \quad (4.37)$$

holds if

$$A(t + 1, \delta) - N(t + 1, \delta) > A(m(t) + 1, \delta) - N(m(t) + 1, \delta) \quad (4.38)$$

is fulfilled. By denoting the part of the additional discounted profit stream from imperfect collusion that is realized in the “high” part of the cycle in the periods from $t + 1$ to $m(t)$ by h and the part that is realized in the “low” part, i.e. in periods $m(t) + 1$ to t , by l analogously to (4.29),

$$\begin{aligned} h &\equiv \delta [\pi_A(a_{t+1}) - \pi_N(a_{t+1})] + \dots + \delta^{m(t)-t} [\pi_A(a_{m(t)}) - \pi_N(a_{m(t)})], \\ l &\equiv \delta [\pi_A(a_{m(t)+1}) - \pi_N(a_{m(t)+1})] + \dots + \delta^{\hat{t}-m(t)+t} [\pi_A(a_{\hat{t}}) - \pi_N(a_{\hat{t}})], \\ &\quad \forall t \in \{1, \dots, \hat{t} - 1\}, \end{aligned} \quad (4.39)$$

the inequality (4.38) can be rewritten in the same way as in the case of joint monopolization of the market,

$$h + \delta^{m(t)-t} l > l + \delta^{\hat{t}-m(t)+t} h. \quad (4.40)$$

Since by (4.34) the additional periodic gain from imperfect collusion increases in the market size, it is larger in any period $\tau' \in \{t + 1, \dots, m(t)\}$ in the high

part than in the corresponding period $\tau'' \in \{m(t) + 1, \dots, t\}$ in the low part of the cycle, $\pi_A(a_{\tau'}) - \pi_N(a_{\tau'}) > \pi_A(a_{\tau''}) - \pi_N(a_{\tau''})$. Furthermore, starting from the present period t the profits from imperfect collusion h that are gained in periods of high demand accrue earlier and are hence discounted less if the current period t falls in a boom (left hand side of (4.40)) instead of a recession (right hand side). The inequalities (4.40) and therefore (4.37) hold, as claimed. Consequently, the scope of collusion is larger in times of rising than of falling demand. The quotas are hence lower and the market price is higher in a boom than in a recession.¹⁵

Close to the corresponding lower bound of the discount factors that are consistent with imperfect collusion, there is hardly any scope for an implicit agreement. If the low value of future profits allows only for a very small restriction of competition, the firms collude in the period of peak demand $\bar{t}$. This holds true because the additional profit gained from such a small extent of collusion rises stronger in the demand level than the additional one-shot gain from defection. Analytically this can be shown as follows: For a certain range of the discount factor above the critical threshold that corresponds to imperfect collusion $\bar{\delta}$, the scope of collusion is very small. Then, the firms implicitly agree on a quota that is slightly lower than the *Nash* output in only one of the periods of the cycle. In all other periods, they compete in the market. Their incentive to collude is given by

$$V(t, \pi_A(a_1), \dots, \pi_A(a_{\bar{t}}), \delta) = \frac{\delta^{\bar{t}}}{1 - \delta^{\bar{t}}} [\pi_A(a_t) - \pi_N(a_t)] - \pi_D(a_t) + \pi_A(a_t). \quad (4.41)$$

The first term accounts for the fact that the additional profit from the implicit agreement accrues every $\bar{t}$ periods due to the infinite repetition of the cyclic pattern. The remaining two terms subtract the additional one-shot profit from defection. The incentive to participate in imperfect collusion in the *Cournot* duopoly with constant demand is given by (4.18). It states the periodic additional gains from participation in and defection from imperfect collusion. In a market with cyclic demand the former must be discounted appropriately by multiplication with $\delta^{\bar{t}} / (1 - \delta^{\bar{t}})$ to obtain the discounted stream of future profits from collusion in one period of the cycle. By (4.34), the discounted additional profits from imperfect collusion are higher the larger the size of the market is. The additional one-shot gain from defection also increases in the market size because the derivative (4.36) is positive for all production quotas that are consistent with imperfect collusion, $q_A < q_N$. At the *Nash* output it is identically to zero, whereas the derivative of the discounted additional gain from participation in the implicit agreement is positive. Since in the vicinity of the *Nash* quantity, the discounted additional profits from collusion rise more strongly in the market size, the first effect of more profitable collusion

¹⁵ *Haltiwanger, Harrington* (1991, Theorem 7) derive the same result for the special case of collusion in a *Bertrand* market.

dominates over the larger incentive to defect. Consequently, the inclination to participate in a small restriction of competition increases in the demand level. The only period where imperfect collusion is feasible even if firms place a low value on future profits is hence the peak of the cycle $\hat{t}$ as claimed.

If the firms compete in quantities due to the high discounting of future profits, $\delta < \bar{\delta}$, individual outputs as well as the market price for the good develop procyclically over time. In the *Cournot* duopoly with a linear inverse demand function, both firms produce the quantity $q_N = (a_t - c)/3$ corresponding to a market price $p_N = (a_t + c)/3$. In the general case of unrestricted quantity or price competition in a market for a horizontally differentiated good, the individual quantities and prices also increase in the demand level and hence in the market size. In all these cases, the price path is described by the chain of inequalities (4.27) with the index $R = N$ since the firms compete in the market.

Figure 4.3 illustrates the results for a market with cyclic demand changes for the more general *Cournot* market that yields positive profits from *Nash* competition (punishment). In the cases of unrestrained *Nash* competition and perfect collusion, the price develops in parallel to demand. The main result of the present analysis is the fact that the colluding firms produce more and realize a lower price in recessionary periods if joint monopolization is impossible. Consequently, the price falls overproportionately in comparison to demand in a recession if the firms cannot monopolize the market over the whole cycle. The finding that the incentive to collude and hence the price-cost margin is higher in booms than in recessions is at the same time the prediction that is tested by empirical studies of collusion in markets with cyclic demand fluctuations. The main difference to the *Bertrand* special case is the fact that there the price is set at marginal costs in the *Nash*-competitive equilibrium. Hence, unrestrained price competition results in acyclical pricing.

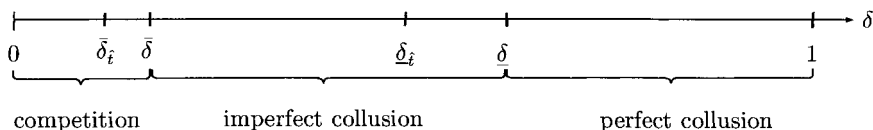


Figure 4.3. Collusion with Cyclic Demand

To illustrate the firms' collusive strategy and the resulting development of the market price, we use the numerical example from the previous section. However, the sequence of the three demand levels $a_1 = 1$, $a_2 = 3$, $a_3 = 2$ repeats itself infinitely and describes a very simple single-peaked cycle of length $\bar{t} = 3$. As explained above, different conditions for collusion apply depending on the position of the

current period in the cycle. In our simple example, perfect collusion requires analogously to (4.24)

$$V(1 + k\bar{t}, \pi_{\bar{A}}(a_1), \pi_{\bar{A}}(a_2), \pi_{\bar{A}}(a_3), \delta) = \frac{1}{1 - \delta^3} \left[\frac{\delta (a_2 - c)^2}{72} + \frac{\delta^2 (a_3 - c)}{72} + \frac{\delta^3 (a_1 - c)^2}{72} \right] - \frac{(a_1 - c)^2}{64} \geq 0, \quad (4.42)$$

$$V(2 + k\bar{t}, \pi_{\bar{A}}(a_1), \pi_{\bar{A}}(a_2), \pi_{\bar{A}}(a_3), \delta) = \frac{1}{1 - \delta^3} \left[\frac{\delta (a_3 - c)^2}{72} + \frac{\delta^2 (a_1 - c)}{72} + \frac{\delta^3 (a_2 - c)^2}{72} \right] - \frac{(a_2 - c)^2}{64} \geq 0, \quad (4.43)$$

$$V(3 + k\bar{t}, \pi_{\bar{A}}(a_1), \pi_{\bar{A}}(a_2), \pi_{\bar{A}}(a_3), \delta) = \frac{1}{1 - \delta^3} \left[\frac{\delta (a_1 - c)^2}{72} + \frac{\delta^2 (a_2 - c)}{72} + \frac{\delta^3 (a_3 - c)^2}{72} \right] - \frac{(a_3 - c)^2}{64} \geq 0, \quad (4.44)$$

$k = 0, 1, 2, \dots$ to hold in any period with a demand level of a_1, a_2 and a_3 , respectively. The values of the discount factor that fulfill the conditions with equality $\underline{\delta}_{a_1} = 0.0443$, $\underline{\delta}_{a_2} = 0.7337$ and $\underline{\delta}_{a_3} = 0.5236$ confirm that collusion is most difficult if current demand is high, but known to fall in the immediate future. If the firms' valuation of future profits corresponds to a value of the discount factor $\delta \geq 0.7337$, perfect collusion is always possible. If it corresponds to a value of $\delta \in [0.5236, 0.7337]$, this is true except for periods of peak demand a_2 . Then, the firms expand the collusive output just enough to fulfill the corresponding condition for collusion

$$V(2 + k\bar{t}, \cdot) = \frac{1}{1 - \delta^3} \left\{ \frac{\delta (a_3 - c)^2}{72} + \frac{\delta^2 (a_1 - c)}{72} + \delta^3 [q_{A,a_2} (a_2 - c - 2q_{A,a_2}) - \frac{(a_2 - c)^2}{9}] \right\} - \frac{(a_2 - c - q_{A,a_2})^2}{4} + (a_2 - c - 2q_{A,a_2}) q_{A,a_2} = 0. \quad (4.45)$$

that replaces (4.43) in the set of conditions above. The inequality (4.45) implicitly states the optimal collusive quantity q_{A,a_2} . For values of $\delta \in [0.0443, 0.5236]$ perfect collusion is possible only in periods of weak demand a_1 . Thus, analogously to (4.45) two conditions for the demand levels a_2 and a_3 must be fulfilled by the collusive outputs q_{A,a_2}

and q_{A,a_3} in parallel to (4.42). If the firms are even less patient, $\delta < 0.0443$, they must confine themselves with the profits from imperfect collusion in all periods of the cycle. Then, they implicitly agree on production levels that fulfill the three corresponding conditions for a_1 , a_2 and a_3 simultaneously. The respective, rounded outputs and prices for optimal collusion at values of the discount factor from the different intervals are summarized in the Tables 4.3 and 4.4 below.¹⁶ They illustrate how the firms' response to cyclical demand changes depends on their valuation of future profits.

Table 4.3. Collusive Quantities in Markets with Cyclic Demand

δ	a_1	a_2	a_3
$\downarrow 0.74$	$q_{\bar{A}} = 0.13, q_{\bar{A}} = 0.63, q_{\bar{A}} = 0.38$		
0.6	$q_{\bar{A}} = 0.13, q_A = 0.69, q_{\bar{A}} = 0.38$		
0.25	$q_{\bar{A}} = 0.13, q_A = 0.79, q_A = 0.46$		
0.05	$q_{\bar{A}} = 0.13, q_A = 0.82, q_A = 0.49$		
0.02	$q_A = 0.16, q_A = 0.83, q_A = 0.50$		
$\downarrow 0.04$	$q_N = 0.17, q_N = 0.83, q_N = 0.5$		

Table 4.4. Collusive Prices in Markets with Cyclic Demand

δ	a_1	a_2	a_3
$\downarrow 0.74$	$p_{\bar{A}} = 0.75, p_{\bar{A}} = 1.75, p_{\bar{A}} = 1.25$		
0.6	$p_{\bar{A}} = 0.75, p_A = 1.62, p_{\bar{A}} = 1.25$		
0.25	$p_{\bar{A}} = 0.75, p_A = 1.43, p_A = 1.08$		
0.05	$p_{\bar{A}} = 0.75, p_A = 1.35, p_A = 1.02$		
0.02	$p_A = 0.68, p_A = 1.34, p_A = 1.01$		
$\downarrow 0.04$	$p_N = 0.67, p_N = 1.33, p_N = 1$		

Figures 4.4 and 4.4 as well as the Tables 4.3 and 4.4 demonstrate that collusion is difficult if current demand is high (most difficult at the peak of the cycle in period $\hat{t}$ with a market size of a_2 in the example). In these periods, the collusive quantity is thus smaller than

¹⁶ Due to rounding, the incentive to collude $V(\cdot)$ is in some cases slightly higher than zero at the values given in Table 4.3 and 4.4. For the same reason, the collusive and *Nash* outputs appear to be identical for the demand levels a_2 and a_3 at $\delta = 0.02$, although the collusive outputs are in fact slightly higher. Solutions with quantities smaller than a half of the monopoly output are excluded since cheating by increasing production would always be profitable. By the same argument, the firms will not implicitly agree to produce more than the *Cournot* quantity. Both remarks also apply to the case of cyclical demand development. The values for a discount factor $\delta = 0.5$ are included for the sake of completeness. They can be compared to those in a market with uncorrelated shocks.

the firms' share in the monopoly output except if their valuation of future profits is very high ($\delta \geq 0.7337$). This effect also arises from the *i.i.d.* shocks on the demand level that was discussed in the previous section. Additionally, the example shows that low future demand, as in periods $\bar{t}$ of the cycle which is followed by the lowest demand level a_1 , also makes collusion difficult. As a consequence, the firms have to increase production in these periods, too, if they do not place a very high value on future profits ($0.0443 \leq \delta < 0.5236$).

The results exemplify furthermore that neither price nor quantity move anticyclical over time in the sense that the price is lowest or quantity highest at the peak of the cycle in the periods $k\bar{t}$, $k = 1, 2, 3, \dots$ even if the firms' valuation of future profits is very small. Only in the case of *Bertrand* competition a development of price over time may be observed that is exactly opposed to the movement of the demand levels over time: If the firms' patience is low, they reduce prices in times of rising demand and raise them in times of falling demand (*Haltiwanger, Harrington 1991, Theorem 5*).

Kandori (1991) and *Bagwell, Staiger (1997)* discuss collusion in markets with autocorrelated demand. Since their conclusions are extremely sensitive to the assumptions of price competition and product homogeneity, we describe more complicated demand patterns as a simultaneous occurrence of cycles and periodic shocks instead.

4.5 Demand Cycles Subject to Stochastic Shocks

In the preceding sections, we separated the analysis of uncorrelated stochastic shocks and deterministic demand cycles. Yet in some markets demand is characterized by a complex autocorrelated pattern. The theoretical models of such fluctuations by *Kandori (1991)* and *Bagwell, Staiger (1997)* however, can only be applied to *Bertrand* price competition or collusive agreements that implement a punishment that yields discounted profits of zero. Therefore, we do not consider such an autocorrelated development, but describe more complicated demand patterns by the simultaneous occurrence of cycles and periodic shocks.

The simultaneous consideration of cycles and shocks requires a great number of case discriminations, especially with respect to the critical upper bound of the shock realization that is still consistent with perfect collusion. If the market demand is characterized by a cyclic trend, the future demand in each period of a full cycle $t = 1 + k\bar{t}, \dots, \bar{t}(1 + k)$, $k = 0, 1, 2, \dots$ is different. The firms' incentive to participate in a collusive agreement thus changes over the cycle. In contrast to a market where *i.i.d.* shocks affect a constant demand level, there is a different realization of the shock for every period of a cycle that results in the highest demand level still consistent with perfect collusion.

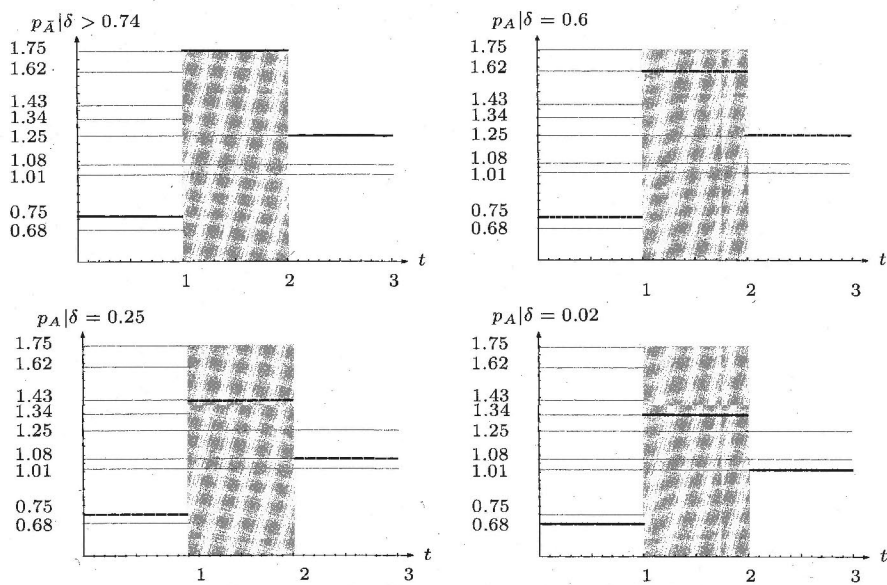


Figure 4.4. Pricing in the *Cournot* Duopoly with Cyclic Demand

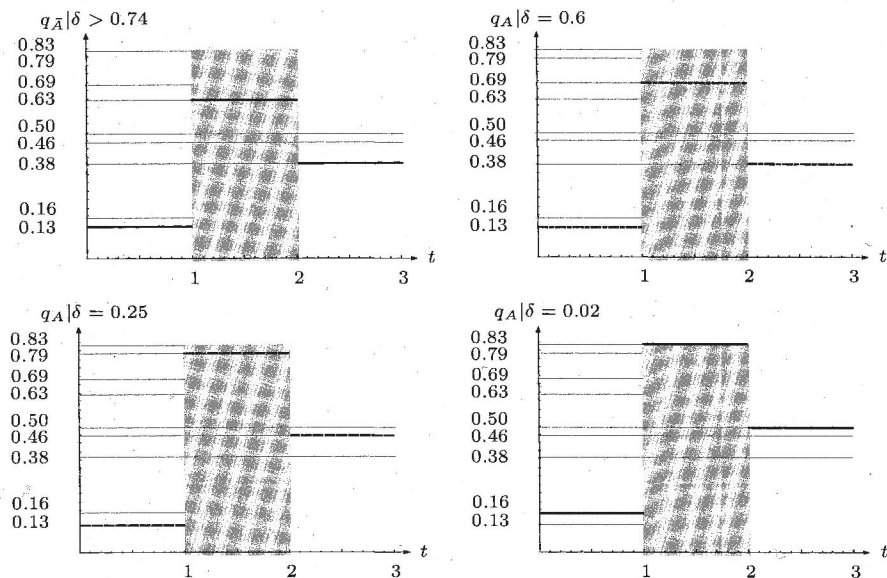


Figure 4.5. Outputs in the *Cournot* Duopoly with Cyclic Demand

Also, the critical values of the discount factors that separate the values that lead to perfect collusion, imperfect collusion and unrestrained competition then depend on the current realization of the market size. Since a contemporaneous analysis of both types of demand development does not yield clear-cut results we discuss this variant of the model only briefly and draw some general conclusion.

Considering additional *i.i.d.* stochastic shocks on demand as they are described in Section 4.3 within each period of the cycle, we model market demand development as a sum of a trend and a stochastic process as customary in time series analysis (cf., e. g. *Harvey* 1993). Then, the cyclic trend as well as the realizations of the stochastic shock determine the firms' expectations on the demand for the good in the future periods. If the expected realization of the shock is the same in all periods of the cycle, the demand levels of the deterministic cycle can be replaced by the expected values of the market size. These expected demand levels will still trace out a single-peak cycle. For each period in the cycle $t = 1 + k\bar{t}, \dots, \bar{t}(1 + k)$, $k = 0, 1, 2, \dots$ there is then again a different stream of future expected profits that determines the firms inclination to collude. As the shock is independently identically distributed, the future development of demand does not depend on the present realization of the shock. Hence, it affects the firms' inclination to collude in the same way as in a market with a deterministic demand cycle discussed before: The higher the expected future demand in a period the higher is the firms inclination to collude. Due to this effect collusion is still easier in boom times of rising demand. However, the stochastic shock on the demand level of the present period might partly offset this effect since it determines the present market size and therefore also the additional profit from deviation. As in the model with purely stochastic shocks that was originally proposed by *Rotemberg, Saloner* (1986), the firms have to react to the effect of the shock on the incentive to deviate by increasing the collusive quantity if the current demand realization is higher than on average. On the other hand, they can tacitly agree on a lower quantity than without the additional shock if the actual realization is low. If the demand level results from a cyclical development with stochastic shocks, the behavior in the product market is therefore a combination of the strategy for cyclical development of demand and the strategy for uncorrelated shocks derived in Section 4.3 above.

Analogous conclusions apply to price competition. Here, the firms do not expand production, but lower the collusive price if a higher realization of the current demand level calls for a reduction of the profit gained by a deviation from the implicit agreement. Conversely, the firms set a higher collusive price if the realization of the stochastic shock implies a current demand level that is more favorable for collusion.

4.6 Comparison of the Market Results

The analysis of the competitive and collusive strategies in markets with uncorrelated stochastic shocks or a cyclical development of the demand levels shows that the firms have to account for the demand development and adjust their implicit agreement accordingly. Thereby they reduce the incentive to defect just sufficiently to make the collusion feasible.

In markets with uncorrelated stochastic shocks, imperfect collusion implies anticyclical pricing. The firms have to reduce the per-period profit in times of high demand to decrease the gain from cheating on the implicit agreement. If they compete in quantities, they expand output beyond their share in the monopoly output. The higher market output causes a fall in price. In price competition, the participants directly set the optimal collusive price (below the monopoly price) and produce the corresponding quantities. Since the present and future demand levels are uncorrelated, the expectation on future demand realizations is unaffected by the current realization of the market size. This difference to markets with cyclic demand development arises from the independence of the shock realizations over time. Hence, this type of fluctuations demonstrates the level effect of demand fluctuations.

The optimal collusive strategy in markets with cyclical development of demand is a reduction of the one-shot gain from cheating in periods where joint monopolization is impossible due to low future demand. This is necessary because the future profits and thus the losses from a breakup of collusion are low in a recession. The smaller potential punishment for cheating must be compensated by lower current profits from the implicit agreement that decrease the incentive to deviate. Thus, a cyclic development of demand implies procyclical pricing: The collusive price tends to be lower in a recessionary period. This is the slope effect of demand fluctuations on the viability of collusion. This basic, procollusive effect of high future expected demand also arises if the development of demand is stochastically autocorrelated (*Kandori 1991, Bagwell, Staiger 1997*).

If demand is subject to cyclical fluctuations and stochastic shocks, the development of prices over time also results from a combination of the optimal collusive strategies for both demand patterns. In this case, the market outcome is determined both by the level and the slope effect of the demand fluctuations.

4.7 Number of Firms

The conditions for collusion for the different demand patterns, (4.2), (4.20), and (4.24), also describe the firms' incentive to collude in an oligopolistic market for a horizontally differentiated good. To see this, the profits $\pi_N(a_t)$, $\pi_A(a_t)$ and $\pi_D(a_t)$ have to be interpreted as the corresponding per-period profits gained by unrestricted competition, collusion or defection from

the implicit agreement.¹⁷ These conditions also describe the special case of collusion in a *Bertrand* market if the per-period profits from unrestricted *Nash* competition are set to zero to account for the fact that firms do not realize profits in the punishment phase. In all these situations, firms maximize their profits by exhausting the scope of collusion. As discussed before, they make the incentive to collude zero by setting the quantities that just fulfill the conditions for collusion, (4.2), (4.20), and (4.24) with equality.

To demonstrate the robustness of our results we will consider collusion in *Cournot* and *Bertrand* oligopolies in turn. In the same manner as in the duopoly described in Section 4.2, the n oligopolistic firms monopolize a *Cournot* market by maximizing joint profits. In the case of perfect collusion each of them produces its share of the monopoly output $q_{\bar{A}} = (a_t - c) / (2n)$ and realizes the corresponding profit¹⁸

$$\pi_{\bar{A}} = (a_t - c)^2 / (4n). \quad (4.46)$$

in every period. If a participant deviates from this implicit agreement, he takes into account that the other firms continue to produce the collusive output $q_{\bar{A}}$ and maximizes its profit by solving

$$\max_{q_i} \pi_i = (a_t - q_i - (n-1)q_{\bar{A}} - c)q_i. \quad (4.47)$$

The resulting output amounts to $q_D = [(a_t - c)(n+1)] / (4n)$. It yields the one-shot profit from defection

$$\pi_D = [(a_t - c)^2 (n+1)^2] / (16n^2). \quad (4.48)$$

The rivals punish the violation of the implicit agreement by producing the *Nash* quantity. Since the deviator anticipates the onset of the punishment phase, he also produces the same output as its competitors. The corresponding profit maximization problem is

$$\max_{q_i} \pi_i = \left(a_t - q_i - \sum_{j \neq i}^n q_j - c \right) q_i. \quad (4.49)$$

Summation of the first order conditions yields a symmetric individual quantity $q_N = (a_t - c) / (n+1)$. Each firm gains a per-period profit of

$$\pi_N = (a_t - c)^2 / (n+1)^2. \quad (4.50)$$

¹⁷ *Albaek, Lambertini* (1998) and others show that the incentive to collude increases in the degree of product heterogeneity. As the effect of product differentiation is discussed in the introduction, we will abstract from product differentiation and focus on a homogeneous market.

¹⁸ Since the market size varies over time, the profits and quantities also depend on time. Yet, in the following we omit the index t except on the demand level to keep the notation concise.

By inserting these profits in the condition for collusion (4.2) we derive the critical threshold of the discount factor $\underline{\delta}_C$ for a *Cournot* oligopoly with linear inverse demand

$$\delta \geq \underline{\delta}_C \equiv \frac{(n+1)^2}{n(n+6)+1}. \quad (4.51)$$

Hence, perfect collusion is feasible only if firms discount future profits less.

If firms compete in prices in a homogeneous market, a defector gains the market profit by setting a price slightly below the collusive price. Since all consumers buy the homogeneous good at the lowest price, the defector attracts the market demand at a price that is almost as high as the collusive price and realizes the market profit. Consequently, his profit is n -times larger than the collusive profit. In the ensuing punishment phase, each firm sets the *Bertrand* price at the level of marginal cost and gains no profits. By (4.3), the critical lower bound of the discount factor for collusion is thus given by

$$\delta \geq \underline{\delta}_B \equiv \frac{n-1}{n}. \quad (4.52)$$

Since this value does not depend on the amount of the collusive profit it applies to all implicit agreements in the range between the *Nash*-competitive price at marginal cost and the monopoly price. Therefore, the thresholds of the discount factor for imperfect and perfect collusion are identical in a *Bertrand* oligopoly with constant demand, $\underline{\delta}_B = \bar{\delta}_B$. Profit-maximizing firms however will choose the most profitable agreement as a *focal point* for coordination and set the monopoly price if they put a sufficiently high value on future profits, i.e. $\delta \geq \underline{\delta}_B$.

The number of firms in the market also determines whether collusion is easier in price or quantity competition. The comparison of (4.51) and (4.52) shows that the threshold of the discount factor for perfect collusion in a *Cournot* oligopoly $\underline{\delta}_C$ is larger than the value in a *Bertrand* oligopoly $\underline{\delta}_B$ only in the special case of duopolistic competition.

$$\frac{(n+1)^2}{n(n+6)+1} > \frac{n-1}{n} \quad \forall n > \lfloor 1 + 2/\sqrt{3} \rfloor = 2, \quad n \in \mathbb{N}. \quad (4.53)$$

If more than two firms compete in the market, collusion is easier in quantity than in price competition. On the first glance, this fact might seem surprising because the *Bertrand* competition in the punishment phase yields no profits. Thus, it implements the maximal punishment that is larger than the one implied by unrestrained *Cournot* competition. Such a harsh punishment facilitates collusion. However, the high profits gained by cheating on the implicit agreement dominate over the procollusive effect of the maximal punishment: In the *Bertrand* oligopoly, colluding firms share the spoils, but gain the full monopoly profit by defection. The additional gain from defection net the alternative per-period profit from continued collusion therefore increases in the number of firms in the market. Consequently, the severe punishment by zero

profits is more than compensated by the higher one-shot profit from defection if the number of firms in the market is large. Additionally, the collusive profit is smaller if more firms share the monopoly profit. In the *Cournot* oligopoly in contrast, the cheating firm does not attract the total demand and gains much less than the market profit. Moreover, the defection profit (4.48) decreases in the number of participants,

$$\frac{\partial \pi_D}{\partial n} = -\frac{(a_t - c)^2 (n + 1)}{8n^3} < 0 \quad \forall n \in \mathbb{N}.$$

The latter effect is stronger than the parallel decrease of collusive and *Nash*-competitive profits. The comparison of the thresholds for perfect collusion (4.51) and (4.52) illustrates that the joint monopolization of the market is almost always easier in quantity than in price competition because the market profit that is gained by defection in price competition is a tantalizing temptation to cheat on an implicit agreement.

The preceding argumentation also shows that the thresholds of the discount factor $\underline{\delta}_C$ and $\underline{\delta}_B$ increase in the number of firms n . Both the higher likelihood of collusion in quantity competition and the procollusive effect of market concentration are robust to the introduction of product differentiation (*Martin* 2002, 311/2).

Furthermore, the two critical thresholds of the discount factor for perfect collusion, $\underline{\delta}_C$ and $\underline{\delta}_B$, demonstrate that the size of the market has not effect on a firm's inclination to collude. The corresponding price however depends on the price elasticity of demand and therefore also on the size of the market. If the demand is extremely sensitive to the price, the volume of sales decreases strongly in response to a price increase. Consequently, the firms gain low profits both in the case of unrestrained competition and collusion. Conversely, this standard argument demonstrates that the firms realize high *Nash* or collusive profits if the price elasticity of demand is low (cf., e.g. *Vives* 1999, 155). The next section demonstrates this effect by a formal analysis.

4.8 Sensitivity of the Price to the Market Size

For comparison with the results of empirical studies on the development of the markup over time in different industries, it is necessary to determine which pattern of the markup results from unrestrained competition and collusion, respectively. If the theoretical model yields a clear prediction in this respect given the characteristics of the market under consideration (e.g. the type of demand fluctuation and additional business strategies with long-term commitment effect), comparison with the empirically observed development indicates whether firms implicitly or tacitly coordinate their product market strategies. A comparison thus requires information on whether the *Nash* and the collu-

sive equilibria, especially the most easily observable market price, reacts pro- or anticyclically to changes in the market demand.

To explore the applicability of our preceding analysis to an oligopoly with a non-linear demand function, we analyze the sensitivity of the different equilibria to changes in the market size. Thereby, we derive the conditions for a pro- and anticyclical development of the collusive outputs and price in the general case. To corroborate our previous results we also reconsider the case of a market with a linear demand function.

In the case of *Cournot* competition among n firms, the margin over marginal cost of a firm i rises in the firms market share, but falls in the elasticity of demand.

In a symmetric *Cournot* oligopoly, each firm maximizes its individual profit

$$\pi_i(q_i, Q_{-i}) = q_i p(q_i + Q_{-i}) - C(q_i)$$

given the total quantity Q_{-i} that is produced by all other firms in the market. The first order condition for profit maximization is

$$\frac{\partial \pi_i(q_i, Q_{-i})}{\partial q_i} = p(q_i + Q_{-i}) - c + q_i \frac{\partial p(q_i + Q_{-i})}{\partial q_i} = 0. \quad (4.54)$$

The difference between price and marginal cost (the markup) indicates the profitability of an additional unit of output. The last term shows the effect of the price decrease that results from this unit on the profitability of all other units the firm produces. From the first order condition (4.54) we have

$$\frac{p(q_i + Q_{-i}) - c}{p(q_i + Q_{-i})} = - \frac{q_i}{p(q_i + Q_{-i})} \frac{\partial p(q_i + Q_{-i})}{\partial q_i} = \frac{s_i}{\eta}. \quad (4.55)$$

The left hand side of the equality is the price-cost margin of firm i measured by the *Lerner* index (*Lerner* 1935), that provides a convenient measure of its market power. On the right hand side, we have the elasticity of direct demand that is defined as

$$\eta = - \frac{p}{Q} \frac{\partial Q(p)}{\partial p} \quad (4.56)$$

multiplied by the market share of the firm i , $s_i = q_i/Q$. The equation (4.55) demonstrates that the *Lerner* index is proportional to the market share of a firm and inversely proportional to the price elasticity of demand. Moreover, given constant marginal cost, it increases in the price $p(q_i + Q_{-i})$. Since firms are symmetric, their market shares are identical and do not change in the size of the market. It is the latter fact that is of special interest for the analysis of collusion in markets with fluctuating demand: If the elasticity of demand increases, the *Lerner* index decreases. Consequently, the equilibrium price is lower. Moreover, the oligopoly equilibrium price reacts less sensitively to a change in the elasticity of demand since it is weighted by the market share $s_i > 1$, whereas the market share is one in the case of monopoly (corresponding

to joint monopolization by colluding firms). Compared to a recessionary period with low demand, the markup is larger in a period with high demand, if the value of the price elasticity in the boom is smaller. Given the constancy of marginal cost the same applies to the price. Consequently, *Nash*-competitive and monopoly pricing is procyclical if the demand elasticity decreases in the market size.

In the example of a symmetric *Cournot* oligopoly with linear, normed demand each of the n firms produces the quantity $q_N = (a - c)/(n + 1)$ in equilibrium (cf. Section 4.7). Therefore, the price elasticity of demand takes the value

$$\eta_C(n) = \frac{a + cn}{n(a - c)}. \quad (4.57)$$

where the index C indicates that this is the value in the *Cournot* equilibrium. The *Lerner* index is given by $(n\eta_C(n))^{-1} = (a - c)/(a + cn)$. Obviously, the elasticity of demand decreases, but the *Lerner* index as an indicator of the firms' market power increases in the size of the market. Also, the markup and hence the market power decreases in the number of market participants. This negative relationship demonstrates that competition is harder and profits are lower the larger is the number of rivals.

The same considerations apply in the case of perfect collusion. If the firms jointly monopolize the market, they maximize the market profit

$$\pi_M(Q) = Qp(Q) - C(Q).$$

The corresponding first order condition

$$\frac{\partial \pi_M(Q)}{\partial Q} = p(Q) - c + Q \frac{\partial p(Q)}{\partial Q} = 0. \quad (4.58)$$

yields

$$\frac{p(Q) - c}{p(Q)} = -\frac{Q}{p(Q)} \frac{\partial p(Q)}{\partial Q} = \frac{1}{\eta} \quad (4.59)$$

as the familiar rule for a monopoly equilibrium. Comparison of the equations (4.55) and (4.59) demonstrates that the same "rule" determines the profit-maximizing product market strategy in a *Cournot* oligopoly and in a monopoly (because the monopolist's market share is one). The price elasticity of demand in the monopoly equilibrium (indexed by $\bar{A}$)

$$\eta_{\bar{A}} = \frac{a + c}{a - c} \quad (4.60)$$

decreases, whereas the *Lerner* index $\eta_{\bar{A}}^{-1}$ and the price in the case of joint monopolization of the market increase in the market size.

In our oligopoly example, the price elasticity is lower in both the noncollusive and collusive equilibria the higher the current market size is. Therefore our assumption on a moderate value of the price elasticity of demand in

boom times of high demand is valid in these cases. The analysis of this section demonstrates that this is indeed a crucial assumption for the applicability of our model to markets with a more general demand function. Then, the price is higher and output lower in the *Nash* and monopoly equilibria only if the price elasticity of demand is lower in periods of strong than in periods of slack demand. Consequently, the price is higher and the output lower in both the noncollusive and collusive equilibria the higher is the level of demand. This fact is important for the analysis of collusion because the reaction of the markup to changes in the demand is a prediction of the theoretical analysis that may be tested by empirical market studies.

In addition, these considerations demonstrate the profitability of collusion: The comparison of the last terms of the first order conditions for a *Cournot* oligopoly (4.54) and monopoly (4.58) demonstrates that each firm's output choice imposes a negative externality on its rivals. A *Cournot* competitor only accounts for decrease in the market price that is due to his own output expansion, but neglects the price decrease due to his rivals' output reaction. In the case of joint monopolization however the participants in the agreement consider the effect of the total market output on the price. Consequently, individual production is "too high" in the case of *Cournot* competition, at least from each firm's point of view (not so, of course, judging from the perspective of a policy agency that aims to maximize the social welfare). Since the market output is higher in the case of unrestrained competition, the market price as well as the individual profit of a firm is lower in *Cournot* competition compared to perfect collusion. It is this negative externality of production that yields an incentive for firms to participate in an agreement to jointly monopolize the market. As was shown above, this implicit agreement is indeed feasible if firms compete infinitely or do not know the end date of competition.

A similar consideration demonstrates that both cases imply a welfare loss in comparison to the first-best case of perfect competition. In this case, the first order condition for profit maximization is the same as in the *Cournot* case (4.54) except that the last term is zero because each firm is too small to affect the market price. Consequently, the *Cournot* quantity that solves the condition (4.54) is smaller than the individual output of a firm in a perfectly competitive market.

4.9 Welfare

The welfare level that results from oligopolistic competition or collusion is judged by comparison with the first-best equilibrium that yields the maximal welfare.

We use the partial-equilibrium approach and consider again a market for a homogeneous good. The focus on a single market basically amounts to assuming that the prices and outputs of all other goods do not de-

pend on the equilibrium in the market under consideration.¹⁹ The other goods are represented by the composite *numéraire* good q^0 with price 1. The utility function is quasilinear and concave in the consumed quantity ($U'_k(q_k) > 0$, $U''_k(q_k) < 0$, $U'_k(\infty) \leq 0$).

The utility of the consumer k from the consumption of the quantity q_k amounts to

$$V_k(q_k^0, q_k) \equiv U_k(q_k) + q_k^0. \quad (4.61)$$

Each consumer $k = 1, \dots, m$ purchases the quantity q_k that yields the highest utility from consumption net the expenditures on the good. Thus, he maximizes his individual surplus

$$\max_{q_k} U_k(q_k) - p q_k. \quad (4.62)$$

The consumer surplus is given by the sum of the individual net utilities (4.62)

$$CS(p) = \sum_{k=1}^m [U_k(q_k(p)) - p q_k(p)] \quad (4.63)$$

Thus, the maximization of the consumer surplus requires that the respective condition for the maximal individual utility (4.62)

$$U'_k(q_k^*) = p \quad \forall k = 1, \dots, m \quad (4.64)$$

holds for each consumer. (The index $*$ denotes equilibrium values.) The producer surplus is given by the sum of the firms' profits

$$PS \equiv \sum_{i=1}^n [p q_i - c q_i]. \quad (4.65)$$

The welfare in the market is determined by the sum of consumer and producer surplus

$$W \equiv CS + PS. \quad (4.66)$$

Since the total output is fully consumed in equilibrium,

$$\sum_{i=1}^n q_i^*(p) = \sum_{k=1}^m q_k^*(p) \quad (4.67)$$

holds. Consequently, the welfare level in the market (4.66) can be written as the total utility of all m consumers net total production costs of the n firms,

¹⁹ The conditions for representability of welfare by a continuous function and the requirements for a well-behaved optimization problem can be found in any text book on microeconomics. *Vives* (1987) discusses the validity of the approach in partial-equilibrium analysis. However, since the present study focuses on the dynamic aspects of oligopolistic competition we do not go into this discussion here.

$$W = \sum_{k=1}^m \left[U_k(q_k) - \sum_{i=1}^n c q_i \right]. \quad (4.68)$$

The *Pareto*-efficient total output maximizes the welfare stated in (4.66) given (4.67). The problem

$$\max_{q_k, q_i} \sum_{k=1}^m U_k(q_k) - \sum_{i=1}^n c q_i - \lambda \left(\sum_{k=1}^m q_k - \sum_{i=1}^n q_i \right) \quad (4.69)$$

yields

$$\begin{aligned} U'_k(q_k^*) &= \lambda \quad k = 1, \dots, m \\ C'_i(q_i^*) &= \lambda \quad i = 1, \dots, n \\ q_k^* &= q_i^* \end{aligned}$$

as the first order conditions for an efficient equilibrium. Since by (4.64) the individual utility is maximal if the marginal utility equals price, the maximization of welfare requires $c = p$, $i = 1, \dots, n$ to hold. The latter requirement is at the same time the condition for profit maximization in a competitive market. The decentral decisions maximize welfare if the market is perfectly competitive.

Since consumption and production q are equal in equilibrium and the utility maximizing consumer equates the marginal individual utility (4.62) with the price, the derivative

$$W'(q) = U'_k(q) - c \quad (4.70)$$

is positive at a price above marginal cost. Consequently, the welfare level (4.68) increases in the quantity. Moreover, given the negative slope of the demand function, welfare decreases in the market price. Hence, the comparison of the market prices or markups from competition (4.55) and collusion (4.59) is sufficient to demonstrate that the welfare in a market is lower the more the firms restrict competition by an implicit agreement.

This welfare analysis also offers conclusions with respect to collusion in markets where the demand level changes over time. If the average condition for collusion, i.e. the average over the conditions that correspond to different demand level in the present period, is more restrictive than the condition for the collusion in a market with constant demand, collusion is made more difficult by the demand fluctuations. Then, the welfare loss from collusion in a market with cyclic or stochastic demand is smaller compared to a market where the demand level is constant at the average level over time.

Additional long-run investment decisions typically change the consumer surplus and the firms' profits in opposite ways. Since general results on the welfare effect of strategic competition in a one-shot setup cannot be derived, the welfare effects of infinitely repeated strategic competition are also unclear

a priori (*Shapiro* 1989). Therefore, we discuss the welfare effect for the strategic decisions on financing, investments and management compensation in the respective chapters along with their effects on competition in the product market.

4.10 Discussion

At the outset, the analysis of dynamic oligopolistic competition was driven by the puzzle why prices fluctuate in oligopolies (*Stigler* 1964). Therefore, the conclusions with respect to the development of the market price are an important touchstone for the empirical relevance of the theoretical analysis.

The initial supergame proposed by *Friedman* (1971) however is not suited to explain periodic breakdowns of collusion that result in price wars or other types of price fluctuations. According to this model, the firms in the market either participate in the implicit agreement or compete if collusion is not viable. Since they only agree on prices or output quotas that can be enforced in the given situation, the punishment is never actually used. The competitive strategies of the firms are therefore stationary over time. This result is due to the assumption of constant market conditions that is of course a severe abstraction from reality. The above discussion shows that the basic supergame of oligopolistic competition can be extended to explain price changes over time if demand fluctuations are integrated into the model.

Seeing their empirical prevalence, demand fluctuations lend more real-world flavor to a model of dynamic competition. Due to the time-varying demand development, the firms' expectations on the future demand levels are usually not constant over time. A first effort to account for changes in the market demand was made by integrating uncorrelated stochastic shocks that occur in every period. Depending on whether the current demand level is observable (*Rotemberg, Saloner* 1986) or unobservable (*Porter* 1983a, *Green, Porter* 1984) these shocks give rise to a pro- or anticyclic price development. If the current demand is not known, it is impossible to distinguish a defection from an apparent slump in demand since the firms that comply with the implicit agreement sell a low quantity in both cases. To prevent a deviation, they carry out the punishment whenever the price falls below a preagreed level. If the current demand is known, as in the situation discussed in Section 4.3, an output expansion or price reduction is necessary in periods of high demand to reduce the incentive to defect and make the implicit agreement viable. Thus, in both cases the demand fluctuations change the firms' incentive to collude and translate to a characteristic development of the market price. However, since the demand realizations are independent over time, the future expected demand does not change in response to the current demand level. Therefore, the future expected profits from collusion does not depend on the present realization of the shock. This however is a stark abstraction since the future demand levels typically are to some extent determined by the current level.

The analysis of a deterministic cyclic trend by *Haltiwanger, Harrington* (1991) accounts for such interrelation. However, the authors take to the other

extreme and assume that the same commonly known cycle is repeated again and again over time. Since the demand in most markets is to some extent serially correlated, the description by a cyclic trend is indeed a great advantage over the strong abstraction implied by the assumption of uncorrelated stochastic shocks. The deterministic cyclic trend is an appropriate description of markets for input goods where demand arises from cyclic replacement in the downstream industry and of many customer markets. The pattern is especially easy to predict if demand is subject to seasonal development (e.g. skiing equipment or heating oil). This is not the case however if it is largely caused by the overall economic development since the turning points of the macro-economic cycle are hardly predictable. Concerning the scope for collusion, this type of demand development yields a higher inclination to collude in periods of rising than of falling demand since the potential loss of future collusive gains implied by the punishment is lower in the latter case. Consequently, demand cycles give rise to procyclic pricing. As already mentioned in the introduction, other more complex patterns of stochastically correlated demand development were analyzed subsequently by *Kandori* (1991) and *Bagwell, Staiger* (1997). At the cost of a restriction to the special case of *Bertrand* competition, they derive the collusive pricing strategies for a very general type of demand development that can be used to describe the complex patterns found by many empirical studies. Based on these assumptions, the authors find the same effects as the previous work: *Ceteris paribus*, high current demand makes collusion difficult, whereas high expected future demand increases the firms' incentive to collude. Thus, these models demonstrate the robustness of the basic conclusions from the earlier analyses.

In short, the integration of demand fluctuations into the standard supergame model of long-term competition gives rise to fluctuations of the market price and offers an explanation for periods where the market price is below average. According to the theoretical analysis, these price movements do not result from a breakdown of collusion, but from an adjustment of the implicit agreement to the changing market conditions. Therefore, the theoretical prediction of the price pattern can be directly used as an indicator of an anticompetitive agreement, but only if the marginal costs of the firms in the market are approximately constant. Otherwise, an assessment of market power requires information on the cost situation of the competitors because price changes then might be caused absent collusion by a pro- or anticyclic development of the marginal cost.

There are of course many other factors aside from the development of demand or cost that may cause cyclic pricing. *Stiglitz* (1984) surveys a great number of circumstances that give rise to changes in the market price that are similar to those that result from collusion in markets with fluctuating demand. Anticyclic pricing for example might arise if the elasticity of demand increases in a recession (cf. also *Bils* 1989). Search cost have the same effect if the real interest rate goes up during a recession. Then, the consumers are less willing to search and postpone consumption. Consequently, the market power

of the firms is higher. Limit pricing to deter entry is another potential reason for anticyclic pricing. If a recession sets in, the amount of excess capacity increases and might be used as an additional deterrent. However, this argument has been criticized on the grounds that the threat of production expansion is not credible in quantity competition since the firms do not produce more than the *Nash* output in the post-entry equilibrium (*Dixit* 1980). *Comanor* (1990) develops upon the problem of consumer search cost and demonstrates that it may trigger price wars in a vertically structured market. *Fershtman, Muller* (1986), *Klemperer* (1989) and *Elzinga, Mills* (1999) explain price wars as an effort to gain a high market share in the event of entry in a market where consumers incur switching costs if they change the supplier. Given the considerable number of possible explanations for cyclic pricing, the decision which factor is the likely explanation for the observed price development in a given market is an empirical question.

Especially in a market with fluctuating demand, the assumption of an exogenous number of market participants limits the applicability of the theoretical framework to some extent. Instead, high current demand might yield an amount of profit that attracts new entrants even if they incur considerable costs upon entry. The present assumption of a constant number of competitors thus corresponds either to moderate fluctuations of the market demand or to high barriers to entry. The latter might be due to high setup costs for high-technology production facilities. The necessity to conduct an extensive market research, to invent around an existing patent or to pay licensing fees are other factors that create high barriers to entry. Due to such sunk costs and the additional expenditures that might be necessary to liquidate the business, most likely only those firms will enter into the competition that are certain to survive the most severe slumps in the market demand. This is likely especially because the basic characteristics of demand, i.e. the highest and lowest shock realization and/or the cyclic trend are commonly known. The present framework is therefore a quite accurate representation of numerous oligopolistic markets. Such relatively high setup cost are characteristic in particular for the production of technology-intensive goods and thus for markets with a very promising future. Since these markets are of great relevance for the future economic development of an economy, a potential anticompetitive agreement may cause harm far beyond the welfare loss in that market alone. The antitrust policy is hence of special importance here.

If however, the cost of entry are rather low, new competitors will nevertheless come into the market. *Harrington* (1989b) and *Vasconcelos* (2004) demonstrate that the firms' incentive to collude is then lower than in absence of potential entrants. Again, the integrability of other factors that affect the firms' incentive to restrict competition proves to be a great advantage of the supergame approach. Moreover, new entry into a market offers another explanation why the collusive market price changes over time.

This chapter offers a discussion of demand fluctuations in an oligopoly where all other market conditions are exogenously given and remain un-

changed over time. An endogenous explanation of the market conditions however is more elegant from a theoretical point of view. It can be achieved by including additional investment decisions of the firms. We will exploit this versatility of the approach in our subsequent analysis of additional strategic decisions on the capital structure, the organization of reinvestments in production as well as the delegation of the business and compensation of the managers.

4.11 Summary and Policy Conclusions

In countries with an effective antitrust regulation, cartelization of the market is most often impossible because the agreements cannot be legally enforced and already the efforts to achieve coordination may be illegal. The analysis of collusion by explicit or implicit coordination of the competitive strategies in markets with constant and fluctuating demand demonstrates that the firms can still realize higher profits than in the unrestrained oligopolistic competition even though the explicit coordination of the product market strategies is prohibited. This is the case, whenever the firms place a high value on their future profits. Then, the possibility to retaliate on the breach of an illegal agreement or the deviation from an implicitly agreed-upon parallel behavior by fierce competition is a sufficient deterrent that makes collusion viable. As the firms weight the future gains from the agreement against the profits from deviation and the subsequent punishment, the loss of future discounted collusive profits caused by a deviation may be even high enough to permit the joint monopolization of the market. If the competitors place a lower value on future profits, the temptation to gain a high current profit by deviation is too large relative to the future profits from the agreement. Since perfect collusion is impossible, the firms settle for the highest possible profit from coordination and agree on the lowest output or the highest price that just makes collusion viable. Consequently, a high valuation of the future implied by a high value of the market discount factor increases the scope of collusion in the product market. Explicit or implicit coordination is impossible only if the competitors are very impatient. Then, the gain from cheating dominates over the low discounted future collusive profits. Consequently, the rivals do not attempt to collude, but compete in the market instead. Only the case of *Bertrand* price competition in a homogeneous market requires a qualification of these conclusions. The harsh punishment of defection that yields no profits results in identical thresholds of the valuation of future profits that are consistent with joint monopolization and a less severe restriction of competition by imperfect collusion. Hence, in a *Bertrand* oligopoly the firms always collude perfectly if the value of the market discount factor lies above this critical threshold and compete in prices otherwise.

The basic mechanism of collusion in long-term oligopolistic price or quantity competition is the same irrespective of the number of rivals or the ex-

tent of product differentiation: The tacit or implicit coordination of product market strategies is self-enforcing because repeated interaction offers the opportunity to punish a violation by aggressive competition in the future. As a larger number of market participants as well as a greater heterogeneity of the good decreases the additional profit from the agreement to a greater extent than the one-shot gain from defection, both market concentration and product differentiation facilitate collusion.

The distinction between different types of market demand development offers further conclusions with respect to the scope of collusion and the resulting market outcome. Two key effects of demand fluctuations determine the viability of collusion: The level effect of demand implies that *ceteris paribus* collusion is more difficult if the demand is currently high because the one-shot gain from defection increases in the present demand level, whereas future collusive profits are unaffected. Consequently, a high positive shock on the demand level in the present period has an adverse effect on the viability of an implicit agreement if the shock realizations are uncorrelated over time. Then, only the profit from defection is high, whereas the future expected profits from collusion and punishment are independent of the present realization. The scope of collusion is therefore lower. If due to the shock the present demand level surpasses a certain critical threshold, perfect collusion is impossible. As deviation is more attractive the larger the present profit from collusion is, the firms then reduce the temptation to defect and implicitly agree on a higher output or a lower price. Imperfect collusion hence triggers anticyclical pricing.

The slope effect of demand in contrast results in procyclical pricing: Collusion is easier if the future demand levels are high because then a defecting firm foregoes the high future profits from collusion. Conversely, low future demand levels yield a punishment that might be insufficient to enforce the joint monopolization of the market. Consequently, the firms must reduce the incentive to defect in recessionary periods of falling demand if their valuation of future profits is too low for continual perfect collusion. In the boom times of the cycle where the demand level still increases, collusion is easily achieved since the punishment of defection is high. This slope effect is decisive in markets with a cyclic development of demand. Except if the firms have a very high valuation of future profits, collusion must be made viable by softening the restriction of competition in periods of falling demand. Then, the participants again set a higher output or lower price to restore the incentive to collude. This adjustment is necessary in more periods of the cycle the lower is the firms' valuation of future profits. If a restriction of competition is possible in only one period of the cycle due to a very low value of the future, the firms collude at the peak of the demand cycle and compete in all other periods. Pricing is hence markedly procyclical for all values of the discount factor that give rise to imperfect collusion.

Consequently, a procyclical price that magnifies the fluctuations of demand is consistent with imperfect collusion in markets with cyclic demand development. If the price develops exactly in parallel to demand, the pattern

points to either perfect collusion or unrestrained competition: In both cases, the outputs and the market price increase in the market demand. This conclusion does not depend on the type of demand fluctuations. Anticyclical pricing in turn is consistent only with imperfect collusion in a market with uncorrelated shocks on the demand level. Furthermore, a simultaneous occurrence of a cyclic trend and uncorrelated stochastic shocks yields a superposition of the corresponding price patterns. Hence, the resulting development of the price over time depends on whether the deterministic cyclic trend or the stochastic element dominates the development of the market demand.

Moreover, a pronounced procyclical or anticyclical development of the market price does not document a breakdown of the collusive agreement. Much to the contrary, changes in the price are caused by the adjustment of the implicit agreement to fluctuations in demand that keep collusion viable. Consequently, the demand fluctuations do not cause price wars in the sense of fierce, unrestrained competition.

The conclusions on the price development however depend on the notion that demand is less responsive to price changes the larger the market is. If, in contrast, demand is extremely price elastic, the firms might be forced to reduce the price in periods of high demand even if joint monopolization of the market is possible. Then, the above conclusions on the cyclicity of pricing do not apply. Since the elasticity of demand in equilibrium can be determined empirically, this fact does not preclude the use of the price pattern as an indicator of the extent of collusion in the market. The econometric studies by *Ellison* (1994), *Borenstein, Shepard* (1996) and *Rosenbaum, Sukharomana* (2001) among others demonstrate the relationship between the development of the market price and the extent of collusion in different industries.

The distinction between different types of market demand development offers further conclusions with respect to antitrust policy. The fluctuations of demand change the firms' incentive to participate in an implicit agreement and result in a distinct development of the market price over time. The price pattern is hence a reliable indicator of restrained competition that can be used by the antitrust authority to assess the likeliness of explicit, anticompetitive agreements. With such an evaluation at hand, close investigations to uncover evidence of illegal, explicit coordination can be tightly focused on likely offenders. Welfare losses from collusion are thus avoided by detection and prosecution at low costs of supervision. If the marginal cost of production is approximately constant over time, its level need not be known to be able to draw conclusions on the existence of an implicit agreement. As cost information is needed to assess the extent of collusion in a market with constant demand by deriving the *Lerner* index, changes in the market demand reduce the amount of necessary information. Since firms typically keep cost information secret, demand fluctuations thus may facilitate the detection of collusion (cf., e.g. *Wolfram* 1999).

Strategic Investment with Fluctuating Demand

However, firms make investments in different areas before they compete in the product market. After setting up their capacities, they repeatedly invest to renew the physical capital stock and replace worn-out equipment. These expenditures keep the production process efficient. Since production with used-up machinery blows up production cost, investments in the replacement of worn-out equipment reduce costs in a similar way as process innovations. Hence, repeated replacement investments foster the competitiveness of a firm. Since the potential efficiency gains might be increased by cooperation between the competitors, collaboration in production is most often legal. Given the rather lenient regulation of cooperation in manufacturing, it is a fundamental question whether the coordination of investments facilitates collusion in the product market.¹ If anticompetitive agreements are indeed more likely, this would be a second welfare-reducing factor aside from the potential increase in market power of the cooperating firms that might arise even without additional coordination of the product market strategies. The expected net benefits from synergies are then further reduced and might not justify the favorable antitrust treatment of cooperation between horizontal competitors.

The model proposed here offers a stylized description of the different types of individual and cooperative investments in physical capital and derives their effect on firms' inclination to collude in the product market. Since to date there is no scholarly work on contractual details of cooperation in production, the assumptions on the design of such agreements are chosen to describe the most prominent features of collaborative projects reported in press releases of the participants and in the business press, e.g. the articles in the *Economist* cited in Chapter 2. As most firms regularly invest in order to optimize the production process, cooperation in manufacturing implies the coordination of such investment decisions. In many cases, the competitors produce in a single, jointly owned plant. The model also accounts for the fact that contracts on cooperation in manufacturing are allowed by antitrust regulation if they

¹ We use the terms manufacturing and production synonymously.

give rise to efficiency gains. Therefore, disagreement on the obligations of the partner firms as well as noncompliance with the cooperation contract can be taken to court.

A smooth production process depends on the quality and the state of preservation of the machinery. Thus, the optimal organization of manufacturing requires recurring reinvestments to offset the degradation of the capital stock. A lack of such expenditures does not immediately disrupt the production process since a part of the equipment consists of durable machinery that hardly wears off. In addition, efficient production typically requires more fragile equipment that depreciates fast, such as gauging heads, cutting tools or dies. Therefore, the costs of production with worn-out equipment are usually higher, e.g. due to higher rate of rejects. Thus, firms have some degree of discretion when deciding on the amount of replacement investments. Additional gains from cooperation in this stage might arise from sharing of information on suppliers and the quality of machinery offered, and more favorable conditions to buy or to finance such investments. *Johnson, Houston* (2000) confirm that participants in horizontal cooperation realize synergies.

5.1 Organization of Production

In order to keep our model simple, we consider again a *Cournot* duopoly and describe this investment-quantity competition as an infinite repetition of a two-stage basic game. In the first stage of each period, firm i expends an amount of $\gamma x_i^2/2$ in order to replace a part of the capital stock. Thereby, it reduces the unit cost c that are incurred in the case of production with partly worn-out equipment by $e_B x_i$. Reinvestment costs $\gamma x_i^2/2$ are determined by the firms' opportunities to renew the production machinery. The higher the value of γ the more costly is the replacement of the equipment. The efficiency parameter e_B , $B = I, J, P$ describes the effectiveness of cost reduction achieved by the different types of production where the index I indicates "individual" investment, index J "joint" investment, and index P joint "production" in a single plant. If firms realize synergies by cooperation, as is often claimed, the efficiency parameter e_B is higher the closer firms coordinate their investment decisions. The investments of all firms are observable by the rivals. This mirrors the fact that firms usually monitor each others activities, and workers of rival firms meet and talk about their work. The function

$$\max \{0, C(x_i) = c - e_B x_i\}, \quad (5.1)$$

describes the unit costs of firm i achieved by investments in the production process if there are no fixed costs of production.

The decision on investment in physical capital is related to the problem of optimal research expenditures (cf., e.g. the models on R&D by *D'Aspremont, Jacquemin* 1988 and *Kamien et al.* 1992). However, research and manufacturing differ in important respects. Reinvestments in production serve to renew

and enlarge the stock of physical capital. Since a machine can be employed in only one factory, investments in one plant do not affect the production process in others: Spillovers are zero. Newly gained knowledge, in contrast, often leaks through informal contacts between researchers. Moreover, the true research efforts and results of a partner firm are difficult to observe and even more difficult to prove. Hence, a researching firm can always claim to be unsuccessful despite of high efforts. Judicial enforcement of a certain R&D effort level or of the honest sharing of research results is therefore impossible even if both is ascertained by a cooperation contract. Capital spending, however, can be documented by invoices and delivery notes. It is thus possible to verify the level and purpose of investments, e.g. to prove (non-)compliance with a agreement on cooperation, if necessary in court. To avoid the high costs of legal settlements and possible liquidated damages, the participating firms abide by the contract on cooperation in manufacturing by coordination of the replacement investments or by production in a jointly-owned plant.²

The firms may achieve the optimal production by regular replacement of worn-off capital without cooperation with competitors. Noncooperative investments in production however give rise to a negative externality on rivals that can be mitigated by cooperation. Collaboration in the investment stage of manufacturing is therefore very attractive. In order to account for the fact that cooperation takes various organizational forms, we distinguish two types, namely loose coordination of replacement decisions by *joint investment* and close cooperation by *joint production* in a single plant. These are compared to non-cooperative, *individual investment*. In the case of *joint investment*, the firms produce separately, but coordinate the replacement of machinery and make the investments that maximize their joint profits. In the case of *joint production* in a single plant, the partner firms share the expenditures on the renewal of the equipment and do not produce additional output in separate facilities. Since the production process as well as the output depends on the decision on cooperation, both are different in the cases of *individual investment*, *joint investment* and *joint production*. The part of the production equipment that wears off in a single period and the optimal effective unit cost of production, $c - e_B x_B$, thus also differ across the three cases.

In stage two, the competitors produce and market the good. Given the inverse demand for the homogeneous good (4.1) the firms realize an individual profit that amounts to

² A liquidated damages provision specifies a certain fixed amount to be paid by the party breaching the contract. In principle, the payment is a predetermined estimate of actual damages from an infringement. However, in common-law jurisdictions, liquidated damages are permitted even if they are much higher than the actual damages, whereas contractual penalties are prohibited. Under the German law, contractual penalties are allowed. The difference between *liquidated damages* and *contractual penalties* thus lies in the wording rather than in the content. We use the term *liquidated damages* throughout given its somewhat broader applicability.

$$\pi_i(a_t) = [a_t - q_i - q_j - (c - e_B x_i)] q_i - \gamma x_i^2/2. \quad (5.2)$$

The firms' behavior in the market is the same as in the situation without investments in the production process that was discussed in Section 4.2. If a firm acts noncooperatively in the product market, it maximizes its individual profit, but if it colludes, it maximizes the sum of both firms' profits, considering in both cases the decision on cooperation or noncooperation in manufacturing in the investment stage which will be discussed in the following subsections.³

To highlight the effect of the different factors that influence the inclination to collude, we demonstrate the impact of a firm's investment decision firstly for a market of a constant size, $a_t = a = \text{const. } \forall t$. The adjustment of these decisions in the presence of demand fluctuations will be considered in a second step.

5.1.1 Market Results

Since the attractiveness of collusion depends on the relative sizes of the profits from unrestricted competition, collusion and unilateral deviation from the collusive agreement, we derive the different equilibria in turn for each type of organization of the production process.

Individual Investment

In this case, firms set their investments non-cooperatively in order to maximize their individual profits. We call this *individual investment* and indicate it by index I . The corresponding outputs, investments and profits are derived by solving the respective stage games by backward induction. If the firms compete in the product market, each produces the quantity that maximizes its own profit. The corresponding optimization problem is given by

$$\max_{q_i} \pi_i = [a - q_i - q_j - (c - e_I x_i)] q_i - \gamma x_i^2/2, \quad i, j = 1, 2, \quad i \neq j. \quad (5.3)$$

From the first order condition

$$a - c - 2q_i - q_j + e_I x_i = 0 \quad (5.4)$$

the individual output conditional on the investment decision in the first stage can be derived as

³ Note, that extended to differentiated products this model can also be applied to demand-increasing investments. Then, $a_t + e_B x_i$ is the market size achieved by expenditures $\gamma x_i^2/2$. The assumption that the effect of investment wears off after one period then describes the fact that consumers get used to the change in the design, packaging, or recipe and demand declines again after a while. Hence, regular changes amounting to "rebranding" or additional advertising are needed to keep demand high over time.. Technically, the model is very similar to the one by D'Aspremont, Jacquemin (1988) on R&D with deterministic result.

$$q_i = \frac{a - c - q_j + e_I x_i}{2}.$$

The second order condition is fulfilled, $\partial^2 \pi_i / \partial q_i^2 = -2 < 0$.

In the investment stage of each period, each firm maximizes its individual profit given this conditional output choice by setting the corresponding investment in capital replacement. Hence, it solves the optimization problem

$$\max_{x_i} \pi_i = \frac{[a - c - e_I (2x_i - x_j)]^2}{9} - \frac{\gamma x_i^2}{2}. \quad (5.5)$$

From the first order condition

$$4e_I (a - c + 2e_I x_i - e_I x_j) / 9 - \gamma x_i = 0$$

$$x_{NI} = x_i = x_j = \frac{4e_I (a - c)}{9\gamma - 4e_I^2} \quad (5.6)$$

results as the profit-maximizing investment in the production process. By inserting the investment x_{NI} in the conditional quantity we obtain

$$q_{NI} = q_i = q_j = \frac{3\gamma (a - c)}{9\gamma - 4e_I^2} \quad (5.7)$$

as the individual output and

$$\pi_{NI} = \pi_i = \pi_j = \frac{\gamma (a - c)^2 (9\gamma - 8e_I^2)}{(9\gamma - 4e_I^2)^2} \quad (5.8)$$

as the resulting per-period profit in the *Nash* equilibrium of the stage game. The second order condition requires $8e_I^2/9 - \gamma < 0$ to hold.

However, robustness to perturbations is another attractive feature of an equilibrium. It guarantees that the firms return to the initial output and investments if they found themselves out of the equilibrium and adjust their choice variables either proportional to the deviation of the current value from the equilibrium or proportional to the marginal profitability of the adjustment (i.e. $dy_i/dt = \xi_i (y_i^* - y_i)$ or $dy_i/dt = \xi_i \partial \pi_i / \partial y_i$, where y_i is the choice variable and ξ_i the proportionality factor of firm i). Conversely, local instability implies that an equilibrium will not be reached again if it is slightly perturbed. As is shown by *Hahn* (1962) for one-shot competition without additional long-run decisions and by *Henriques* (1990) and *Suzumura* (1992) for two-stage competition that is technically very similar to the present game with investments in the production process, the equilibrium of a stage game is locally stable if

$$\left| \left(\frac{\partial^2 \pi_i}{\partial x_i \partial x_j} \right) / \left(\frac{\partial^2 \pi_i}{\partial x_i^2} \right) \right| < 1 \quad (5.9)$$

is fulfilled. This condition states that the own effect on the marginal profitability of a change in the variable x_i must be larger than the cross effect of

a change in the variable x_j by the rival. For the present case of competition in the investment levels x_i and x_j , the corresponding condition is given by

$$\left| \frac{4e_I^2}{9\gamma - 8e_I^2} \right| < 1 \Leftrightarrow \gamma > \frac{4e_I^2}{3}.$$

It excludes extremely favorable circumstances for the capital replacement that correspond to very low investment cost implied by a low value of the parameter $\gamma \leq 1.33$.⁴

If a firm participates in an implicit quota agreement, it maximizes the sum of its own and its competitor's profits by setting the corresponding output in the second stage of each period.⁵ To derive the optimal quantity, it solves the problem

$$\begin{aligned} \max_{q_i} \pi_i + \pi_j = & [a - q_i - q_j - (c - e_I x_i)] q_i - \gamma x_i^2 / 2 + \\ & [a - q_i - q_j - (c - e_I x_j)] q_j - \gamma x_j^2 / 2. \end{aligned} \quad (5.10)$$

In the symmetric equilibrium, both firms produce the same collusive quantity conditional on the investment in the first stage. It is given by

$$q_i = (a - c + e_I x_i) / 4, \quad i = 1, 2.$$

In the first stage, firms do not coordinate the replacement of worn-out capital. Each firm invests in the production process to maximize its own profits. Given the collusive quantities determined previously, the corresponding optimization problem amounts to

$$\max_{x_i} \pi_i = \frac{(c - a - e_I x_i) (2c - 2a - 3e_I x_i + e_I x_j)}{16} - \frac{\gamma x_i^2}{2}. \quad (5.11)$$

The optimal *individual investment* that solves this problem is given by

$$x_{AI} = x_i = x_j = \frac{5e_I (a - c)}{16\gamma - 5e_I^2}. \quad (5.12)$$

By inserting the expenditure on capital replacement in the conditional quantity and profit, we calculate the equilibrium values. The collusive output amounts to

$$q_{AI} = q_i = q_j = \frac{4\gamma (a - c)}{16\gamma - 5e_I^2}. \quad (5.13)$$

By producing this quantity, each firm realizes a per-period profit of

⁴ It is simple to verify that the corresponding condition for local stability in the output stage $\left| \left(\frac{\partial^2 \pi_i}{\partial q_i \partial q_j} \right) / \left(\frac{\partial^2 \pi_i}{\partial q_i^2} \right) \right| < 1$ is globally fulfilled for all equilibria discussed in this chapter.

⁵ Since the derivation of the collusive equilibrium requires the same steps as the *Nash*-equilibrium, we shorten the presentation slightly.

$$\pi_{\bar{A}I} = \pi_i = \pi_j = \frac{\gamma (a - c)^2 (64\gamma - 25e_I)}{2 (16\gamma - 5e_I^2)^2}. \quad (5.14)$$

The second order condition in the output stage is again fulfilled, $\partial^2 \pi_i / \partial q_i^2 = -2 < 0$. In the investment stage, the second order condition is given by $3e_I^2/8 - \gamma < 0$. As in the noncollusive equilibrium, the condition for local stability (5.9) implies an additional parameter restriction,

$$\left| \frac{e_I^2}{16\gamma - 6e_I^2} \right| < 1.$$

This inequality rules out very favorable situations for the investment activities that are characterized by values of the technological parameter $\gamma \leq 7e_I^2/16$.⁶

In the case of an unilateral violation of the implicit agreement, the defector maximizes its individual profit and anticipates that the rival continues to collude. If he cheats on the agreement already in the investment stage, the rival firm learns from the noncollusive investment that its competitor plans to cheat on the agreement. Not to raise the suspicion of the rival, a firm hence always sets the collusive investment in the production stage and defects only in the market stage. A deviating firm maximizes its individual profit

$$\max_{q_i} \pi_i = [a - q_i - q_{AI} - (c - e_I x_{AI})] q_i - \gamma x_{AI}^2 / 2. \quad (5.15)$$

by producing the output

$$q_{\bar{A}I} = q_i = \frac{6\gamma (a - c)}{16\gamma - 5e_I^2} \quad (5.16)$$

and gains the one-shot profit

$$\pi_{DI} = \pi_i = \frac{\gamma (a - c)^2 (72\gamma - 25e_I^2)}{2 (16\gamma - 5e_I^2)^2} \quad (5.17)$$

in the period of defection. If it cheats on the agreement already in the investment stage, the rival firm realizes reacts in the second stage by producing a quantity that maximizes its individual profits. In this case, the profit of the defector,

$$\pi_{DI,alt.} = \frac{4\gamma (a - c)^2 (8\gamma - 5e_I^2)^2}{(9\gamma - 8e_I^2) (16\gamma - 5e_I^2)^2},$$

is lower than the one from the first strategy of defection in the output stage alone, π_{DI} , for values of the technological parameter $\gamma > 161e_I^2/136 = 1.18382e_I^2$. Hence, defection only in the second stage is optimal for all locally stable equilibria.

⁶ Note that values of the investment cost parameter $\gamma > 4e_I^2/3$ fulfill the strictest of these conditions. Hence, we restrict attention to such cases.

Table 5.1 summarizes the individual quantities, investments, and per-period profits from competition, collusion, and defection in the market stage that result if firms do not cooperate in the replacement of equipment in the first stage of each period.

Table 5.1. Quantities, Investments, and Profits with *Individual Investment*

	Quantities	Investments	Profits
Punishment	$q_{NI} = \frac{3\gamma(a-c)}{9\gamma-4e_I^2}$	$x_{NI} = \frac{4e_I(a-c)}{9\gamma-4e_I^2}$	$\pi_{NI} = \frac{\gamma(a-c)^2(9\gamma-8e_I^2)}{(9\gamma-4e_I^2)^2}$
Collusion	$q_{AI} = \frac{4\gamma(a-c)}{16\gamma-5e_I^2}$	$x_{AI} = \frac{5e_I(a-c)}{16\gamma-5e_I^2}$	$\pi_{AI} = \frac{\gamma(a-c)^2(64\gamma-25e_I)}{2(16\gamma-5e_I^2)^2}$
Deviation	$q_{DI} = \frac{6\gamma(a-c)}{16\gamma-5e_I^2}$	$x_{DI} = x_{AI}$	$\pi_{DI} = \frac{\gamma(a-c)^2(72\gamma-25e_I^2)}{2(16\gamma-5e_I^2)^2}$

If firms cooperate in manufacturing and coordinate the replacement of physical capital, they set the investments and quantities following the same line of thought. Next, we consider the case of collaboration by *joint investment*.

Joint Investment

If firms cooperate in manufacturing by coordinating their expenditures on the renewal of equipment, they specify their obligations in a formal contract. We model such *joint investment* by assuming that the participating firms choose the level of investment that maximizes joint profits. The corresponding values of investments, quantities and profits are indicated by index J . As capital replacement is firm-specific, the rival's efforts do not directly lower a firm's production costs despite of coordination. However, synergies are often cited as the main motive to cooperate. Most likely they are indeed obtained, for example by improved access to financial markets or shared and thus more detailed information on the quality of capital goods and the sales conditions and reliability of their producers or vendors. In our model, such efficiency gains can be captured by assuming that the effectiveness of cost reducing activities is higher if firms coordinate their investments than in the case of non-cooperative investment, $e_J > e_I$.

In difference to the previous case of *individual investment*, the firms now maximize their joint profits by investing in capital replacement in the first stage of every period, irrespective of whether they compete or collude in the product market. Since the valuation of future profits is determined by the commonly known market discount factor, the firms also foresee whether they will reach a viable implicit agreement and specify the corresponding investment level in the cooperation contract. In the case of infringement, firms incur the cost of a legal settlement and maybe additionally liquidated damages.

Moreover, even the unanimous dissolution of the contract implies transaction costs. Most likely, these costs are prohibitively high, so that a firm that deviates from an illegal quota agreement in the market continues to set the joint-profit-maximizing investment.

The equilibria in the cases of deviation, perfect collusion, and punishment given in Table 5.2 below are again derived by solving the corresponding basic games by backward induction.⁷ Since this solution procedure was demonstrated in detail for the preceding case of *individual investment* we skip the derivations here.

Table 5.2. Quantities, Investments, and Profits with *Joint Investment*

	Quantities	Investments	Profits
Punishment	$q_{NJ} = \frac{3\gamma(a-c)}{9\gamma-2e_J^2}$	$x_{NJ} = \frac{2e_J(a-c)}{9\gamma-2e_J^2}$	$\pi_{NJ} = \frac{\gamma(a-c)^2}{9\gamma-2e_J^2}$
Collusion	$q_{\bar{A}J} = \frac{\gamma(a-c)}{4\gamma-e_J^2}$	$x_{\bar{A}J} = \frac{e_J(a-c)}{4\gamma-e_J^2}$	$\pi_{\bar{A}J} = \frac{\gamma(a-c)^2}{2(4\gamma-e_J^2)}$
Deviation	$q_{DJ} = \frac{3\gamma(a-c)}{2(4\gamma-e_J^2)}$	$x_{DJ} = x_{\bar{A}J}$	$\pi_{DJ} = \frac{\gamma(a-c)^2(9\gamma-2e_J^2)}{4(4\gamma-e_J^2)^2}$

If a firm deviates already in the investment stage, it obtains the one-shot profit

$$\pi_{DJ,alt.} = \frac{4\gamma(a-c)^2(2\gamma-e_J^2)^2}{(4\gamma-e_J^2)^2(9\gamma-8e_J^2)}.$$

Comparison of this alternative profit with the deviation profit gained from an investment at the collusive level π_{DJ} given in Table 5.2 shows that the latter is higher if the slope of the investment cost function fulfills $\gamma > 26e_J^2/17$. This condition holds for all stable equilibria. As in the case of *individual investment*, a defection in the investment stage does not occur even if the investment levels are not contractible.

However, *joint investment* is not the only way to organize collaboration in the manufacturing process. The second widespread type of cooperation consists in production in a jointly owned plant. Next, we will analyze the market performance in this case of close collaboration in the investment stage.

⁷ $\gamma > 10e_J^2/9$ and $\gamma > 3e_J^2/8$ are the second order conditions and $-1 < \frac{8e_J^2}{9\gamma-10e_J^2} < 1$ and $-1 < \frac{e_J^2}{8\gamma-3e_J^2} < 1$ the conditions for local stability of the equilibria in the case of non-cooperative and collusive quantity setting, respectively. In order to ensure stability, we assume $\gamma > 2e_J^2$ to hold. *Salant, Shaffer* (1998) analyze R&D investments in a model that is technically very similar to the one presented here. They show that in the case of cooperative investments profits are maximized by asymmetric R&D expenditures for certain parameter configurations. However, for our linear, normed demand function and perfect appropriability, this is true only for values $\gamma < 2$ ($e_J = 1$ in their setting) that are not consistent with stable equilibria.

Joint Production

If firms cooperate in manufacturing by producing in a single plant, they jointly decide on reinvestments in the stock of physical capital. In the market, however, firms sell their output individually. As mentioned in Chapter 2, prime examples of such collaboration can be found in the automobile industry. We term this type of cooperation *joint production* and denote it by index P . Such close cooperation implies that firms jointly choose the level of cost reduction, $e_P X = e_P (x_i + x_j)$, and share the total investment costs $\gamma X^2/2$ equally.

As firms produce in a jointly owned plant, they cannot reduce the investment without the partner noticing this and taking the case to court. To avoid legal expenses, the firms continue to produce jointly even in the case of defection from the implicit agreement on joint monopolization of the market and the ensuing punishment phase. Defection and punishment is hence restricted to the market stage. All equilibrium values for this type of close cooperation are summarized in Table 5.3. The equilibria are again obtained by solving the corresponding stage games by backward induction.⁸

Table 5.3. Quantities, Investments, and Profits with *Joint Production*

	Quantities	Investments	Profits
Punishment	$q_{NP} = \frac{3\gamma(a-c)}{9\gamma-4e_P^2}$	$x_{NP} = \frac{2e_P(a-c)}{9\gamma-4e_P^2}$	$\pi_{NP} = \frac{\gamma(a-c)^2}{9\gamma-4e_P^2}$
Collusion	$q_{\bar{A}P} = \frac{\gamma(a-c)}{2(2\gamma-e_P^2)}$	$x_{\bar{A}P} = \frac{e_P(a-c)}{2(2\gamma-e_P^2)}$	$\pi_{\bar{A}P} = \frac{\gamma(a-c)^2}{4(2\gamma-e_P^2)}$
Deviation	$q_{DP} = \frac{3\gamma(a-c)}{4(2\gamma-e_P^2)}$	$x_{DP} = x_{\bar{A}P} = \frac{e_P(a-c)}{2(2\gamma-e_P^2)}$	$\pi_{DP} = \frac{\gamma(a-c)^2(9\gamma-4e_P^2)}{16(2\gamma-e_P^2)^2}$

With help of the equilibria derived above, we are now able to compare the effect of the cost-reducing investments in the replacement of equipment on an implicit agreement. Since the market results depend on the organization of the production process, the firms' incentive to collude differs in the three cases of non-cooperation and cooperation in manufacturing.

5.1.2 Feasibility of Collusion

As was shown in the previous chapter, firms participate in perfect collusion if they place a high value on the future. Consequently, there is a critical lower bound of the firms' valuation of future profits that is just sufficient to reach a viable implicit agreement. The joint monopolization of the market is more likely the lower this critical valuation is. At the corresponding threshold of the

⁸ The second order condition for the punishment is given by $\gamma > 4e_P^2/9$, and for the collusive equilibrium by $\gamma > e_P^2/2$. As firms choose the investment required to achieve the cost reduction X_P jointly, local stability of the equilibria is not an issue here.

discount factor, the discounted stream of current and future collusive profits is exactly as large as the one-time gain from cheating and the profit stream in the ensuing infinite punishment phase. Then, the condition for perfect collusion

$$VB(\pi_{AB}, \delta) \equiv \frac{\delta}{1-\delta} (\pi_{\bar{A}B} - \pi_{NB}) - \pi_{DB} + \pi_{\bar{A}B} \geq 0, \quad B = I, J, P \quad (5.18)$$

holds with equality. It is the analog to the one for a market without strategic investments (4.4). Since the per-period profits from the implicit agreement, defection and punishment differ between the cases of *individual investment*, *joint investment*, and *joint production*, different thresholds result from the alternative formulation

$$\delta \geq \underline{\delta}_B \equiv \frac{\pi_{DB} - \pi_{\bar{A}B}}{\pi_{DB} - \pi_{NB}}. \quad (5.19)$$

If the firms' valuation of future profits is insufficient for perfect collusion, they will adjust their implicit agreement and set collusive outputs and investments that fulfill the condition (5.18) as an equality. As the per-period profits from imperfect collusion and defection depend on both the quantity and the expenditure on replacement investments, there is a continuum of quantity-investment combinations that yield an incentive to collude of zero.

To be able to compare the three types of the organization of production with respect to the likeliness of an implicit quota agreement, we calculate the three critical values of the discount factor for perfect collusion between the firms in turn.

If the value of future profits is small due to a low value of the market discount factor, perfect collusion by joint monopolization of the market is impossible. Instead, the firms set the minimal outputs that fulfill the condition for collusion (5.18) as an equality at this value of the discount factor. Compared to joint monopolization of the market, the resulting collusive profits are then lower. Since the basic working of imperfect collusion is clear from the discussion of an implicit agreement in a market without strategic investment, we do not analyze this case in more in detail here. We will return to it in the section on the effect of demand fluctuations below.

For the benchmark case without cooperation in the investment stage, we obtain

$$\delta \geq \underline{\delta}_I \equiv \frac{8 (9\gamma - 4e_I^2)^2}{\gamma (1224\gamma - 233e_I^2) - 58e_I^4} \quad (5.20)$$

by inserting the profits from Table 5.1 in (5.19). The inequality states the condition for perfect collusion between rivals that compete in the investments. If firms value future profits highly, corresponding to a discount factor at least as large as $\underline{\delta}_I$, the above condition is fulfilled and the firms participate in the implicit agreement.

With help of the critical threshold $\underline{\delta}_I$, we are also able to derive the effect of increased efficiency in the replacement of physical capital on the inclination

to collude. The partial derivative of the critical value of the discount factor with respect to the relevant parameter e_I

$$\frac{\partial \delta_I}{\partial e_I} = - \frac{304 \gamma e_I (9 \gamma - 4 e_I^2) (405 \gamma - 104 e_I^2)}{(58 e_I^4 + 233 \gamma e_I^2 - 1224 \gamma^2)^2}$$

is negative by the second order condition for competition. Therefore, collusion in the product market is facilitated if the firms' efforts to reduce production costs are more effective. The reason for this effect is the negative externality of own cost reduction on the rival's profits. Since the profit from defection appears in the denominator and numerator of the critical discount factor (5.20), the effect is largely driven by the changes in the profits from punishment and collusion. By the second order conditions the sign of the partial derivatives

$$\begin{aligned} \frac{\partial \pi_{NI}}{\partial e_I} &= \frac{64 \gamma e_I^3 (a - c)^2}{(4 e_I - 9 \gamma)^3} < 0, \\ \frac{\partial \pi_{AI}}{\partial e_I} &= \frac{5 \gamma e_I (a - c)^2 (25 e_I^2 - 48 \gamma)}{(5 e_I^2 - 16 \gamma)^3} > 0, \end{aligned}$$

can be determined. The competitive profit π_{NI} falls with increasing efficiency because a greater effectiveness of the rival's cost reduction lowers a firm's own profit strongly and requires high investments in its own production process. The lower competitive profit implies a higher potential punishment of a defector. Moreover, the collusive profit π_{AI} rises with greater efficiency e_I . Colluding firms maximize their joint profits and internalize the negative strategic effect. Therefore, a smaller effective cost reduction $e_I x_i$ is optimal, which is achieved by a lower investment in capital replacement. Both effects increase a firm's inclination to participate in an implicit quota agreement.

The inclination to collude and the additional effect of a change in the efficiency of the investment activities differs if firms invest jointly. In this case, the per-period profits given in Table 5.2 determine a firm's incentive to participate in an implicit agreement. In order to derive the lowest value of the discount factor that is consistent with perfect collusion we insert these profits in the corresponding condition (5.19) and obtain

$$\delta \geq \delta_J \equiv \frac{9 \gamma - 2 e_J^2}{17 \gamma - 4 e_J^2}. \quad (5.21)$$

Hence, firms that cooperate by *joint investment* collude if they value future profits highly implying a discount factor that is at least as high as the threshold δ_J given by (5.21).

According to business representatives, an increase in efficiency is the most important reason for cooperation in manufacturing. Thus, it is interesting to determine how such synergies, described by a rise in the efficiency parameter e_J , influence a firm's inclination to collude. The partial derivative of the critical discount factor with respect to the efficiency parameter e_J

$$\frac{\partial \underline{\delta}_J}{\partial e_J} = \frac{4\gamma e_J}{(17\gamma - 4e_J^2)^2}$$

is positive. Therefore, collusion is less likely the higher the effectiveness of cost reductions e_J . The partial derivatives

$$\begin{aligned}\frac{\partial \pi_{NJ}}{\partial e_J} &= \frac{4\gamma e_J (a - c)^2}{(2e_J^2 - 9\gamma)^2} > 0, \\ \frac{\partial \pi_{AJ}}{\partial e_J} &= \frac{\gamma e_J (a - c)^2}{(e_J^2 - 4\gamma)^2} > 0\end{aligned}$$

show that both the profit from competition and collusion increase with rising efficiency e_J . Here, the firms internalize the negative externality either only by cooperation in the investment stage or additionally by implicit coordination in the market. However, the increases of competitive and collusive profits have counteracting effects on the feasibility of collusion. The negative sign of the difference between these partial derivatives

$$\frac{\partial \pi_{NJ}}{\partial e_J} - \frac{\partial \pi_{AJ}}{\partial e_J} = \frac{\gamma^2 e_J (a - c)^2 (4e_J^2 - 17\gamma)}{(2e_J^2 - 9\gamma)^2 (e_J^2 - 4\gamma)^2} < 0.$$

demonstrates that the competitive profit rises less than the collusive profit. Hence, *joint investment* makes illegal anti-competitive agreements less likely if it yields synergies.

If the firms cooperate in manufacturing by producing in a joint plant, their inclination to participate in an implicit agreement depends on the corresponding per-period profits given in Table 5.3. By inserting these profits in condition (5.19), we obtain

$$\delta \geq \underline{\delta}_P \equiv \frac{9\gamma - 4e_P^2}{17\gamma - 8e_P^2}. \quad (5.22)$$

as the condition for perfect collusion. Firms that cooperate by *joint production* participate in collusion if they value future profits highly, i.e. if the discount factor is at least as high as the critical value $\underline{\delta}_P$ defined by (5.22).

As in the case of *joint investment*, the positive sign of the partial derivative with respect to the efficiency parameter

$$\frac{\partial \underline{\delta}_P}{\partial e_P} = \frac{8\gamma e_P}{(17\gamma - 8e_P^2)^2}$$

demonstrates that the firms have to place a higher value on future profits to be able to collude if they realize high synergies. The difference between the partial derivatives of the per-period profits from competition and from a quota agreement

$$\frac{\partial \pi_{NP}}{\partial e_P} - \frac{\partial \pi_{\bar{A}P}}{\partial e_P} = \frac{\gamma^2 e_P (a-c)^2 (8e_P^2 - 17\gamma)}{2(4e_P^2 - 9\gamma)^2 (e_P^2 - 2\gamma)^2} < 0$$

is negative by the second order condition for collusion. If the firms' effectiveness in cost reductions rises, the increase in the collusive profit does not outweigh the greater reduction of the potential punishment. Thus, the reason for the lower inclination to collude is the same as in the case of *joint investment*.

As in the basic case without investment in production, the feasibility of collusion depends on the value that firms place on future profits. Since the critical threshold of the discount factor is a convenient measure of a firm's inclination to collude, the effect of the organization of production and the efficiency of the cost-reducing replacement investments can be illustrated by a graphical representation of the three critical lower bounds, $\underline{\delta}_I$, $\underline{\delta}_J$ and $\underline{\delta}_P$ derived above.

These lowest values of the discount factor, that are consistent with perfect collusion are depicted in Figure 5.1. Note, that the second order conditions require $\gamma > 8e_I^2/9 \simeq 0.89e_I^2$ in the case of *individual investment*, $\gamma > 10e_J^2/9 \simeq 1.1e_J^2$ in the case of *joint investment*, and $\gamma > e_P^2/2$ in the case of *joint production*. These conditions are represented by the dashed vertical lines in Figure 5.1 for values of the efficiency parameter $e_B = 1$, and $e_B = 1.5$, $B = I, J, P$.

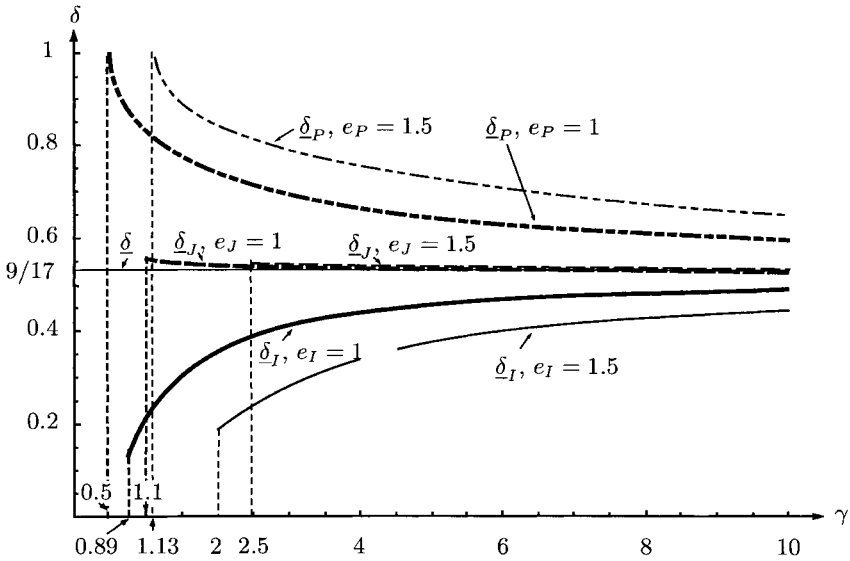


Figure 5.1. Feasibility of Collusion with Different Organization of Production

The lower the threshold of the discount factor the larger is the scope for collusion. Thus, a comparison of the thresholds for *joint production* $\underline{\delta}_P$, *joint investment* $\underline{\delta}_J$, and *individual investment* $\underline{\delta}_I$ determines the ranking of the three types of production organization with respect to the feasibility of collusion. It demonstrates that firms gain the widest scope for collusion if they do not cooperate in the investment stage. This finding stands in sharp contrast to experts' warnings in the discussions on the legal treatment of cooperation in manufacturing.

Technically, straightforward comparisons of the analytical expressions for the critical values $\underline{\delta}_P$ in (5.22), $\underline{\delta}_J$ in (5.21), and $\underline{\delta}_I$ in (5.20) lead to the following conclusions. The inequality $\underline{\delta}_P > \underline{\delta}_J$ holds for all values of the investment cost parameter γ that fulfill the respective second order conditions if the effectiveness of cost reductions is the same in the cases of *joint investment* and *joint production*, $e_P = e_J$. Comparison of the derivatives of the last two thresholds with respect to the efficiency parameter shows that the critical threshold $\underline{\delta}_P$ rises stronger in the efficiency parameter e_P than $\underline{\delta}_J$ in e_J . Therefore, the inequality $\underline{\delta}_P > \underline{\delta}_J$ is all the more true if firms realize synergies and make more effective reinvestments if they cooperate more closely, $e_P > e_J$. Furthermore, the ranking $\underline{\delta}_J > \underline{\delta}_I$ holds for $\gamma < 2e^2 (378 - 19\sqrt{17})/2613$ and $\gamma > 2e^2 (378 + 19\sqrt{17})/2613$ if investments are equally effective in both cases, $e_I = e_J = e$. The first range of γ is excluded, but the last inequality holds by either of the second order conditions for the collusive equilibria, $\gamma > 3e_I^2/8$ or $\gamma > 3e_J^2/8$. Above, we demonstrated that the critical value of the discount factor $\underline{\delta}_I$ falls, but $\underline{\delta}_J$ rises in the efficiency of cost reductions. The conclusion that collusion is more difficult in the case of *joint investment* than in the case of *individual investment*, $\underline{\delta}_J > \underline{\delta}_I$, is therefore strengthened if the *joint investment* gives rise to efficiency gains, $e_J > e_I$. Figure 5.1 illustrates these results that are summarized by the chain of inequalities

$$\underline{\delta}_P > \underline{\delta}_J > \underline{\delta}_I. \quad (5.23)$$

It confirms that collusion is most difficult in the case of joint production, less difficult in the case of joint investment, and least difficult if firms compete in the investments.

Already the basic case of collusion without investments demonstrates that the

attractiveness of an implicit agreement depends on the relative amounts of the profits from collusion, defection and punishment (cf. condition (4.2)). The relative size of profits also offers an explanation why the critical threshold of the discount factor for collusion is lowest in the case of *individual investment*. Figure 5.1.2 illustrates the development of the corresponding per-period profits, adjusted by division by $(a - c)^2$, in dependence of the investment cost parameter γ . The thin lines show the profits obtained without investments, the thick lines those gained from *individual investment* when $e_I = 1$.

Figure 5.1.2 demonstrates that the profit from unrestrained competition is lower than without such cost-reducing capital replacement. This illustrates

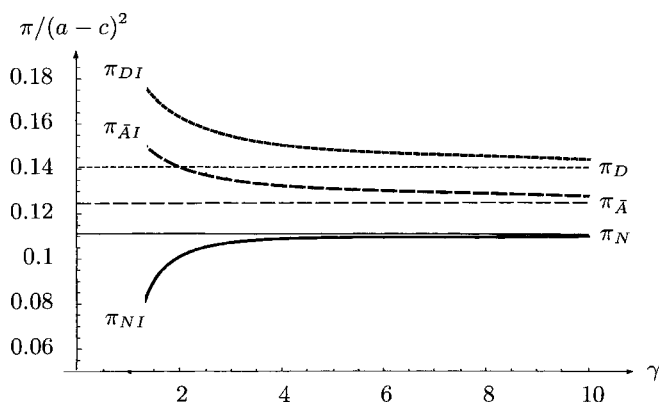


Figure 5.2. Per-Period Profits with *Individual Investment* and without Investments

that cost reduction is a “tough” strategy in the terminology introduced by *Fudenberg, Tirole* (1984) if firms compete in strategic substitutes (as is the case with quantity competition when the good is homogeneous, cf. *Bulow et al.* 1985). Here, a high production by a firm induces its rival to set a low output. Production of a large quantity is especially profitable if the production cost is low due to high expenditures on capital replacement. Since the competitors are symmetric, this argument applies to both of them. Hence, both make high investments and produce a large output. Not investing would even make the situation worse because a firm gains even lower profits if the competitor alone invests. The possibility to reduce the production cost hence gives rise to a prisoners’ dilemma, where the rivals compete more aggressively and gain lower profits than in a market without investments in the production process. Profits from collusion and defection in the market stage, however, are increased by efforts to reduce unit costs by capital replacement compared to profits gained without replacement investments. When colluding, firms internalize the negative effect of own cost reduction on the rival’s profit by joint-profit maximization in the market stage. This effect together with the lower competitive profit, i.e. higher punishment, overcompensates the increased one-shot gain from defection so that collusion is more stable than without the replacement of physical capital. As argued in the discussion of the effect of increased effectiveness of the investment activities, this “tough” strategic effect also determines the changes of per-period profits caused by efficiency gains. Therefore, the effects of investments are even more pronounced the higher the synergies.

Perhaps surprisingly, firms’ inclination to collude is lower than without investment if they invest jointly. Such cooperative cost-reducing capital replacement increases the profit from defection more than the collusive profit which in turn rises stronger than the profit from punishment compared to

the respective profits gained without a regular renewal of worn equipment. Analytically,

$$(\pi_{DJ} - \pi_D) - (\pi_{AJ} - \pi_A) = \frac{(a-c)^2 e_J^2 (8\gamma - e_J^2)}{64 (4\gamma - e_J^2)^2} > 0 \quad \text{for } \gamma > e_J^2/8 \quad \text{and}$$

$$(\pi_{AJ} - \pi_A) - (\pi_{NJ} - \pi_N) = \frac{e_J^2 (a-c)^2 (17\gamma - 2e_J^2)}{72 (4\gamma - e_J^2) (9\gamma - 2e_J^2)} > 0 \quad \text{for } \gamma > 2e_J^2/17.$$

Thus, both differences of profits are positive by the second order condition for collusion. This holds for all degrees of efficiency e_J . For the sake of concreteness, Figure 5.1.2 shows the per-period profits for an effectiveness in cost reduction of $e_J = 1$.

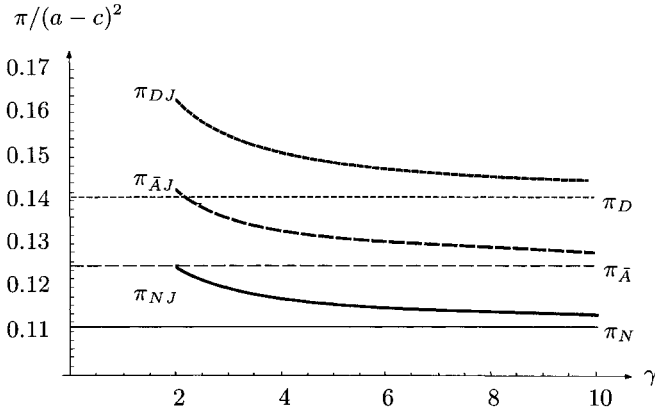


Figure 5.3. Per-Period Profits with *Joint Investment* and without Investments

As firms that invest jointly internalize the negative effect of unit-cost reductions, cheating on a competitor that trustfully sets the collusive output quota is all the more profitable. Moreover, the profit from competition in the market stage is also higher implying a lower punishment. The collusive profit does not offset this incentive to defect from the agreement. Therefore, collusion is less stable than in a market where firms cannot reduce production costs.

In the case of *joint production* the incentive to collude is even lower than in the case of *joint investment* due to the additional increase of profits that results from the saving of investment costs implied by production in a single plant. Again, the competitive profit and the defection profit rise stronger than the collusive profit. The effect on these profits and the corresponding profits without investment is qualitatively identical to the case of *joint investment*. The analytical derivation is thus omitted.

Note also, that the above effects of cost-reducing investments in the cases of *individual investment*, *joint investment* and *joint production* are most pro-

nounced for low replacement costs, corresponding to a low value of the parameter γ . If conditions for reinvestment in physical capital are unfavorable, however, these are small and the critical thresholds of the discount factors converge against the critical value $\delta = 9/17$ that is relevant in a market where unit costs cannot be reduced by investing.

5.1.3 Profitability of Cooperation in Production

The ranking of profits gained by *individual investment*, *joint investment*, and *joint production* is also a result of different extents of the strategic effect of cost-reducing investments in the production process. If firms compete in the investment stage, the cost-reduction imposes a negative externality on the rival's profit. If firms cooperate by *joint investment* or by *joint production*, they internalize this negative effect. Moreover, the individual profit gained by *joint production* is higher than the one gained by *joint investment* because equipment has to be replaced in only one plant. If a firm takes part in an implicit agreement in the market stage, it also accounts for the negative effect of a larger production on rival's profit. Therefore, collusive profits are higher than competitive profits given the organization of production. In short, the per-period profit is larger, the more intense cooperation in the investment decision. Furthermore, it is higher if firms also implicitly coordinate their output decisions in the market stage.⁹ Figure 5.1.3 shows the per-period profits for a situation where the organization of production does not influence firms' effectiveness in cost reduction and $e_I = e_J = e_P = 1$. The vertical lines again indicate the lower bounds of the investment cost parameter γ that are consistent with the respective second order conditions for unrestricted competition.

Analytically, these conclusions are confirmed by comparisons of the per-period profits given in Tables 5.1, 5.2, and 5.3. They lead to the following inequalities:

$$\begin{aligned} \pi_{\bar{A}P} &> \pi_{\bar{A}J} \quad \text{for} \quad e_P > e_J/\sqrt{2}, \\ \pi_{\bar{A}J} &> \pi_{\bar{A}I} \quad \text{for} \quad \gamma > [25e_I^2(e_J^2 - e_I^2)] / [64e_J^2 - 60e_I^2], \\ \pi_{NP} &> \pi_{NJ} \quad \text{for} \quad e_P > e_J/\sqrt{2} \quad \text{and} \\ \pi_{NJ} &> \pi_{NI} \quad \text{for} \quad \gamma > [8e_I^2(e_J^2 - e_I^2)] / [9e_J^2]. \end{aligned}$$

These inequalities hold by the respective second order condition.

$$\begin{aligned} \pi_{NP} &< \pi_{\bar{A}I} \quad \text{for} \quad e_P > \left\{ 9\gamma - \left[2(16\gamma - 5e_I^2)^2 \right] / [64\gamma - 25e_I] \right\} / 4 \quad \text{and} \\ \pi_{NP} &< \pi_{\bar{A}J} \quad \text{for} \quad \gamma > 2(e_P^2 - e_J^2) \end{aligned}$$

⁹ Firms anticipate whether the value of future profits is sufficiently high to allow for collusion and compete in the market otherwise. Therefore, defection does not occur in equilibrium. Hence, the profits from defection are not discussed here and are also omitted in the Figure 5.1.3.

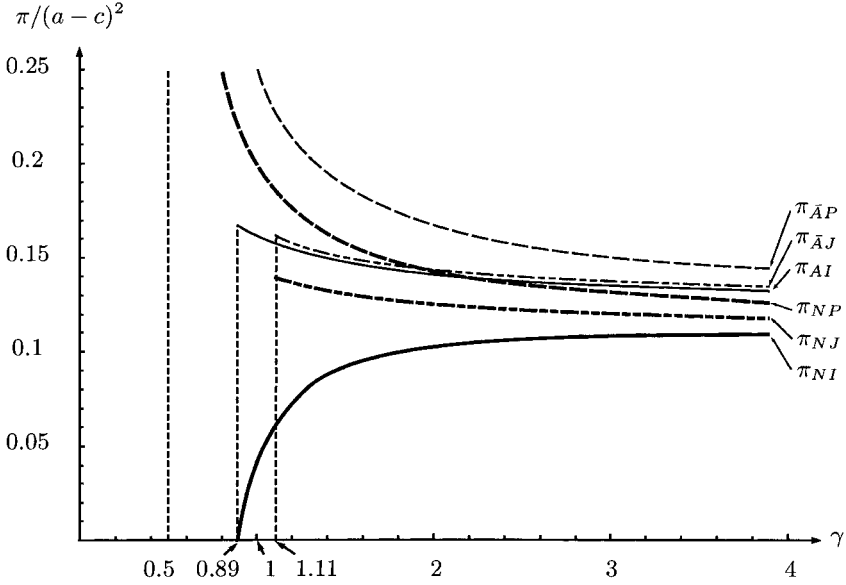


Figure 5.4. Per-Period Profits from Collusion and Quantity Competition

complete the comparison. In short,

$$\pi_{\bar{A}P} > \pi_{\bar{A}J} > \pi_{\bar{A}I} > \pi_{NP} > \pi_{NJ} > \pi_{NI}, \quad (5.24)$$

holds for values γ fulfilling $e_P > \left\{ 9\gamma - \left[2(16\gamma - 5e_I^2)^2 \right] / [64\gamma - 25e_I] \right\} / 4$. Put differently, this profit ranking results except if the conditions for investments in production are extremely favorable.

Thus, even the lowest collusive profit $\pi_{\bar{A}I}$ is higher than the highest competitive profit π_{NP} except if the capital replacement is inexpensive due to a very shallow slope γ of the investment cost. Since in the case of *joint production* firms need only invest in a single plant, the replacement investments that are necessary to achieve a certain level of unit costs are lower than in all other cases. If the costs of capital replacement are low, this cost saving outweighs the profit increase associated with collusion. As a result, the profit from *joint production* is higher than from *individual investment* even if firms compete in the first and collude in the second case. In all other situations, the ranking of profits is independent of technological conditions that is described by the investment cost parameter γ .

5.1.4 Number of Firms, Market Size and Welfare

Apart from the negative impact of cooperation in production on collusion, the present model proves the robustness of the previous results on the market size and, most importantly, welfare.

Earlier work, e.g. by *Brod, Shivakumar (1997)* and *Hinloopen (2000)*, accounts for the number of competitors in the market. Except for the potential efficiency gains measured by e_B , these models are technically identical to the present two-stage basic games and so their conclusions continue to hold. Since the derivation of the results for the oligopoly case is in large parts a replication of earlier work, we skip this analysis here.

The effect of the market size on *Nash*-competitive and collusive pricing is determined by the sensitivity of the price to demand changes. Hence, we postpone its analysis to the section on demand fluctuations.

From the perspective of policy agencies, the social welfare is the most appropriate benchmark for a comparison of the market results with different degrees of cooperation in the investment stage and different product market strategies, i.e. collusion or competition.

By (4.66), welfare is defined as the sum of consumer surplus and the sum of the firms' profits. If both firms produce in separate plants this amounts to

$$W(Q) = (a - Q/2) Q - [c - e_B x] Q - \gamma x^2, \quad B = I, J \quad (5.25)$$

where Q is the total quantity produced in the market. The first term states the sum of the consumer surplus and the gross profits of both firms, the second term the total production costs and the third term the total expenditures on capital replacement. If production takes place in a jointly owned plant, welfare is given by

$$W(Q) = (a - Q/2) Q - [c - e_P X] Q - \gamma X^2/2, \quad (5.26)$$

By inserting the equilibrium quantities and investments from Tables 5.1, 5.2, and 5.3 in these equations we derive the social welfare achieved by the three types of organizing production. The resulting welfare levels are summarized in Table 5.4.

Table 5.4. Welfare with Different Organization of Production

	Punishment	Collusion
<i>Individual Investment</i>	$W_{NI} = \frac{4\gamma(a-c)^2}{(9\gamma-4e_I^2)^2}$	$W_{\bar{AI}} = \frac{\gamma(a-c)^2(96\gamma-25e_I^2)}{(16\gamma-5e_I^2)^2}$
<i>Joint Investment</i>	$W_{NJ} = \frac{4\gamma(a-c)^2(9\gamma-e_J^2)}{(9\gamma-2e_J^2)^2}$	$W_{\bar{AJ}} = \frac{\gamma(a-c)^2(6\gamma-e_J^2)}{(4\gamma-e_J^2)^2}$
<i>Joint Production</i>	$W_{NP} = \frac{4\gamma(a-c)^2(9\gamma-2e_P^2)}{(9\gamma-4e_P^2)^2}$	$W_{\bar{AP}} = \frac{\gamma(a-c)^2(3\gamma-e_P^2)}{2(2\gamma-e_P^2)^2}$

As one would expect, the welfare levels are higher the higher firms' efficiency in cost reduction is. In order to see this, consider the partial derivatives

$$\begin{aligned}
\partial W_{NI} / \partial e_I &= 32 \gamma e_I (a - c)^2 / (9 \gamma - 4 e_I^2)^2 > 0. \\
\partial W_{\bar{A}I} / \partial e_I &= 10 \gamma e_I (a - c)^2 (112 \gamma - 25 e_I^2) / (16 \gamma - 5 e_I^2)^3 > 0 \\
\partial W_{NJ} / \partial e_J &= 8 \gamma e_J (a - c)^2 (27 \gamma - 2 e_J^2) / (9 \gamma - 2 e_J^2)^3 > 0 \\
\partial W_{\bar{A}J} / \partial e_J &= 2 \gamma e_J (a - c)^2 (8 \gamma - e_J^2) / (4 \gamma - e_J^2)^3 > 0 \\
\partial W_{NP} / \partial e_P &= 16 \gamma e_P (a - c)^2 (27 \gamma - 4 e_P^2) / (9 \gamma - 4 e_P^2)^3 > 0 \\
\partial W_{\bar{A}P} / \partial e_P &= \gamma e_P (a - c)^2 (4 \gamma - e_P^2) / (2 \gamma - e_P^2)^3 > 0.
\end{aligned}$$

The first derivative is obviously positive. The sign of the following five derivatives follows from the respective second order conditions.

If production takes place in two plants, investments are required in both of them in order to reduce unit costs, but if the total quantity is produced in one plant there is only one production process that has to be optimized. Investment costs are lower and welfare is higher in this case. Thus, a social planner maximizes the welfare level (5.26) and sets $X^* = [(a - c) e_P] / [\gamma - e_P^2]$ and $Q^* = [\gamma (a - c)] / [\gamma - e_P^2]$ as the optimal investment and quantity. In the first best case, the social welfare level is

$$W^* = \frac{\gamma (a - c)^2}{2 (\gamma - e_P^2)}. \quad (5.27)$$

In the benchmark case without investment, social welfare amounts to

$$W_N = 4/9 (a - c)^2, \quad (5.28)$$

$$W_{\bar{A}} = 3/8 (a - c)^2, \quad (5.29)$$

in the case of competition and collusion between the firms, respectively. If unit-cost-reducing investments are prohibitively expensive, firms' investment levels converge to zero and the above levels of welfare result.

Figure 5.1.4 shows the different welfare levels for the case without synergies from collaboration, $e_I = e_J = e_P = 1$. Comparison of the welfare achieved by investing shows that no extent of cooperation leads to the maximal welfare that would result from investments and quantities chosen by a social planner. The second best in terms of welfare is *joint production* with competition in the market. This follows from the avoidance of duplicative investments. Whereas in the cases of *joint investment* and *individual investment* both firms have to spend the same amount in order to achieve a certain level of unit cost, they invest in a single plant and share the resulting expenses in the case of *joint production*. Thus, they reach the same level of production costs by much lower investments. This saving makes *joint production* superior to the other two types of organizing manufacturing given competition or collusion in the product market. In the other two cases, the firms produce in separate plants. Hence, both competitors have to optimize their production process. Out of the two cases with separate production, the non-cooperative, *individual investment* should be chosen by a policy maker since here firms do not internalize

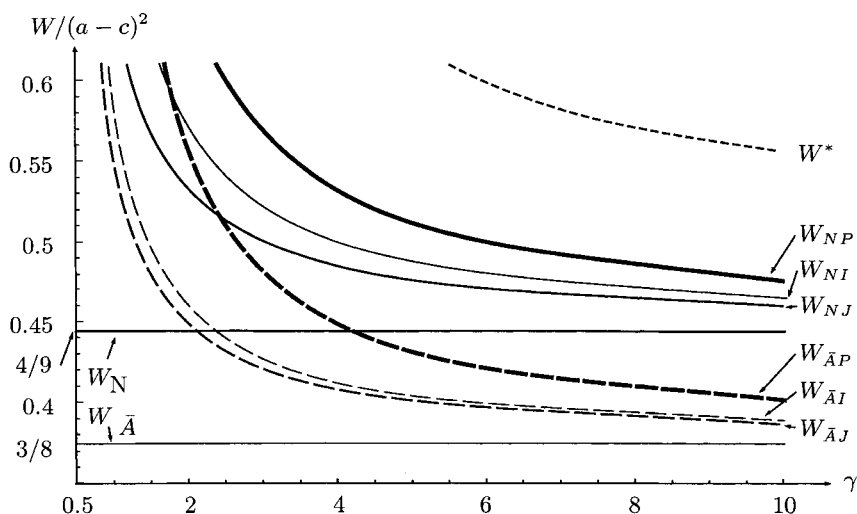


Figure 5.5. Welfare with Different Organization of Production

the negative effect of own cost reduction on rivals' profits. Hence, investments and quantities are higher, the market price is lower, and a higher welfare than in the case of *joint investment* results. Moreover, given the organization of production, collusion implies a lower welfare than competition. As a firm that takes part in an implicit agreement accounts for the fact that a reduction of its own quantity increases the rival's profit, it invests less and additionally reduces output in order to achieve a higher market price. This in turn hurts consumers and reduces welfare. Only in the case of low investment costs (a low value of γ) is *joint production* superior to all other cases (except of course *joint production* with competition in the market) even if the firms collude. The results for equal efficiency are obtained by straightforward comparison of the welfare levels given in Table 5.4. The ranking for differences in the efficiency parameters are obtained analogously. The proof is hence omitted.

To sum up, the welfare ranking of *joint production*, *individual investment*, and *joint investment* results in the case of either unrestrained quantity competition or an implicit quota agreement. Given the organization of production, welfare is lower in the case of collusion than in the case of competition in the product market, except if the investment costs are low, i.e. the value of the technological parameter γ is very small.

The preceding discussion of individual and cooperative reinvestments in the capital stock demonstrated their private and social profitability as well as their effect on collusion. However, the results were derived for the special case of a market where the demand level is constant over time. Since the market demand level typically changes over time, it is important to check whether

the conclusions still apply in a framework that accounts for demand fluctuations. Only if the theoretical analysis proves to be robust to the integration of changing market demand, it offers some reliable guidance for the assessment of market power and the appropriability of the antitrust regulation of cooperation in production.

5.2 Demand Fluctuations

Consider first the effect of demand fluctuations on the individual profits and welfare levels gained from the three types of organization of production. These are given in the Tables 5.1, 5.2, 5.3 and 5.4, respectively. Inspection of the analytical expressions demonstrates that the current demand level always enters in a quadratic difference of the market size and the initial level of the production cost. This term $(a - c)^2$ does not affect the comparison of the individual profits or the welfare levels. Therefore, the rankings with respect to the private and social profitability that we derived in the Sections 5.1.3 and 5.1.4 hold irrespective of the demand development. Consequently, the results also apply to the cases of independently identically distributed shocks and cyclic demand changes.

Our main interest however lies in the effect of noncooperative and cooperative manufacturing on the viability of collusion in the product market. The basic trade-off between the discounted stream of profits gained by participation in a quota agreement and the sum of the one-shot defection profit and the discounted future profits from the subsequent punishment phase arises without and with fluctuations of the market demand. Yet, the sizes of the two alternative discounted profit streams depend on the current and future demand levels. To make collusion viable the firms have to account for demand changes by implicitly agreeing on output levels conditional on the current and expected future demand for their good.

The analysis of long-term competition without strategic investments in Chapter 4 demonstrates that the adjustment of a firm's competitive or collusive strategy depends on the exact pattern of the demand development. It may be expected that this is also true if the competitors invest in cost-reducing replacement of worn-out production equipment. Therefore, we again derive the product market strategies for the cases of uncorrelated stochastic shocks and cyclic fluctuations of the demand level. Since changes in the firms' inclination to collude result in changes of the market price over time, the pattern of price fluctuations can be used as an indicator of the scope of collusion in the product market. To be able to relate different patterns of the price development to the underlying collusive strategies, we derive the parameter constellations that correspond to a pro- or anticyclic development of the output and prices for the three types of organization of production.

To facilitate the discussion of demand shocks and cycles, we will first derive the effect of an increase or decrease in the market demand level on

outputs and prices. The inspection of the outputs in the noncollusive and collusive equilibria stated in Tables 5.1, 5.2, and 5.3 is sufficient to verify that they are larger the higher is the demand level in the current period. For the convenience of the reader, we summarize the resulting prices in equilibria with *individual investment*, *joint investment*, and *joint production*, and their reaction to demand changes in Tables 5.5 and 5.6.

Table 5.5. Prices with Different Organization of Production

	Punishment	Collusion
<i>Individual Investment</i>	$p_{NI} = \frac{6c\gamma + a(3\gamma - 4e_I^2)}{9\gamma - 4e_I^2}$	$p_{AI} = \frac{8c\gamma + a(8\gamma - 5e_I^2)}{16\gamma - 5e_I^2}$
<i>Joint Investment</i>	$p_{NJ} = \frac{6c\gamma + a(3\gamma - 2e_J^2)}{9\gamma - 2e_J^2}$	$p_{AJ} = \frac{2c\gamma + a(2\gamma - e_J^2)}{4\gamma - e_J^2}$
<i>Joint Production</i>	$p_{NP} = \frac{6c\gamma + a(3\gamma - 4e_P^2)}{9\gamma - 4e_P^2}$	$p_{AP} = \frac{c\gamma + a(\gamma - e_P^2)}{2\gamma - e_P^2}$

Table 5.6. Derivatives of Prices with Respect to the Demand Level

	Punishment	Collusion
<i>Individual Investment</i>	$\frac{\partial p_{NI}}{\partial a} = \frac{3\gamma - 4e_I^2}{9\gamma - 4e_I^2}$	$\frac{\partial p_{AI}}{\partial a} = \frac{8\gamma - 5e_I^2}{16\gamma - 5e_I^2}$
<i>Joint Investment</i>	$\frac{\partial p_{NJ}}{\partial a} = \frac{3\gamma - 2e_J^2}{9\gamma - 2e_J^2}$	$\frac{\partial p_{AJ}}{\partial a} = \frac{2\gamma - e_J^2}{4\gamma - e_J^2}$
<i>Joint Production</i>	$\frac{\partial p_{NP}}{\partial a} = \frac{3\gamma - 4e_P^2}{9\gamma - 4e_P^2}$	$\frac{\partial p_{AP}}{\partial a} = \frac{\gamma - e_P^2}{2\gamma - e_P^2}$

The derivatives of the equilibrium prices with respect to the demand level stated in Table 5.6 are positive by the conditions for local stability of the equilibria if firms invest individually or jointly. The corresponding perfectly collusive and *Nash*-competitive prices also increase in the level of demand. Pricing is hence procyclical both if the firms compete and if they jointly monopolize the market.

Joint production is an exception to this however. If the technological conditions for reinvestments are very favorable, the price decreases in the demand level. This effect arises in the case of *Nash* competition for a value of the investment cost parameter γ in the small interval $[0.44e_P^2, 1.33e_P^2]$ and for collusion in $[0.5e_P^2, e_P^2]$. In the cases where the respective partial derivative is negative, the equilibrium prices decrease in the demand level. This seemingly counterintuitive effect is caused by very favorable technological conditions that result from a smooth slope of the investment cost function γ . At low cost of capital replacement large cost reductions are optimal that offer the possibility to produce high quantities at low prices. However, the profits still increase in the demand level due to very low expenditures on reinvestments

in the production process. Since the critical parameter range is very small, we exclude these cases in the detailed discussion of demand fluctuations that follows.

With all other types of organization of production, the effect of cost savings by replacement investment is never as strong since production takes place in two plants and reinvestments have to be made in both of them. Therefore, the market price as well as outputs and profits of the firm increase in the demand level in the corresponding equilibria.

5.2.1 Demand Shocks

Firstly, we consider again the periodic independently, identically distributed shocks on the demand level that are introduced in Section 4.3. The preceding analysis demonstrated the procollusive effect of a high market discount factor that implies a high value of future profits. Hence, we focus on the effect of changes in the demand level here. To be able to describe perfect and imperfect collusion in the same model, we assume again that joint monopolization is possible at the lowest level $V(\pi_{\bar{A}B}, \underline{a}, \delta) > 0$, but impossible at the highest level of the market demand $V(\pi_{\bar{A}B}, \bar{a}, \delta) < 0$ irrespective of the organization of production.

By inserting the equilibrium profits from Tables 5.1, 5.2, and 5.3, we obtain the incentive to collude in a market with *i.i.d.* shocks on the demand level analogous to (4.20) as

$$V(\pi_{AB}, a_t, \delta) \equiv \frac{\delta}{1 - \delta} \left[\int_{\underline{a}}^{\bar{a}_B} \pi_{\bar{A}B}(q_{\bar{A}B}, a) f(a) da + [1 - F(\bar{a})] \pi_{AB}(q_{AB}, \bar{a}) - \int_{\underline{a}}^{\bar{a}} \pi_{NB}(q_{NB}, a) f(a) da \right] - \pi_{DB}(q_{DB}, q_{AB}, a_t) + \pi_{AB}(q_{AB}, a_t), \quad B = I, J, P. \quad (5.30)$$

The right hand side in the first line states the discounted profits from the implicit agreement and accounts for the fact that perfect collusion is possible only if the level of market demand is not too high. The integral in the second line indicates the profit from the punishment phase and the last two terms subtract the net gain from defection. Hence, the incentive to collude is given by the total discounted profits from participation in the agreement net the alternative discounted profit stream that is realized by defection and the ensuing punishment. As in a market where firms do not invest in the production process, the firms participate in the implicit agreement as long as the additional net gain from collusion given by $V(\pi_{AB}, a_t, \delta)$ is not negative.

Since the additional expected future collusive profits are independent of the current demand realization, the incentive to collude decreases in the present demand level a_t if the additional gain from defection increases in demand. The signs of the respective partial derivatives

$$\frac{\partial [\pi_{DI}(a_t) - \pi_{AI}(a_t)]}{\partial a_t} = \frac{8(a_t - c)\gamma^2}{(16\gamma - 5e_I^2)^2} > 0 \quad (5.31)$$

$$\frac{\partial [\pi_{DJ}(a_t) - \pi_{AJ}(a_t)]}{\partial a_t} = \frac{(a_t - c)\gamma^2}{2(4\gamma - e_J^2)^2} > 0 \quad (5.32)$$

$$\frac{\partial [\pi_{DP}(a_t) - \pi_{AP}(a_t)]}{\partial a_t} = \frac{(a_t - c)\gamma^2}{2(4\gamma - e_P^2)^2} > 0 \quad (5.33)$$

demonstrate that the latter is indeed the case. As perfect collusion is viable at the lowest level of demand $\underline{a}$, but not at the highest $\bar{a}$ there is a single demand realization $\tilde{a}_B$, $B = I, J, P$ that fulfills the respective condition for collusion

$$V(\pi_{AB}, a_t, \delta) \geq 0 \quad (5.34)$$

with equality. As in the case without additional investments, perfect collusion is possible only in the lower range of the demand realizations $[\underline{a}, \tilde{a}_B]$.

To decrease the incentive to cheat on the agreement in periods of high demand $a_t \in (\tilde{a}_B, \bar{a}]$, the firms have to reduce the current per-period profit from collusion by setting the investment level and output that just fulfills the condition for collusion (5.34) with equality. These investment and production levels that make the firms indifferent between participation and defection in the present period yield the highest gain from the implicit agreement because they require the smallest sacrifice of current collusive profits. Since the firms can influence the level of current profits both by changing the output and the investment, there is a continuum of quantity-investment combinations that yield an incentive to collude of zero.

Hence, the adjustment of the implicit agreement yields an additional problem of coordination on an optimal pair of collusive strategies compared to the situation without strategic investments. Since the decision on the investment level determines the firms' strategy for a longer time than the output decision it seems likely that the firms will continue to make the expenditures that are consistent with perfect collusion and adjust the output level only. Then, the duopolists decrease the collusive profit below the level that is consistent with joint monopolization in periods of high demand by producing a larger quantity. Consequently, the market price develops anticyclically. However, at the other extreme, the same result is achieved by the continual setting of the output that corresponds to joint monopolization, while only the investment level is adjusted to make the incentive to collude zero. The market price is then constant over time. All other solutions lie between these extreme cases. Thus, the output is always expanded above the monopoly level and causes a fall of the market price, except if the firms adjust the implicit agreement by changing only the amount of reinvestment. Apart from this particular case, the resulting pricing is anticyclical over the whole continuum of solutions as in a market without investment decisions.

From the discussion of collusion between firms that do not make additional investments it is clear that there is an inverse relationship between the

lower bound of the discount factor and the upper bound of the demand level that still allow for perfect collusion. Figure 5.1 demonstrates that the critical thresholds of the discount factor for perfect collusion depend on whether the firms reinvest in the capital stock and also on the organization of the manufacturing process. Therefore, the corresponding upper bounds of the demand level are also different in these four situations. Since perfect collusion is easier if the firms invest individually than if they do not make reinvestments, the firms take part in joint monopolization of the market up to a higher level of demand if they invest noncooperatively. Moreover, the relative size of the thresholds given by (5.23) implies the inverse ranking of the upper bounds of the demand levels that are consistent with perfect collusion

$$\tilde{a}_P < \tilde{a}_J < \tilde{a} < \tilde{a}_I. \quad (5.35)$$

Also, the reduced scope of collusion in the cases of *joint investment* or *joint production* indicates that the corresponding threshold of the demand level $\tilde{a}_B$, $B = J, P$ is lower than the respective value for a market without cost-reducing investments $\tilde{a}$.

The relationship (5.35) between the critical demand levels also offers conclusions on the cyclicity of prices. If the current demand is lower than $\tilde{a}_B$, the incentive to defect is weak. In this case, the firms produce their share of the monopoly output and realize the monopoly price. The positive sign of the derivatives of the prices with respect to the demand level in the second column of Table 5.6 demonstrates that the monopoly price develops procyclically over time, irrespective of whether the firms cooperate in the investment stage or not (except for the small range of $0.5e_P^2 \leq \gamma \leq e_P^2$ in the case of *joint production*). Conversely, imperfect collusion implies lower per-period profits achieved by an expansion of the individual production.¹⁰ The corresponding higher total output results in a lower market price. Therefore, the cyclicity of prices exhibits the familiar pattern: As in a market where the firms do not make additional long-term investments, the adjustment of the collusive agreement to the demand shocks results in an anticyclical development of the market price. Thus, the finding of “price wars during booms” by Rotemberg, Saloner (1986) is robust to the introduction of replacement investments that reduce a firm’s production cost.

The periods of implicit collusion and anticyclical pricing are more frequent the lower the level of demand is that is still consistent with perfect collusion. In the case of *i.i.d.* shocks on the demand level, a strongly anticyclic development of the market price over time therefore indicates that the scope of collusion in the market is low. The relative size of the critical demand levels (5.35) implies that in a market with reinvestments the anticyclicity of prices is most pronounced if the firms cooperate closely by *joint production*, somewhat less

¹⁰ As argued above, this output expansion occurs except if the firms make the implicit agreement viable by adjusting only the investment level.

pronounced if they invest jointly and least noticeable if the firms invest non-cooperatively in the manufacturing process.

If the firms are extremely impatient due to a high discounting of the future, the present one-shot gain from defection always outweighs the long-term gains from collusion. Then, the competitors cannot coordinate their production decisions in a viable quota agreement. According to the derivatives in Table 5.6, an increase in the market size raises the *Nash*-competitive price (except for *joint production* with an investment cost parameter $\gamma \in [0.44 e_P^2, 1.33 e_P^2]$). If firms do not restrain competition and compete in quantities, their outputs as well as the market price increases in the realization of demand level. Thus, pricing is procyclical if even imperfect collusion is impossible.

As we will demonstrate in the following section, the basic conclusions on the anticollusive effect of demand fluctuations continue to hold if the development of the market demand is determined by a cyclical trend. Again, the scope of collusion results in a specific pattern of the price development that can be used as an indicator in antitrust analysis.

5.2.2 Demand Cycles

If the market size is subject to fluctuations that can be described by the infinite repetition of a single-peaked cycle (4.22), the firms have to adjust their collusive agreement in a similar manner as in the case of competition without investments in the production process.

To derive the effect of the decision on whether to cooperate in production or not on the incentive to collude in a market with cyclic demand development we repeat the analysis that was presented in Section 4.4. We redefine the discounted profit stream that accrues from period t analogously to (4.23) as

$$RB(t, \delta) \equiv \left[\pi_{RB}(a_t) + \delta \pi_{RB}(a_{t+1}) + \dots + \delta^{\bar{t}-t} \pi_{RB}(a_{\bar{t}}) + \delta^{\bar{t}-t+1} \pi_{RB}(a_1) + \dots + \delta^{\bar{t}-1} \pi_{RB}(a_{t-1}) \right] / (1 - \delta^{\bar{t}}), \quad R = \bar{A}, A, N, B = I, J, P. \quad (5.36)$$

Again, index $\bar{A}$ denotes joint monopolization, index A imperfect collusion and index N unrestrained quantity competition. The incentive to collude is still determined by the relative size of the discounted profit stream from collusion and the alternative discounted profit stream that is gained by defection and unrestrained competition thereafter. In a market with demand cycles, the firms collude as long as the net gain from collusion

$$VB(t, \pi_{AB}(a_1), \dots, \pi_{AB}(a_{\bar{t}}), \delta) \equiv \delta [AB(t+1, \delta) - NB(t+1, \delta)] - \pi_{DB}(a_t) + \pi_{AB}(a_t) \geq 0, \quad (5.37)$$

is nonnegative. The restatement of the discounted profit stream (5.36) and the incentive to collude (5.37) illustrate that the basic situation for competition or collusion is the same in markets with and without investments in

the replacement of physical capital. Consequently, there are again two critical thresholds of the discount factor. The first, lower one separates the values that correspond to unrestrained competition from the values that enable firms to restrict competition by imperfect collusion. The second value indicates the firms' lowest valuation of future profits that is consistent with joint monopolization of the market.

The upper end of the interval of discount factors that give rise to imperfect collusion is determined by the lowest valuation of future profits that is consistent with the joint monopolization of the market $\underline{\delta}$. In the range of values immediately below, perfect collusion over the whole cycle is impossible. The firms make their implicit agreement viable by reducing the restriction of competition in one of the periods of the cycle. As collusion is difficult if the potential punishment is small due to low expected demand, the period that is most critical for joint monopolization of the market lies in the part of the cycle where demand is falling.

To prove this, we will proceed in the same way as in the previous chapter. It is important to note that the additional profit from perfect collusion increases in the market size. This is shown by the sign of the following partial derivatives that result from the respective second order conditions.

$$\frac{\partial [\pi_{AI}(a_t) - \pi_{NI}(a_t)]}{\partial a_t} = \frac{(a_t - c) \gamma^2 (576 \gamma^2 + 343 e_I^2 \gamma - 186 e_I^4)}{(16 \gamma - 5 e_I^2)^2 (9 \gamma - 4 e_I^2)^2} > 0, \quad (5.38)$$

$$\frac{\partial [\pi_{AJ}(a_t) - \pi_{NJ}(a_t)]}{\partial a_t} = \frac{(a_t - c) \gamma^2}{(9 \gamma - 2 e_J^2) (4 \gamma - e_J^2)} > 0, \quad (5.39)$$

$$\frac{\partial [\pi_{AP}(a_t) - \pi_{NP}(a_t)]}{\partial a_t} = \frac{(a_t - c) \gamma^2}{2 (9 \gamma - 4 e_P^2) (2 \gamma - e_P^2)} > 0. \quad (5.40)$$

Since by the definition (4.28), the demand level is higher in $m(t)$ than in t , the period $m(t)$ is the last period of a recession where both the additional profit from joint monopolization is larger than in the corresponding period in the boom t . Conversely, in the following periods $\tau' \in \{t+1, \dots, m(t)\}$ the additional gain is higher in the boom period than in the corresponding recessionary period $\tau'' \in \{m(t)+1, \dots, t\}$. Thus,

$$\pi_{AB}(a_{\tau'}) - \pi_{NB}(a_{\tau'}) > \pi_{AB}(a_{\tau''}) - \pi_{NB}(a_{\tau''}) \quad (5.41)$$

holds.

Further, we define the discounted stream of future profits HB which accrues in the periods of a cycle from $t+1$ to $m(t)$ that are characterized by a high demand level and the discounted profits LB gained in the periods with low demand analogously to (4.29) as

$$\begin{aligned} HB &\equiv \delta [\pi_{AB}(a_{t+1}) - \pi_{NB}(a_{t+1})] + \dots + \delta^{m(t)-t} [\pi_{AB}(a_{m(t)}) - \pi_{NB}(a_{m(t)})], \\ LB &\equiv \delta [\pi_{AB}(a_{m(t)+1}) - \pi_{NB}(a_{m(t)+1})] + \dots + \delta^{\hat{t}-m(t)+t} [\pi_{AB}(a_t) - \pi_{NB}(a_t)], \\ &\quad \forall t \in \{1, \dots, \hat{t}-1\}. \end{aligned} \quad (5.42)$$

By the derivatives (5.31) to (5.33), a defection from an agreement on joint monopolization of the market is more profitable the larger the market is. Therefore, the incentive to collude is larger in a boom if the additional discounted periodic profits from the implicit agreement are higher than in a recession. This is the case if the inequality

$$\bar{A}B(t+1, \delta) - NB(t+1, \delta) > \bar{A}B(m(t)+1, \delta) - NB(m(t)+1, \delta)$$

holds. By using the definitions (5.42) this can be rewritten as

$$HB + \delta^{m(t)-t} LB > LB + \delta^{\bar{t}-m(t)+t} HB. \quad (5.43)$$

The last inequality states that the discounted profit stream that starts with periods of high demand that yield the discounted profits HB (left hand side) is larger than the one that starts with periods of low demand that offer the corresponding discounted profits LB (right hand side). According to the inequality (5.41) this is indeed true. Therefore, the period of the cycle that is most critical for collusion is part of a recession as claimed. The main finding of procyclical pricing for valuations of future profits that corresponds to a discount factor below the threshold for perfect collusion therefore continues to hold if the firms reinvest in the production process.

Starting in a period of recession, the firms expand production beyond their share in the monopoly output in more periods of the cycle the lower their valuation of future profits is. Thus, the number of periods where the firms take part in imperfect collusion is inversely related to the value of the discount factor $\underline{\delta} > \delta \geq \bar{\delta}$.

If their valuation of the future falls in this range, the firms are confined to imperfect collusion. Then, their incentive to participate in the implicit agreement is always higher in a period of rising than of falling demand provided that the demand level in the boom is at least as high as in the recession. This is the case, since the potential loss from punishment is then higher compared to times of falling demand. We will proceed as before to show that this result still holds if the firms invest in the replacement of physical capital. To furnish the proof, we will first demonstrate the additional periodic profit from collusion as well as the additional one-time gain from cheating on the agreement increase in the market size.

Analogously to a market without investment decisions (4.35), the additional profit from cheating amounts to

$$\begin{aligned} \pi_{DB}(a_t) - \pi_{AB}(a_t) &= (a_t - q_{AB} - c + e_B x_{AB})^2 / 4 - \\ &\quad (a_t - 2q_{AB} - c + e_B x_{AB}) q_{AB}, \quad B = I, J, P \end{aligned} \quad (5.44)$$

since the expenditures on the reinvestment are the same in the case of collusion and defection.¹¹ As the colluding firms produce less than the conditional Cournot output $q_N(x) = (a_t - c + ex)/3$, the derivative

¹¹ Remember, that warning the rival of the defection by deviating in the first stage yields a lower gain from defection than setting the collusive investment level.

$$\partial [\pi_{DB}(a_t) - \pi_{AB}(a_t)] / \partial a_t = (a_t - c - 3q_{AB} + e_I x_{AB}) / 2 > 0 \quad (5.45)$$

is positive. The additional gain from defection increases in the market size irrespective of the organization of production.

The additional gain from the implicit agreement in contrast depends on whether the firm cooperate in the investment stage. In all three cases, this gain increases in the demand level. If the firms invest noncooperatively, the periodic additional profit amounts to

$$\pi_{AI}(a_t) - \pi_{NI}(a_t) = (a_t - 2q_{AI} - c + e_I x_{AI}) q_{AI} - \frac{\gamma (a_t - c)^2 (9\gamma - 8e_I^2)}{(9\gamma - 4e_I^2)^2}. \quad (5.46)$$

It increases in the market size because

$$\partial [\pi_{AI}(a_t) - \pi_{NI}(a_t)] / \partial a_t = q_{AI} - \frac{2\gamma (a_t - c) (9\gamma - 8e_I^2)}{(9\gamma - 4e_I^2)^2} > 0 \quad (5.47)$$

holds for imperfect collusion. By either the second order condition for unrestrained competition or collusion, the second term on the right hand side is smaller than one half of the monopoly output q_{AI} . The last inequality is therefore fulfilled for any higher output that is chosen in the case of imperfect collusion.

Analogous considerations demonstrate that the same conclusions hold if the firms cooperate by *joint investment* or by *joint production*. If the firms invest jointly, the periodic additional collusive profit amounts to

$$\pi_{AJ}(a_t) - \pi_{NJ}(a_t) = (a_t - 2q_{AJ} - c + e_I x_{AJ}) q_{AJ} - \frac{\gamma (a_t - c)^2}{9\gamma - 2e_J^2}. \quad (5.48)$$

It increases in the market size because

$$\partial [\pi_{AJ}(a_t) - \pi_{NJ}(a_t)] / \partial a_t = q_{AJ} - \frac{2\gamma (a_t - c)}{9\gamma - 2e_J^2} > 0 \quad (5.49)$$

since again $[2\gamma (a_t - c)] / (9\gamma - 2e_J^2) < q_{AJ}$ holds by the less restrictive second order condition for collusion.

If the firms produce in a single plant, the periodic additional profit from imperfect collusion amounts to

$$\pi_{AP}(a_t) - \pi_{NP}(a_t) = (a_t - 2q_{AP} - c + e_P x_{AP}) q_{AP} - \frac{\gamma (a_t - c)^2}{9\gamma - 4e_P^2}. \quad (5.50)$$

It also increases in the market size

$$\partial [\pi_{AP}(a_t) - \pi_{NP}(a_t)] / \partial a_t = q_{AP} - \frac{2\gamma (a_t - c)}{9\gamma - 4e_P^2} > 0 \quad (5.51)$$

since the second term on the right hand side is smaller than the individual output in the case of joint monopolization of the market by either of the second order conditions.

Furthermore, we define the profits from the part of the cycle with high and low demand levels analogously to (4.39) as

$$\begin{aligned} hB &\equiv \delta [\pi_{AB}(a_{t+1}) - \pi_{NB}(a_{t+1})] & \delta^{m(t)-t} [\pi_{AB}(a_{m(t)}) - \pi_{NB}(a_{m(t)})], \\ lB &\equiv \delta [\pi_{AB}(a_{m(t)+1}) - \pi_{NB}(a_{m(t)+1})] & \delta^{\hat{t}-m(t)+t} [\pi_{AB}(a_t) - \pi_{NB}(a_t)], \\ & & \forall t \in \{1, \dots, \hat{t} - 1\}, B = I, J, P. \end{aligned} \quad (5.52)$$

As the demand level is higher in the period $m(t)$ than in period t , the resulting additional profit that is gained by a deviation from the implicit agreement is higher in the former than in the latter by (5.45). The incentive to participate in collusion is therefore higher in a boom than in a recession

$$VB(t, \pi_{AB}(a_1), \dots, \pi_{AB}(a_{\hat{t}}), \delta) > VB(m(t), \pi_{AB}(a_1), \dots, \pi_{AB}(a_{\hat{t}}), \delta), \quad \forall t \in \{1, \dots, \hat{t} - 1\} \quad (5.53)$$

if the additional gain from the implicit agreement is higher in periods of rising demand,

$$AB(t+1, \delta) - NB(t+1, \delta) > AB(m(t)+1, \delta) - NB(m(t)+1, \delta). \quad (5.54)$$

Since the additional profits h in periods of high demand $\tau' \in \{t+1, \dots, m(t)\}$ are larger than in periods of low demand $\tau'' \in \{m(t)+1, \dots, t\}$ the alternative formulation of (5.54)

$$hB + \delta^{m(t)-t} lB > lB + \delta^{\hat{t}-m(t)+t} hB. \quad (5.55)$$

is fulfilled and the inequality (5.53) holds. Consequently, the incentive to collude is indeed higher in times of rising than of falling demand, as in a market without reinvestments.

If the firms' valuation of future profits is very low and corresponds a value of the discount factor immediately above the critical threshold for imperfect collusion $\bar{\delta}_B$, an implicit agreement is hardly viable. Then, a small restriction of competition is possible at the peak of the demand cycle in $\hat{t}$ where the firms implicitly agree on a quota and an investment level that are only slightly different from *Nash*-equilibrium values. In all other periods, they compete in the market. As in a market without reinvestments, this result is again driven by the relative sensitivity of the additional profits from collusion and defection to changes in the market size. Analogously to (4.41), the incentive to participate in such an agreement amounts to

$$\begin{aligned} V(t, \pi_{AB}(a_1), \dots, \pi_{AB}(a_{\hat{t}}), \delta) &= \frac{\delta^{\hat{t}}}{1 - \delta^{\hat{t}}} [\pi_{AB}(a_t) - \pi_{NB}(a_t)] \\ &\quad - \pi_{DB}(a_t) + \pi_{AB}(a_t). \end{aligned} \quad (5.56)$$

By (5.47), (5.49) and (5.51) the additional periodic profit from collusion in the cases of *individual investment*, *joint investment* and *joint production* increase in the market size. Furthermore, the derivatives are still strictly larger than zero at the respective *Nash* quantity. Therefore, the same conclusions apply to the discounted stream of future additional profits from collusion given by the first term of (5.56). The respective additional gain from defection, given by (5.44), also increases in the market size. At the *Nash* quantity however its derivative (5.45) is zero. For outputs and investments close to the *Nash* equilibrium, the discounted additional profit from collusion therefore rises more strongly in the market size than the gain from deviation. Since the difference between both additional profits constitutes the incentive to collude (5.56), the latter increases in the market size. Consequently, the only period where imperfect collusion is feasible even if firms place a low value on future profits is the peak of the cycle $\bar{t}$, as in a market without strategic investments.

In addition, any critical value of the discount factor for the viability of a certain implicit agreement may be again higher or lower compared to a market without changes in the demand level. As the additional gain from defection depends only on the current profits, it is the same in a market with cyclic demand and with demand that is constant at the level of the present period t . Therefore, the scope for collusion depends only on the future additional collusive profits that are different across the periods if demand fluctuates. Consequently, the discounted additional gain from collusion is again lower than in a market without demand fluctuations if the average additional per-period profit from collusion over the cycle is lower than the one in a market with constant demand and higher otherwise,

$$\delta_{B \text{ crit.}} \geq \delta_{t, B \text{ crit.}} \quad \text{for} \quad [AB(t+1, \delta) - NB(t+1, \delta)](1 - \delta^{\bar{t}})/\bar{t} \leq \pi_{AB}(a_t) - \pi_{NB}(a_t), \quad B = I, J, P. \quad (5.57)$$

This also applies to the thresholds $\bar{\delta}_B$ and δ_B that mark off the range of valuations of the future that constrain the firms to imperfect collusion.

The analysis of the stochastic shocks and the deterministic cycles proves the robustness of the model of collusion in a market with demand fluctuations presented in the Section 4.3 and 4.4 to the integration of strategic investments in the replacement of physical capital. The descriptions of time-varying market demand as a result of periodic uncorrelated shocks or a deterministic cyclic trend can hence be combined to analyze the firms' investment and output choices in a market where the development of demand is more complex.

5.2.3 Demand Cycles Subject to Stochastic Shocks

The preceding analysis demonstrates that the basic working of collusion in a market with fluctuating demand does not depend on whether the firms reinvest in physical capital or not. If the market demand results from a cyclic

trend and additional periodic shocks it is therefore again optimal to use combination of the collusive strategies which are optimal in the respective cases. Thus, the firms reduce the restriction of competition if the current demand is high and also if the future, expected demand levels are low. The former is the optimal adjustment of the implicit agreement to stochastic shocks, the latter accounts for the impact of cyclic fluctuations.

Again, the reaction of the colluding firms to the fluctuations depends on the details of the demand pattern. If the shocks are uncorrelated, the current demand level conveys no information on the future development. Consequently, the adjustment of the implicit agreements only accounts for today's realization of the demand level. This is the level effect of demand fluctuations. If, however, the cyclical trend in the development of future demand is known to the firms, they additionally consider the growth or decline of demand and offset the high incentive to defect in periods of falling demand by restricting competition less in such recessionary times. This is the slope effect of changing demand. Therefore, we observe higher outputs and lower prices from less severe restriction of competition in periods of falling demand in addition to the "price wars during booms" effect that is caused by the periodic stochastic shocks.

5.3 Discussion

To assess the applicability of the theoretical analysis, it is necessary to relate it to the empirical evidence on competition in markets that are characterized by frequent reinvestments and cooperative production. However, there is no scholarly work on the organization of production so far. Therefore, our model is chosen to describe the most prominent features of cooperative projects reported by the business press. The relative frequency of the different types of organization of production though is not yet documented.

Furthermore, the number of empirical studies on reinvestments is very small. The analysis of market power in US-two digit industries by *Galeotti, Schiantarelli* (1998) is most closely related to our model of cost-reducing replacement investments. It offers a fairly close representation of the preceding theoretical framework because it accounts for adjustments of the capital stock. Unfortunately, the authors do not consider the additional effect of cooperation in production, but focus on individual investment decisions. According to the estimation results, a high current demand level decreases, but high expected demand increase the scope of collusion. These findings support our theoretical result that the basic conclusions on collusion and the cyclicity of pricing in markets with fluctuating demand continue to hold if firms invest in the renewal of their capital stock. With such reinvestments, anticyclical pricing should be observed if demand is subject to stochastic shocks (the level effect of demand fluctuations). If demand develops cyclical, the slope effect induces procyclical pricing by the firms. These price fluctuations are indeed found

by *Galeotti, Schiantarelli*. The positive effect of future expected demand is likewise confirmed by *Chirinko, Fazzari* (1994) who also consider the adjustment of capital. These authors use the difference between two consecutive output levels as a proxy for demand growth. However, there is an important discrepancy to our theoretical setup insofar as seven of the eleven industries considered are characterized by increasing returns to scale. Since the econometric specification accounts for this fact, the results of the study can still be interpreted along the lines of our model.

It is also very interesting to note that a simpler specification of the econometric model by *Galeotti, Schiantarelli* that neglects the adjustment of physical capital predicts positive effects of both the demand level and of future expected demand. The latter result documents the importance of capital investments for the scope of collusion in the product market.

Aside from the consistency with the empirical evidence, the appropriateness of the model can be discussed from a theoretical perspective.

Since the high scope of collusion in the case of noncooperative replacement of physical capital is due to severe punishment by low *Nash* profits, the *individual investment* offers an example for *Shapiro's* (1989) *topsy-turvy principle*. The lower scope of collusion in the cases of collaboration in production may likewise be interpreted as a confirmation of this principle since collaboration yields high *Nash* profits and decreases the punishment. Yet, capital reinvestments always rise the profits from collusion and defection irrespective of the organization of production. The preponderance of the higher punishment however might well depend on the curvature of the demand function as is shown by in the case of cross shareholdings analyzed by *Malueg* (1992).

An obvious point of criticism is the simplicity of the present framework of replacement investments in long-term imperfect competition. The case of quantity competition between two producers of a homogeneous good is chosen to avoid complications that are not necessary to point out the collusive potential of cooperative and noncooperative investments in the replacement of physical capital. The extension to markets for a good that is horizontally differentiated is straight forward, albeit tedious. The generalized framework can be used to reconsider the impact of the degree of product differentiation on the incentive to collude in markets where firms regularly reinvest in the production process. Therefore, it stands to expect that our conclusions also apply if the present model is extended to account for product heterogeneity. Then, this model can be reinterpreted as an analysis of demand increasing investments in advertising. Furthermore, the basic anticollusive effect of a higher number of market participants is evident from the discussion of the oligopoly case in Section 4.7. Therefore, the simplicity of the present theoretical framework is an advantage rather than a detriment that realizes the principle of the economy of means.

A more critical point is the rather crude description of synergies that most likely arise from coordination of the investment decision. Such synergies from cooperation could be endogenized, e.g. as a consequence of learning in a man-

ner proposed by *Roy Chowdhury*, *Roy Chowdhury* (1999). A further extension in the description of efficiency gains could be achieved by the integration of the “absorptive capacity” (*Kamien, Zang* 2000) of a firm, i.e. an explanation of the extent to which a competitor benefits from a rival’s efforts. However, irrespective of the underlying reason and the theoretical explanation of the efficiency gains, even the simplified representation used here demonstrates the decisive impact of the effectiveness of reinvestment activities that sharpen the results on the likeliness of collusion and increase the welfare in the market.

Another potential problem arises from the representation of dynamic competition as a supergame, i.e. as an infinite repetition of two-stage investment-quantity competition. This description of repeated reinvestments in production focuses on the equilibrium values of the investments, outputs and profits, but does not offer an explanation on how the equilibrium is reached in the first place. Since we consider long-term competition in a mature oligopoly, the market conditions are indeed constant and the adjustment process is likely to be completed. Hence, the market is in a steady state. The model is an adequate description of such a long-run equilibrium in the investment levels and outputs that is reached by a dynamic adjustment that took place in the past and is now endlessly repeated because the market conditions remain unchanged. *Petit, Tolwinski* (1999), *Cellini, Lambertini* (2004) for example develop a dynamic continuous-time version of the R&D model by *D’Aspremont, Jacquemin* (1988) that could be reinterpreted as a description of the dynamic adjustment of capital replacement expenditures until the reinvestments and corresponding outputs converge to the long-run optimal levels. Once this optimal amount of replacement investments is reached the same expenditures are made again and again to keep production efficient. The negligence of the adjustment to equilibrium is thus a minor point of criticism since the model is chosen to explain the firms’ strategic decisions on investments and their effect on the product market strategy in an established, long-run oligopoly.

Further, our model abstracts from the fact that there are other reasons for real capital investments. Especially the discontinuous nature of technological progress may yield sporadic breakthroughs in the field of manufacturing systems engineering that offer improvements in the production of a certain good. In such cases, the appropriate restructuring of the production process and investments in the newly developed equipment exceed the level of standard reinvestments that compensate for depreciation. However, the logic behind the collusive strategy in the market applies unchanged: Even if the expenditures on the replacement of capital goods are temporarily higher, the firms gain higher profits by participating in the implicit agreement than by competing in the product market. Punishment for defection is still possible since competition continues after the implementation of the improvements. Defection in the period of technological restructuring is especially unlikely because retaliation at lower production cost is even more severe. For the same reason, the ranking of the three types of organizing production, *individual investments*, *joint investment* and *joint production* is

likely to apply since the cooperation in the investment stage still implies the internalization of the negative strategic effect of cost reduction on rivals and hence reduces the possibilities to punish a defector. Thus, qualifications are necessary to account for such sporadic technical innovations, but the general conclusions continue to hold.

The fact that studies in the line of *Petit, Tolwinski* (1999) as well as supergames are partial-equilibrium models implies another drawback especially for the analysis of efficiency increasing activities as capital replacement or R&D. These efficiency gains most likely exert positive effects on other markets or sectors, e.g. a reduction of input prices or learning effects. Both the differential game and the supergame approach abstract from such possible long-run general-equilibrium effects of synergies. Therefore, the welfare gains from a lower likelihood of collusion and higher efficiency of production that are shown to arise from cooperative manufacturing are most likely underrepresented by the present partial equilibrium model.

Of course, with respect to the effects of demand fluctuations the comments and criticism raised in Section 4.10 of the previous chapter apply. However, most likely the extensions that were proposed in the literature in reaction to the most important points of critique, especially the absence of entry and exit despite changes in the demand situation, could be integrated in the present setup with reinvestments. Therefore, the openness to further extensions is a great advantage of the present setup. Moreover, to the best knowledge of the author, it is the first approach proposed so far that offers conclusions on the effect of cooperation in manufacturing on collusion in the product market. Aside from the direct results that may be used as a guideline for the design and implementation of antitrust regulation, the analysis demonstrates the importance of a theoretical foundation of competition policy. It documents that cooperation between horizontal competitors – quite contrary to the perceived wisdom (e.g. *Shapiro, Willig* 1990, *McFalls* 1998) – not necessarily increases the scope for collusion. Hence, it shows that regulation based on intuition alone may even preclude welfare gains by undue scrutiny or even outright prohibition of business strategies that is not justified economically.

5.4 Summary and Policy Conclusions

Experts warned that collaboration in manufacturing might facilitate anti-competitive agreements in the product market. Our analysis disproves these conjectures. Compared to non-cooperation in the investment stage, collusive agreements are less likely in the case of cooperation by *joint investment* or *joint production*.

If firms do not cooperate in production, they reduce their unit costs by investing individually in the production process and compete more aggressively in the product market. If they coordinate their cost-reducing investments,

they internalize this negative effect on rivals' profits and invest less. In consequence, the competitive profit rises strongly relative to the profit gained from participation in collusion. The potential punishment for defection from an implicit agreement is thus lower in the case of *joint investment* compared to non-cooperation in manufacturing. For the same reason, the firms' incentive to collude is lower if they invest jointly. Moreover, collusion is even less likely if firms produce in a single jointly-owned plant. In this case, they share the expenditures on the renewal of the equipment. The competitive profit is therefore even higher and consequently the potential punishment lower than in the case of *joint investment*. These results are strengthened if cooperation gives rise to synergies in capital replacement.

Furthermore, the reinvestments in production do not qualitatively change the collusive behavior of the firms in markets with fluctuating demand. A high current level of demand that is caused by a large positive stochastic shock still requires an adjustment of the implicit agreement. To make it viable, the firms increase the quotas beyond their share in the monopoly output whenever the market size surpasses a certain critical threshold. Given that collusion is more difficult to achieve the closer the cooperation in production is, this upper bound of the demand levels that are consistent with the joint monopolization of the market is lowest if the competitors produce in a single plant, higher if they invest jointly and highest if they invest individually. Consequently, the anticyclicity of pricing is more pronounced if the firms cooperate closely in the investment stage. However, pricing is procyclical if the development of the market demand is determined by a cyclic trend instead of periodic shocks. This holds irrespective of the organization of production and of the competitors' valuation of the future. However, if the latter does not allow for the joint monopolization of the market over the full cycle, the firms reduce the extent of collusion first in a period of falling demand. If they are even less patient, they expand the production quotas beyond the monopoly levels in more periods of the cycle. Since the inclination to collude is always higher in periods of rising than of falling demand, they adjust the quotas in boom periods only if the higher production in recessionary periods is insufficient to make the implicit agreement viable. Further, the peak of the cycle again proves to be most favorable for imperfect collusion if the value of future profits is so low that an implicit agreement is hardly viable. Therefore, an overproportionate decrease of the market price in times of falling demand may still serve as an indicator for imperfect collusion in a market with cyclic demand development. Given that an implicit agreement is more difficult to achieve the closer the firms cooperate in manufacturing, these price fluctuations are most pronounced if the competitors produce in a joint plant, moderate if they invest jointly and least noticeable if they do not cooperate in the investment stage.

In addition to these results on the collusive behavior of the firms, our model demonstrates that cooperation by *joint production* also yields the highest welfare level if the firms compete in the product market and is second best only compared to the social-planner solution. Comparison of *individual*

investment and *joint investment* shows that in the latter case firms invest less and produce less in order to mitigate the negative effect of cost reduction and high production on the rival's profit. Therefore, welfare is lower in the case of *joint investment* than in the case of non-cooperative capital replacement. The welfare ranking of *joint production*, *individual investment*, and *joint investment* applies given collusion or competition in the product market. The exploitation of market power by colluding firms implies that the welfare is lower if firms participate in an implicit agreement than if they compete in quantities given the decision on the organization of production. An exception to this is the case of *joint production* that is superior to the other market outcomes even in the case of collusion if investment costs are very low.

Hence, contrary to the intuition, *joint production* is a very attractive form of cooperation in manufacturing as it yields the highest welfare level given either competition or collusion in the product market. Above all, in this case it is most difficult for the firms to collude in the market. If competitors are not willing to cooperate closely in *joint production*, for example for fear of leakage of proprietary knowledge concerning research, marketing and other business areas, policy makers have to weigh the increased probability of collusion in the product market against the higher welfare level that results from *individual investment* in comparison to *joint investment*. As *individual investment* yields a higher welfare level than *joint investment* if firms compete in the market, encouraging collaboration by *joint investment* is only advisable if implicit collusion is a severe threat. In short, contrary to conventional wisdom, relatively lenient antitrust regulation of cooperation in manufacturing is appropriate especially if firms have a high valuation of future profits and hence an inclination to collude in the product market.

Strategic Financing with Fluctuating Demand

A firm's financial resources are not always sufficient to realize a profitable investment project. If the internal funds are scarce, a firm may seek outside capital in the financial market in order to finance the initial investment in the venture. Since leverage affects the firm's future profits, it changes its incentives to enter into agreements with other market participants. A further important aspect of leverage are the comparatively high transaction costs that are incurred in case of a change of the contract conditions. Irrespective of the motives behind the seeking of outside funds, the financing decision thus binds a firm over a long time period. Therefore, outside financing is another strategic decision that credibly commits the firm to a certain competitive strategy in the product market. There is thus a strong dependency between a firm's decisions on financing and pricing or production levels.

The review of the previous theoretical work in the Introduction demonstrates that the main effects of leverage on competition in the product market result from the increased probability of bankruptcy and the reduction of current profits by repayments. Since financial obligations reduce the current and future profits and increase the likeliness of insolvency if the firms compete over a long time horizon, leverage also changes their equity value in long-term competition. If leveraged firms are protected by limited liability, they maximize the equity value instead of the profits. Then, the repayments and the risk of bankruptcy that increase with the debt-equity ratio alter the competitive strategy. The pro- or anticollusive potential of financing decisions depends on the level of financial obligations and limited liability since the resulting equity value affects a firm's incentive to renege on a collusive agreement.

All previously published articles on long-run and one-shot competition between leveraged firms treat demand fluctuations in the simplest possible fashion. They describe demand as subject to independently, identically distributed shocks or neglect them altogether. However, since the incentive to participate in collusion depends in a decisive way on the development of demand over time, it is necessary to consider strategic decisions in a framework that accounts for demand fluctuations. This approach allows to assess whether a long-term business strategy can be used as an ancillary device to facilitate collusion. As in the chapter on investments in production, the integration of leverage and demand fluctuations provides a discriminating analysis of the effect of debt on the viability of an implicit agreement.

To make the working of debt clear, we first present a brief summary of *Maksimovic's* (1988) findings for a market where demand is constant over time. Secondly, we consider the simpler case of stochastic shocks. The effects of outside finance here are qualitatively identical, but less extreme than those in price competition between producers of a homogeneous good derived by *Stenbacka* (1994). As an alternative to this uncorrelated demand shocks, we thirdly analyze the impact of debt in a market with demand cycles. Again, the *Cournot* duopoly is used as an illustration throughout. The following analysis shows that debt influences the incentive to cheat on an implicit agreement to the disadvantage of the equityholders, but the possible loss depends on the exact pattern of demand.

6.1 Financing by Bonds

We consider bonds as a simple means to finance a certain investment. As an example, outside funds might be necessary to build a plant for the production of a new good. Before competition in the product market begins, each firm issues obligations to raise the amount $b_i/r = b_i \delta / (1 - \delta)$ to finance the investment. In return, firms have to repay b_i in every period to the holders of these bonds. The variable b is chosen as a mnemonic for “bonds”. For ease of exposition, it is assumed that the need for outside funds b_i/r is identical for all firms. Therefore, we drop the firm index. On the one hand, this is plausible as firms are symmetric in every respect. On the other hand, if the debt levels were different, arguments analogous to those given below would apply. The only difference would be that in absence of side payments and given symmetric product market strategies, the firm with the highest indebtedness would determine the highest collusive price or the smallest quantity which does not destabilize the implicit agreement. To abstain from transfer payments and complicated asymmetric collusive strategies is sensible since these leave a “paper trail” and thus increase the risk of detection. As obligations are issued and sold in the capital markets, the liabilities of each firm

are common knowledge.¹ All other market conditions are the same as in the previous analysis.

As lenders are rational, they will not buy corporate bonds worth more than the discounted profit stream attainable in equilibrium. Furthermore, investors in the capital market buy bonds only if firms' profits are large enough to serve the resulting financial obligations. The resulting repayments are therefore not higher than the smallest per-period profits attainable in equilibrium. Therefore, the financial obligations are constrained to amounts between the *Nash* and the collusive profit $b \in [\pi_N, \pi_A]$. Profits from competition are still lower than those from constrained collusion, so that the firms can be forced into bankruptcy by punishment if they issue the maximal number of bonds that corresponds to the value of the firm in the case of collusion. Bankruptcy costs are excluded here since the explicit consideration does not change the qualitative results.

After the firms have issued bonds and invested, they compete in the product market over an infinite time horizon. Payments to bondholders b are due every period. The residual profit is distributed equally amongst equityholders. In effect, each period is again divided into two stages: First, the good is produced and sold in the market and secondly, creditors receive the interest and owners their share in the net profit, e.g. as dividend payouts. Equityholders run the firms as long as these remain solvent. Alternatively, managers could be employed to act on their behalf.² If a firm is insolvent, debtholders become claimants of current and future profits, whereas the equityholders lose everything. However, neither the equityholders nor the manager can be held liable for outstanding repayments that exceed the salvage value of their firm. Thus, they aim to maximize its equity value and do not consider the value of debt in their decisions on the capital structure and the product market strategy.

As we argued previously, the firms have an incentive to restrict competition by tacitly agreeing on lower output or higher prices if they face the same rivals in the market over a long time span. This is still true if they are leveraged. In this case, the equityholders who run the firms maximize their joint returns on the investment by setting either the lowest possible quantities or the highest possible collusive prices. Since they expand outputs or reduce prices just enough to offset the incentive to deviate given their valuation of the future profit shares or dividend payouts, the implicit agreement is always viable. As in a market without outside finance, the punishment only serves as a threat and is never actually used in equilibrium. In the case of outside finance however, the equityholders gain their share of the firm's profits only as long as it is solvent. If the repayments exceed the per-period profit from *Nash* competition, the punishment bankrupts the firm. A large amount of outside

¹ Due to the observability of bond issues, firms can indeed credibly commit to a competitive strategy by taking up the corresponding amount of capital in the market.

² This situation is considered in detail in the next chapter.

capital increases the risk of insolvency and therefore the expected punishment for defection. As the alternative to the continuation of collusion, defection and the subsequent loss from a breakdown of the agreement determines the incentive to participate in the implicit agreement even though the punishment is never actually implemented. Since at the start of competition the equityholders, but not the creditors are in charge of the firms, they decide on collusion or competition in the product market. The incentives of debtholders are irrelevant in this respect. However, to specify the situation completely we assume that after a change of ownership due to insolvency caused by a defection, the lenders running the firms cannot regain the trust of their rivals. Thus, they are forced to compete in the market.

Note that the proceeding analysis also holds if the firms make reinvestments in the production process as described in the preceding chapter. The theoretical model of competition between leveraged firms can be extended to account for investments in physical capital by simply exchanging the gross per-period profits by the respective profits gained by *individual investment*, *joint investment* or *joint production*.

6.1.1 Market Results

The effect of debt on the incentive to collude is most obvious in a market with stable demand. If firms remain solvent in the worst case of *Nash* competition, the repayment b is due in every period. If profits net repayments are inserted in the condition for collusion in a market with stable demand (4.2), the repayments cancel.

$$V(\pi_A, \delta, b_l) = \frac{\delta}{1 - \delta} (\pi_A - \pi_N) - \pi_D + \pi_A \geq 0 \quad (6.1)$$

is the condition for collusion between leveraged firms that are always solvent. We add b_l for “low repayment” in the incentive to collude if the firm is always solvent and b_h if the “high repayment” drives the firm into bankruptcy in the punishment phase. The last inequality shows that the incentive to collude $V(\pi_A, \delta, b_l)$ is unchanged by the debt if *Nash* profit π_N is higher than the repayment. Of course, this does not apply if the firms produce a homogeneous good and compete in prices because *Bertrand* profits are then zero.

In *Bertrand* competition and in all other situations where the repayment is higher than the per-period profit in the punishment phase, the firms are driven into bankruptcy by the start of the punishment phase. Since the creditors are the residual claimants and take over the management of the firm, the equityholders’ gains after bankruptcy are zero.³ Consideration of the limited liability of the equityholders yields

³ Note that equityholders anticipate the insolvency in the period after deviation. As they receive zero profits anyway, they are indifferent between the *Nash* output and all higher outputs (or the *Nash* price and all lower prices). For the present argument, however, it is sufficient that equityholders receive nothing in this pe-

$$V(\pi_A, \delta, b_h) = \frac{\delta}{1-\delta} (\pi_A - b_h) - \pi_D + \pi_A \geq 0 \quad (6.2)$$

as the condition for collusion in the case of insolvency in the punishment period. Only the profit stream from the implicit agreement is reduced by the repayments, whereas it nets out in the additional gain from deviation. Hence, the incentive to participate in the agreement is reduced by increased reliance on outside funds.

By solving inequality (6.2) for the discount factor, we obtain an alternative version of the condition for collusion, analogous to (4.3),

$$\delta \geq \delta_{b,\text{crit.}} \equiv \frac{\pi_D - \pi_A}{\pi_D - \max\{\pi_N, b\}}. \quad (6.3)$$

It demonstrates that the scope for collusion described by the lower bound of the discount factors that are consistent with the implicit agreement depends on the capital structure of the firms. More precisely, the debt level determines whether or not firms are forced into insolvency by the start of the punishment period. If so, the threshold is higher and the scope for collusion is more limited the higher is the periodic repayment. Otherwise, leverage does not change a firm's incentive to participate in an implicit agreement. In any case, equityholders will set the monopoly output or price if the condition for collusion (6.3) does not bind even in the case of perfect collusion, and the lowest quantity or the highest price that fulfills the condition with equality otherwise, as in a situation with full equity finance.

Given the equityholders' valuation of future profits δ , the highest financial obligation that does not reduce the scope of collusion although it leads to insolvency in the case of punishment can be derived by solving the respective condition (6.2) for the repayment

$$b_h \leq b_{\text{crit.}} \equiv \pi_D - (\pi_D - \pi_A)/\delta. \quad (6.4)$$

It shows that the firms can borrow only up to the maximal amount of debt $b_{\text{crit.}}/r$ if they do not want to disrupt their implicit agreement on a quota or price that yields the collusive profits π_A . However, if the investment project necessitates a higher amount of outside capital and leads to a greater repayment, the equityholders need not refrain from collusion. They still have the opportunity to realize supra-competitive profits by choosing the collusive output or price that just fulfills the condition for collusion (6.2) or (6.4) as an equality. As they must expand the output or reduce the price in order to compensate for the lower incentive to participate in the agreement, the realized collusive profits are lower then. However, most analyses focus on perfect collusion and neglect the possibility to make the agreement viable by abandoning the joint monopolization of the market and settling for the lower profits gained

riod. The exact value of the equilibrium output or price in the period of deviation is not decisive.

by imperfect collusion. This also applies to *Maksimovic's* (1988) study. Yet, the latter behavior is perfectly rational since the resulting profits are in any case higher than those realized by unrestrained competition.

As is well known, the firms' profits are higher the greater the degree of horizontal product differentiation is (cf. *Martin* 2002, 59, 63). Thus, the condition for bankruptcy in the punishment phase $\pi_N(a_t) < b_h$, translates to a critical degree of differentiation where the profits from *Nash* competition are just sufficient to meet the financial obligations. There is a critical level of substitutability up to which the firms are driven into bankruptcy if the punishment sets in. Only if the firms are insolvent when facing unrestrained competition does the debt level reduce the scope for collusion. In this respect, product heterogeneity increases the scope for collusion. If instead the firms are always solvent, higher substitutability leads to a higher punishment. As the theoretical literature demonstrates, collusion between solvent firms is easier if products are less differentiated. Hence, the degree of product differentiation has two opposite effects on the stability of collusion between leveraged firms. Moreover, the impact of debt on the intensity of competition in the market is non-monotonous in that parameter. This effect is not discussed in the previous analyses by *Maksimovic* (1988) and *Stenbacka* (1994).

The interrelation between collusion and indebtedness is even more obvious in a *Cournot* duopoly. The analysis in Section 4.2 demonstrates that the critical threshold of the discount factor for perfect collusion between the duopolists is $\underline{\delta} = 9/17$. By (6.1), this is at the same time the relevant threshold of the discount factor if the repayments do not bankrupt the firms in *Nash* competition. If however the firms' indebtedness is high, their incentive to participate is reduced by high repayments. The condition for perfect collusion, obtained inserting the per-period profits from collusion and defection (4.8) and (4.11) in (6.3) then reads

$$\delta \geq \underline{\delta}_{b,C} \equiv \frac{(a-c)^2}{9(a-c)^2 - 64b_h}. \quad (6.5)$$

Obviously, the threshold of the discount factor $\underline{\delta}_b$ decreases in the market size. As in the situations discussed before, an implicit agreement is hence easier to reach the higher the level of demand. Consequently, the profits from imperfect collusion increase in the market size whether the firms are leveraged or not. However, the critical level of the demand up to which collusion is stable is lower with than without leverage because collusion is more difficult if firms are insolvent in the punishment phase, $\underline{\delta}_b > 9/17 \forall b_h > \pi_N$.

Furthermore, inspection of (6.5) illustrates that the threshold $\underline{\delta}_{b,C}$ increases in the repayment b as it is shown by the more general version of the condition of collusion (6.3). Conversely, the critical upper bound of the repayment that allows for the joint monopolization of the market amounts to

$$b_{c,crit.} \equiv \frac{(a-c)^2 (9\delta - 1)}{64\delta}. \quad (6.6)$$

Yet, bankruptcy in the punishment phase implies that the repayment is higher than the *Cournot* profit. Perfect collusion between firms that are leveraged to such an extent requires a high valuation of future profits. It corresponds to a discount factor that is greater than the threshold $\delta_C = 9/17$ for perfect collusion between competitors that are always solvent. This can be seen by inserting the *Cournot* profit (4.15) for the repayment in (6.6) and solving for the discount factor. If perfect collusion between the firms is possible at this level of repayment $b = \pi_N$, the amount of outside capital that can be taken without disrupting the implicit agreement increases in the current level of demand.

If the equityholders are impatient and place a low value on future profits, they have to confine themselves to imperfect collusion even if their financial liabilities never lead to insolvency. Their incentive to participate in imperfect collusion is then the same as in the case without leverage (4.18). If the punishment drives the firms into bankruptcy, the incentive to participate in imperfect collusion amounts to

$$V(\pi_A, \delta, b_h) = \frac{\delta}{1-\delta} [(a - 2q_A - c) q_A - b_h] - \frac{(a - q_A - c)^2}{4} + (a - 2q_A - c) q_A. \quad (6.7)$$

The output that yields the highest collusive profits and makes the firms' owners indifferent between participation and deviation is given by⁴

$$q_A|_{b_h > \pi_N} = \frac{(a - c)(3 - \delta) - 2\sqrt{\delta[(a - c)^2 - b_h(9 - \delta)]}}{9 - \delta}. \quad (6.8)$$

Most importantly, the inspection of (6.8) shows that the equityholders agree on a higher output the larger the firms' liabilities are. However, the expression under the square root is negative if the repayment exceeds a certain upper bound. Then, the problem does not have a solution. This applies if the condition $b_h < (a - c)^2 / (9 - \delta)$ is violated.⁵ The derivative with respect to the market size

$$\frac{\partial q_A|_{b_h > \pi_N}}{\partial a} = \frac{3 - \delta + 2\delta(a - c) / \sqrt{\delta[(a - c)^2 - b_h(9 - \delta)]}}{9 - \delta} \quad (6.9)$$

⁴ The second root that solves $V(\pi_A, \delta, b_h) = 0$ is irrelevant since this larger quantity yields lower collusive profits.

⁵ If it is fulfilled, the quantity (6.8) is smaller than the *Cournot* output (4.14). Furthermore, it is larger than the output produced in the case of joint monopolization (4.7) unless a small repayment $b_l < b_{c, \text{crit.}}$ allows for perfect collusion. This is can be verified by subtracting the outputs q_N and $q_{\bar{A}}$ from $q_A|_{b_h > \pi_N}$. Hence, the above quantity (6.8) lies in the range of outputs $[q_N, q_{\bar{A}}]$ that are consistent with imperfect collusion.

is negative since the corresponding condition

$$b_h > \frac{(a-c)^2 (1-\delta)}{(3-\delta)^2} \quad (6.10)$$

is fulfilled if the repayments force the firms into insolvency, $b_h > \pi_N$. Thus, a smaller expansion of output suffices to make the implicit agreement viable if the level of demand is high. The resulting collusive profits also increase in demand.

6.1.2 Number of Firms, Market Size and Welfare

With respect to the number of the market participants, the effect of an increase in the market size and the welfare loss from implicit collusion, the results of the Sections 4.7, 4.8 and 4.9 continue to hold: The above analysis demonstrates that leverage makes collusion more difficult if the firms are bankrupted by the onset of punishment. Hence, debt decreases the incentive to collude and adds to the difficulties of coordination that arise if the group of colluding firms is large.

In a *Cournot* oligopoly perfect collusion requires a valuation of future profits that is higher than the one that corresponds to the respective threshold of the discount factor. This condition,

$$\delta \geq \delta_{b,C}(n) \equiv \frac{(a-c)^2 (n-1)^2}{(a-c)^2 (n+1)^2 - 16 b_h n^2}, \quad (6.11)$$

is derived by inserting the profits from joint monopolization of the market (4.8) and defection from this implicit agreement (4.11) and the level of the periodic repayment b_h in (6.3). The derivative with respect to the number of firms

$$\frac{\partial \delta_{b,C}(n)}{\partial n} = \frac{4(a-c)^2 (n-1) \left\{ (a-c)^2 + n \left[(a-c)^2 - 8 b_h \right] \right\}}{\left[(a-c)^2 (n+1)^2 - 16 b_h n^2 \right]^2} \quad (6.12)$$

is positive because the investors never buy obligations that require repayments that are larger than the firm's profit in the case of joint monopolization of the market. Hence, collusion between leveraged firms is indeed more difficult the larger the number of participants. Furthermore, the critical threshold stated in (6.11) increases in the repayment. Consequently, collusion requires a higher degree of patience the larger are the liabilities of the firms. Since the above inequality, $\delta \geq \delta_{b,C}(n)$, is a special case of the condition for collusion (6.3) this was to be expected.

The sensitivity of the equilibria with respect to the market size derived in Section 4.8 continues to hold without qualifications since the repayment as a

fixed amount enters neither in the equilibrium outputs nor in the elasticity of demand.

Most importantly, the welfare level in the market is at least as high with debt as with full equity finance. This conclusion applies to price and quantity competition irrespective of the extent of product differentiation. If a firm is never insolvent, the scope of collusion does not depend on the debt-capital ratio. Then, leverage has no effect on the welfare in the market. If the punishment bankrupts the firm, the resulting lower inclination to collude forces the equityholders to produce higher outputs and accept a lower market price than without leverage. Since by (4.70) the welfare level increases in output, it also increases in the level of the repayments. The indebtedness of the firms may therefore yield a welfare gain due to more competitive behavior of the firms in the market.

6.2 Demand Fluctuations

To assess the likeliness of collusion in a certain market it is important to understand the interplay of debt and demand fluctuations since both affect the firms' incentive to take part in an anticompetitive agreement. Thus, we analyze next whether leverage also reduces the scope of collusion in markets with different types of demand development. Moreover, we derive the development of the firms' outputs and prices over time that can be expected if the competitors participate in an implicit agreement.

6.2.1 Demand Shocks

As before, we start with an analysis of outside finance in markets where demand changes stochastically. To analyze the impact of uncorrelated, periodic shocks, we generalize the *Bertrand* model proposed by *Stenbacka* (1994) to the case of competition between firms that produce a differentiated good or compete in quantities. As we will see, without limited liability of equityholders, debt still has no effect on the intensity of competition in the product market.

We consider again the periodic, identically, independently distributed shocks on the demand level that are described in Section 4.3. As before, we assume that perfect collusion is possible if demand is constant at the level that results from the lowest shock realization of $\underline{a}$, but impossible if it is constant at the highest level that corresponds to a shock realization of $\bar{a}$ irrespective of the amount of outside capital.

Case 1: Firms are Solvent during the Punishment Phase

Consider first a situation where firms are solvent in the case of punishment. Under such circumstances, equityholders never lose control of the firms. They

take part in a joint monopolization of the market if the corresponding profits are higher than those from unilateral deviation. Since the repayment is due in every period irrespective of whether the firm's owner colludes, defects or competes in the market, the repayments cancel in the condition for collusion. Thus, it is again identical to the inequality (4.20) that describes the situation with full equity finance. Consequently, the amount of debt has no effect on the equityholders' inclination to participate in an implicit agreement even if demand is subject to periodic, stochastic shocks. The results derived in the analysis of competition between equity-financed firms in Section 4.3 apply unchanged.

The situation is more interesting if the firms are forced into insolvency by punishment of a defection. For the sake of clarity, we distinguish two cases: Firstly, we will consider a market, where *Nash* competition always leads to the bankruptcy of the firms. Secondly, we will discuss the more general case of a market, where this occurs only if the demand level is low due to a "recessionary" shock.

Case 2: Firms are Made Bankrupt by Punishment

The simplest case where firms are driven to bankruptcy by punishment is *Bertrand* competition. But the profits from *Cournot* competition or from unrestrained price or quantity competition in a market for a differentiated good could also be insufficient to meet the obligations to repay the debt. Then, the periodic *Nash* profit is insufficient to meet the financial obligations even for the highest demand realization, i.e. $b > \pi_N(\bar{a})$ holds. In contrast to the previously investigated situation, debt in these cases changes the condition for an implicit agreement. Equityholders' incentive to collude is now given by

$$V(\pi_A, a_t, \delta, b_h) = \frac{\delta}{1-\delta} \left\{ \int_{\underline{a}}^{\bar{a}} \pi_{\bar{A}}(a) f(a) da + [1 - F(\bar{a})] \pi_{\bar{A}}(\bar{a}) - b_h \right\} - \pi_D(a_t) + \pi_A(a_t). \quad (6.13)$$

To indicate certain bankruptcy in the case of unrestrained competition, b_h is again added in the incentive to collude. As in a market with constant demand, the firms go into insolvency if the current demand level is low or indebtedness and hence repayments are high. Then, *Nash*-competitive profits are insufficient to serve the debt and creditors take charge of the firms. Due to limited liability owners are free from financial obligations if firms are bankrupt in the punishment phase. Only the discounted collusive profits are reduced by the repayments, whereas it nets out in the additional profit of a deviating firm. Hence, the incentive to collude is lower the more the firms rely on outside funds. Consequently, the critical level of the demand realization up to which perfect collusion is stable is lower with than without leverage.

To prove this, we first show that there is again a unique realization of the demand shock where gains are identical whether the equityholders abide by

the tacit agreement or cheat. Then we argue that this critical realization is indeed lower if the firms are driven into bankruptcy by a breakdown of their implicit agreement. As equityholders are protected by limited liability, they have to consider the reduction of per-period profits from collusion due to the repayments. Existence of a single value of the demand shock $\check{a} \in (\underline{a}, \bar{a})$ leaving the equityholders indifferent between perfect collusion and deviation if bankruptcy occurs during the punishment phase, $V(\pi_{\bar{A}}, \check{a}, b_h) = 0$, can be shown analogously to the existence of the upper bound $\bar{a}$ of the demand levels that are consistent with perfect collusion in the case of equity finance. By assumption, we still have perfect collusion if demand is constant at its lowest level $V(\pi_{\bar{A}}, \underline{a}, b_h) > 0$, whereas the joint monopolization of the market is impossible if demand is currently at the highest level, $V(\pi_{\bar{A}}, \bar{a}, b_h) < 0$. But in the case of bankruptcy the additional gain from collusion is lower as per-period profits are now reduced by the repayment and not by the lower per-period profit from *Nash* competition. For all demand realizations it is thus more difficult to make the tacit agreement viable and the incentive to collude is smaller than in the case of solvency in the punishment phase. Hence, we have $V(\pi_{\bar{A}}, \underline{a}, b_h) < V(\pi_{\bar{A}}, \underline{a}, b_l)$ and $V(\pi_{\bar{A}}, \bar{a}, b_h) < V(\pi_{\bar{A}}, \bar{a}, b_l)$. Again, the future additional profit stream from collusion is unaffected by the current demand level if shock realizations are stochastically independent. The incentive to collude $V(\pi_{\bar{A}}, a_t, \cdot)$ is changed by a variation in the demand level only by its effect on the additional gain from cheating. This additional profit is the same regardless whether the firms are made bankrupt by punishment or not. Therefore, the slope must also be identical in both cases, $V'(\pi_{\bar{A}}, a_t, b_h) = V'(\pi_{\bar{A}}, a_t, b_l)$. With $0 < V(\pi_{\bar{A}}, \underline{a}, b_h) < V(\pi_{\bar{A}}, \underline{a}, b_l)$, $0 > V(\pi_{\bar{A}}, \bar{a}, b_l) > V(\pi_{\bar{A}}, \bar{a}, b_h)$ and $V'(\pi_{\bar{A}}, a_t, b_h) = V'(\pi_{\bar{A}}, a_t, b_l)$ as shown, the shock realization that leaves the equityholders indifferent between collusion and defection is indeed lower if the firms are insolvent in the punishment phase. So, $\check{a} < \bar{a}$ holds, as claimed above.

Case 3: Firms are Made Bankrupt by Punishment Only if Demand is Very Low

Suppose the profits from *Nash* competition are smaller than the repayment only if the market size is lower than a^* . Then, the firms are driven into insolvency by punishment and the ownership changes only with some probability. To indicate such cases we add b_m with index m for “middle” level of debt in the incentive to collude. As long as the shock realizations are higher than the critical value a^* , the firms are solvent and the equityholders stay in charge of the firm even after a deviation from the tacit agreement. In this case, denoted by b_m , the equityholders’ incentive to collude amounts to

$$V(\pi_A, a_t, b_m) \equiv \frac{\delta}{1-\delta} \left\{ \int_{\underline{a}}^{\hat{a}} \pi_{\bar{A}}(a) f(a) da + [1 - F(\hat{a})] \pi_{\bar{A}}(\hat{a}) - b_m \right\} - \sum_{\tau=1}^{\infty} \delta^{\tau} \left[\int_{a^*}^{\bar{a}} \pi_N(a) f(a) da - b_m \right] \mathbf{S} - \pi_D(a_t) + \pi_A(a_t). \quad (6.14)$$

$$\mathbf{S} = \begin{cases} 1 & \text{for } \{\tau \mid \tau \in [t, \bar{\tau}] \wedge a_{\tau} \geq a^* \wedge a_{\bar{\tau}+1} < a^*\}, \tau = t, t+1, \dots \\ 0 & \text{for } \tau > \bar{\tau} \end{cases} \quad (6.15)$$

The indicator function $\mathbf{S}$ takes the value 1 until $a_t < a^*$ holds for the first time and 0 thereafter. If the firms are solvent, the repayment is due irrespective of the firms' decision to abide by the implicit agreement or to violate it. As the second term in (6.14) shows, for market sizes higher than a^* , the profit stream from collusion is reduced by the per-period profits from *Nash* competition. If, however, the current demand level is lower, the firms are forced into bankruptcy and their ownership changes. For such realizations, the financial obligations reduce the additional profits from collusion. As for such low demand levels the repayment is higher than the per-period profit from *Nash* competition, the reduction of the collusive profit stream is greater here compared to situations where the firms are solvent in the punishment phase. By the same argument, the reduction is lower than in the case of bankruptcy after defection regardless of the demand realization, $V(\pi_A, a_t, b_l) > V(\pi_A, a_t, b_m) > V(\pi_A, a_t, b_h)$. This is true for all demand realizations $a_t \in [\underline{a}, \bar{a}]$. Thus, the respective incentives to participate in the implicit agreement are higher the lower the shock realization is that induces insolvency in the punishment phase. By assumption, perfect collusion is still stable if demand is constant at its lowest level but not if the current demand is determined by the highest possible realization. Hence, the inequalities $0 < V(\pi_{\bar{A}}, \underline{a}, b_h) < V(\pi_{\bar{A}}, \underline{a}, b_m) < V(\pi_{\bar{A}}, \underline{a}, b_l)$ and $0 > V(\pi_{\bar{A}}, \bar{a}, b_l) > V(\pi_{\bar{A}}, \bar{a}, b_m) > V(\pi_{\bar{A}}, \bar{a}, b_h)$ hold. The additional gain from defection is not changed by the firms' bankruptcy in the punishment phase. Further, the additional future profits from collusion are independent of the present demand realization. Thus, limited liability has no effect on the slope of the incentive to collude, $V'(\pi_{\bar{A}}, a_t, b_h) = V'(\pi_{\bar{A}}, a_t, b_m) = V'(\pi_{\bar{A}}, a_t, b_l)$. If the firms are bankrupt in the punishment phase only if the demand realization is low, the critical threshold for indifference between collusion and deviation $\hat{a}$ lies between the value corresponding to situations where the firms are always solvent or bankrupt after defection, i.e. $\tilde{a} > \hat{a} > \check{a}$. The chain of inequalities shows that the anticyclicity of pricing is higher in this case than if the firms were always solvent, but lower than if they are bankrupt due to punishment for all demand realizations.

Again, the critical realization of the market size a^* where the firms are still solvent in *Nash* competition is lower the greater the degree of product differentiation. The firms are less likely to be made bankrupt by unrestrained competition if the degree of heterogeneity is high. The stability of collusion

and hence the critical value of the demand realization where the equityholders are indifferent between collusion and deviation therefore rises in the degree of heterogeneity. In contrast to traditional results for competition between unleveraged firms, product differentiation can facilitate collusion if firms are indebted.

If collusion is constrained by the level of outside capital, the firms produce quantities that are higher than in the case of joint monopolization of the market and gain a lower price. The preceding analysis shows that an important conclusion from the *Rotemberg, Saloner* (1986) model holds for competition between leveraged firms that produce a differentiated good: Market prices that are lower than those resulting from perfect collusion cannot be taken as evidence that there is no tacit agreement. In fact, the firms could be hindered to attain the maximal degree of collusion by unfavorable shocks on demand as well as by the need for outside funds.

Thus, with stochastic shocks, outside finance has the same effect on product market competition as in the case without demand fluctuations. In sum, our analysis following *Maksimovic* (1988) and *Stenbacka* (1994) shows that an increase in the debt level leads to more aggressive competition if producers of a heterogeneous good compete over an infinite horizon in a market where demand is subject to identically independently distributed, stochastic shocks. The equity value in the case of collusion is reduced by debt, both as the payment rises and as the interval of demand levels allowing for perfect collusion $[\underline{a}, \hat{a}]$ is smaller. The equityholders have to expand their outputs or to reduce prices for lower demand levels to keep the implicit agreement stable: The anticyclicity of pricing is stronger due to limited liability of equityholders. The firms cannot gain a competitive advantage by issuing debt. On the contrary, collusion is destabilized by leverage.

The collusive strategy of limitedly liable firms in the presence of uncorrelated demand shocks can be illustrated on the example of a *Cournot* duopoly. The situations where the firms are always either solvent or bankrupt in the punishment phase are special cases of Case 3. In the first case, demand is always higher than the critical level that makes a leveraged firm insolvent, $\underline{a} > a^*$ and $\mathbf{S} = 1$, whereas in the second case the demand level always falls short of the critical value, $\bar{a} < a^*$ and $\mathbf{S} = 0$. Therefore, we consider the *Cournot* duopoly only for intermediate levels of debt b_m . By (6.14), the condition for collusion in this case is

$$V_m(\pi_{\bar{A}}, a_t, b_m) \equiv \frac{\delta}{1-\delta} \left\{ \int_{\underline{a}}^{\hat{a}} \frac{(a-c)^2}{8} f(a) da + [1-F(\hat{a})] \frac{(\hat{a}-c)^2}{8} - b_m \right\} \\ - \sum_{\tau=1}^{\infty} \delta_{\tau} \left[\int_{a^*}^{\bar{a}} \frac{(a-c)^2}{9} f(a) da - b_m \right] \mathbf{S} - \frac{(a_t-c)^2}{64} \geq 0, \quad (6.16)$$

where a^* is the lowest level of demand that still allows to make the repayment b_m . The critical lower bound of demand for solvency in the punishment phase hence fulfills the equation

$$b_m = (a^* - c)^2 / 9. \quad (6.17)$$

Consequently, the additional future gain from collusion is not reduced by the repayments as long as the firms remain solvent in the punishment phase. Then, the indicator function (6.15) takes the value $\mathbf{S} = 1$. The equation (6.17) demonstrates the interrelation of leverage and demand on the example of the *Cournot* duopoly: The critical lower bound of the market size for solvency in the punishment phase a^* is independent of the demand development over time. If the firms take a high amount of outside finance however, a high demand level is required to be able to make the repayment. Consequently, the risk of bankruptcy increases. As can be seen from (6.16) and (6.15), the corresponding incentive to participate in the implicit agreement is smaller. Hence, the firms cannot use leverage as an ancillary device to facilitate collusion.

Since the basic anticollusive effect of outside capital does not depend on the details of the demand pattern it also arises if the development of demand is determined by a cyclical trend. The following section clarifies the adjustment of the implicit agreement between leveraged firms in a market with such demand cycles.

6.2.2 Demand Cycles

In this section, we prove that debt also increases the intensity of long-run competition if market demand develops in recurring cycles. To demonstrate the effect of outside finance on competition in a market with cyclic demand fluctuations, we firstly consider the general model of demand cycles presented in Section 4.4 and examine the possibility of outside finance in that setup. Secondly, we discuss the effect in the special case of a *Cournot* duopoly.

Case 1: Firms are Solvent in the Case of Punishment

In the simplest case where firms are always solvent in the punishment phase, the repayment has to be made in every period irrespective of whether the firms participate in the implicit agreement or not. Therefore, the financial obligations have no influence on equityholders' incentive to collude. The competitive behavior of leveraged and unleveraged firms is then identical. The corresponding condition for viable collusion is given by the inequality (4.24). Since the resulting collusive strategy in a market with cyclic demand fluctuations is discussed in detail in Section 4.4, we do not repeat the analysis here.

Case 2: Firms are Bankrupt in the Case of Punishment

The situation is also clear if the firms are always bankrupt after a defection. This is the case if the periodic repayment is higher than the per-period profit from *Nash* competition at the peak of the cycle, $b_h > \pi_N(a_t)$.

The equityholders still decide whether to collude or deviate by comparing the respective profit streams. Analogously to (4.24), their incentive to collude is given by

$$V(t, \pi_A(a_1), \dots, \pi_A(a_t), \delta, b_h) \equiv \delta [A(t+1, \delta) - b_h/(1-\delta)] - \pi_D(a_t) + \pi_A(a_t). \quad (6.18)$$

Due to insolvency in the punishment phase, the repayments do not cancel. Comparison with the corresponding incentive of firms that are always solvent (4.24) shows the impact of leverage on competition in the market. As by assumption the repayment exceeds the profits from *Nash* competition even for the highest level of demand, the reduction of collusive gains is higher in the case of bankruptcy. The inclination to participate in an implicit agreement declines with rising indebtedness. This is true irrespective of the value of the discount factor and thus regardless of the extent of collusion.

In sum, the arguments given for situations where the firms are never bankrupt continue to hold qualitatively, but due to the lower additional stream of net profits from the implicit agreement, all critical thresholds of the discount factor for perfect and imperfect collusion as well as for *Nash* competition are higher if the firms are insolvent after a breakdown of collusion. The critical values given in figure 4.3 are shifted to the right by an increase in the debt level.

Case 3: Firms are Bankrupted by Punishment Only if Demand is Very Low

Again, an intermediate case is possible where firms are bankrupt only in periods of low demand, i.e. if demand is lower than the critical level a^* . If the implicit agreement breaks down, the equityholders gain per-period profits from unrestrained competition as long as the demand level is still higher than this critical value. Then, the *Nash* profits are sufficient to make the repayment b_m . If demand falls below this level, the firms are insolvent and creditors take over. In this case, the equityholders participate in collusion if the condition

$$V(t, \pi_A(a_1), \dots, \pi_A(a_t), \delta, b_m) \equiv \delta [A(t+1, \delta) - b_m/(1-\delta)] - \sum_{\tau=1}^{\infty} \delta^\tau [\pi_N(a_{t+\tau}) - b_m] \mathbf{S} - \pi_D(a_t) + \pi_A(a_t) \geq 0 \quad (6.19)$$

holds. The function $\mathbf{S}$ specified in (6.15) again indicates whether the *Nash* profits are sufficiently high to meet the financial obligations. The formal analysis is hence the same as in the case of immediate bankruptcy after defection described by (6.18), but the sum of discounted *Nash* profits net repayments that are gained in the periods where the firms are solvent is deducted additionally. Therefore, the discounted profits from collusion are only reduced by the repayments that are due in the periods where demand is so low that firms would be bankrupt in the case of unrestrained competition. Since this

happens at a lower level of demand, insolvency occurs at a later point in time compared to a market where punishment always drives the firms into bankruptcy. As repayments are higher than the per-period profits from *Nash* competition in periods where firms are insolvent, the reduction of the stream of future collusive profits is now stronger than in the case of solvency, but less severe compared to a situation where firms are bankrupt immediately after a defection. Consequently, the critical values of the discount factors that separate the different collusive strategies are lower than in the case of bankruptcy immediately after a breakdown of the collusive agreement, but higher than in situations where firms are always solvent. The basic procompetitive effect of limited liability of the equityholders is the same as in the case of uncorrelated stochastic shocks.

The above analysis shows that the scope of collusion decreases with leverage if demand develops cyclically as long as the firms face insolvency due to punishment in some period of the cycle where demand is low. However qualitatively, the collusive strategy remains unchanged by debt. The analysis of collusion between unleveraged firms in Section 4.4 shows that there are two decisive consequences of this type of demand fluctuations for collusion. They also determine the collusive behavior if the firms are partly financed by outside capital.

Firstly, the incentive to participate in a certain implicit agreement is lower than in a market without demand fluctuations if the average additional profit from collusion gained over one full cycle from period $t + 1$ to $t + \bar{t}$ is smaller than the present additional collusive profit in period t and higher otherwise. As stated by (4.25), the converse relationship applies to the corresponding critical threshold of the discount factor. If the firms are indebted, the average additional collusive profit is net repayment. Therefore, the preceding result applies unchanged if the firms are leveraged to an extent that punishment leads to insolvency in a certain period of the cycle. The potential bankruptcy by unrestrained competition reduces the expected future additional profits from collusion. Furthermore, bankruptcy is even more likely if demand fluctuates compared to a situation where the firms are solvent if demand remains constant at the current level. Hence, the lower bound of the discount factor for perfect collusion is higher than the threshold in a market where the demand is stable at the peak level a_i , $\bar{\delta} \in [\underline{\delta}_i, 1]$ and their difference increases in the amount of debt. By (6.3), we have $\bar{\delta}_i = [\pi_D(a_i) - \pi_{\bar{A}}(a_i)] / [\pi_D(a_i) - \max\{\pi_N(a_i), b\}]$.

Secondly, in markets with demand cycles the loss from a breakup of the implicit agreement is higher in periods of rising than of falling demand. By an analogous reasoning as for the case of collusion between unleveraged firms, this result can be shown to hold if the firms are indebted. The *Cournot* duopoly exemplifies the resulting collusive behavior.

By (6.19), the two equityholders jointly monopolize the market if

$$V(t, \pi_A(a_1), \dots, \pi_{\bar{A}}(a_{\bar{t}}), \delta, b_m) \equiv \delta [\bar{A}(t+1, \delta) - b_m/(1-\delta)] - \sum_{\tau=1}^{\infty} \delta^\tau [(a_{t+\tau} - c)^2/9 - b_m] \mathbf{S} - (a_t - c)^2/64 \geq 0, \quad (6.20)$$

holds, where

$$\begin{aligned} \bar{A}(t+1, \delta) = & \left[(a_{t+1} - c)^2/8 + \delta (a_{t+2} - c)^2/8 + \dots + \delta^{\bar{t}-t} (a_{\bar{t}} - c)^2/8 + \right. \\ & \left. \dots + \delta^{\bar{t}-t+1} (a_1 - c)^2/8 + \delta^{\bar{t}-1} (a_t - c)^2/8 \right] / (1 - \delta^{\bar{t}}) \end{aligned}$$

is the discounted stream of collusive profits. As in the case of uncorrelated stochastic demand shocks, the indicator function is defined by (6.15), whereas the critical lower bound of the demand level for solvency in unrestrained competition is indirectly given by (6.17). The rather complex inequality (6.20) illustrates that the incentive to collude depends on the shape of the demand cycle. In particular, its exact shape determines the number of periods where the firms are solvent in unrestrained competition and the amount of profits gained then.

However, qualitative conclusions can be derived in the same way as in the case of equity finance. For values of the discount factor that are lower, but still very close to the critical threshold for perfect collusion, $\underline{\delta}$, the equityholders make the implicit agreement viable by expanding output in one period t^* of the demand cycle. In all other periods, they continue to monopolize the market. As without outside capital, the critical period for perfect collusion t^* is part of a recession.

The result is proved as follows: The repayment does not enter into the additional profit gained by defection from perfect collusion that is given by the last term in the condition (6.20). Since this additional profit, given by (4.17), increases in the market size, it is again larger in a recessionary period $m(t)$ than in a boom period t by the definition of $m(t)$ in (4.28). Thus, the incentive to collude is higher in periods of rising than of falling demand if the discounted additional collusive profits are larger in the former case. Analogously to the inequality (4.30), it is sufficient to show that

$$\begin{aligned} \bar{A}(t+1, \delta) - \sum_{\tau=1}^{\infty} \delta^\tau [\pi_N(a_{t+\tau}) \mathbf{S} - b_m(1-\mathbf{S})] > \\ \bar{A}(m(t)+1, \delta) - \sum_{\tau=1}^{\infty} \delta^\tau [\pi_N(a_{m(t)+\tau}) \mathbf{S} - b_m(1-\mathbf{S})] \end{aligned} \quad (6.21)$$

is true to prove the claim. Since, by inspection, a firm's share in the monopoly profit (4.8) as well as the additional periodic profit from perfect collusion (4.16) increases in the market size, both are larger in any period $\tau' \in \{t+1, \dots, m(t)\}$ of high than in a period $\tau'' \in \{m(t)+1, \dots, t\}$ of low demand. So, $\pi_{\bar{A}}(a_{\tau'}) - \pi_N(a_{\tau'}) > \pi_{\bar{A}}(a_{\tau'') - \pi_N(a_{\tau'')}$ as well as $\pi_{\bar{A}}(a_{\tau'}) - b_m > \pi_{\bar{A}}(a_{\tau'') - b_m$

hold. Also, the additional profits that are gained in times of high demand $a_{\tau'}$ are realized earlier and are discounted to a lesser extent if the current period is part of a boom. This consideration shows that the stream of discounted additional future profits from the joint monopolization of the market is larger then. The incentive to collude is thus higher in a period t of rising than in a period of falling demand $m(t)$ and the inequality (6.21) holds. Therefore, the equityholders make the implicit agreement viable by expanding output in a period of falling demand if their valuation of future profits is just too low to allow for the joint monopolization of the market in all periods of the cycle.

If the equityholders are less patient, they are forced to reduce the restriction of competition in ever more periods of the cycle. The corresponding pronouncedly procyclical pricing is hence observed if they have an intermediate valuation of future profits and participate in imperfect collusion, $\delta \in [\bar{\delta}, \underline{\delta}]$. Then, the incentive to participate in the implicit agreement is also larger in booms than in recessions. Since the additional profits gained by defection from imperfect collusion (4.35) increase in the market size by (4.36), it is again sufficient to show that the analogon to (6.21) for imperfect collusion,

$$A(t+1, \delta) - \sum_{\tau=1}^{\infty} \delta^{\tau} [\pi_N(a_{t+\tau}) \mathbf{S} - b_m(1 - \mathbf{S})] > A(m(t)+1, \delta) - \sum_{\tau=1}^{\infty} \delta^{\tau} [\pi_N(a_{m(t)+\tau}) \mathbf{S} - b_m(1 - \mathbf{S})], \quad (6.22)$$

holds to prove the assertion. As the partial derivative (4.34) demonstrates, the additional periodic gain from imperfect collusion (4.33) increases in the market size. The same is true for the per-period profit from the implicit agreement $\pi_A(a_t) = (a_t - c - 2q_A)q_A$. Therefore, $\pi_A(a_{\tau'}) - \pi_N(a_{\tau'}) > \pi_A(a_{\tau''}) - \pi_N(a_{\tau''})$ as well as $\pi_A(a_{\tau'}) - b_m > \pi_A(a_{\tau''}) - b_m$ hold. As in a market without outside finance, the additional gain from imperfect collusion in any period $\tau' \in \{t+1, \dots, m(t)\}$ is larger than in a period of slack demand $\tau'' \in \{m(t)+1, \dots, t\}$. Since the profits from periods of high demand are gained earlier and discounted less if competition starts in period t instead of $m(t)$ the inequality (6.22) holds. As in the case of internal finance, imperfect collusion is easier in a boom as claimed.

The reason for the adjustment of the implicit agreement in recessions is again the smaller loss of collusive profits in times of falling compared to rising demand that reduces the potential punishment for defection and makes joint monopolization of the market as well as imperfect collusion more difficult. For this reason, the market price is always higher in a period of rising than of falling demand if the market size is equal in both cases. This is even more true if the market size is higher in the boom period.

If equityholders place a low value on future profits, there is hardly any scope for collusion. If only a very small restriction of competition is possible,

the firms collude in the period of peak demand at the top of the cycle.⁶ This is still true if the firms are leveraged since the derivative of the additional profit from imperfect collusion

$$V(t, \pi_A(a_1), \dots, \pi_A(a_{\bar{t}}), \delta) = \frac{\delta^{\bar{t}}}{1 - \delta^{\bar{t}}} [\pi_A(a_t) - b] - \pi_D(a_t) + \pi_A(a_t). \quad (6.23)$$

is positive. The additional one-shot profit from defection in contrast remains unchanged by the repayment. Most importantly, at the *Nash* quantity the derivative of the per-period profit from collusion $\pi_A(a_t) = (a_t - c - 2q_A)q_A$ is larger than zero, whereas the derivative of the additional gain from defection (4.36) is identical to zero. Since the former gain rises more strongly in the market size than the latter, the incentive to take part in such imperfect collusion (6.23) increases in the market size a_t . Consequently, the single period where the equityholders' low valuation of future profits gives rise to some small scope of imperfect collusion is indeed the peak of the demand cycle in period $\hat{t}$.

If instead the equityholders are very impatient, collusion is not viable. Accordingly, they compete in the market. Since the creditors do not regain trust after a defection occurred, the same holds true after insolvency and a change in the firms' ownership and management. The resulting *Nash*-competitive price moves exactly in parallel to the demand level over time. If their valuation of future profits is high, the equityholders participate in the joint monopolization of the market. They charge the monopoly price that also develops in parallel to demand. In both cases, pricing is procyclical. If the firms' owners collude imperfectly, the market output is higher and the price therefore lower than in the monopoly equilibrium in some periods of the cycle. As in a market where the competitors are fully equity financed, it is thus an overproportionate decrease of the market price in recessions that signals the existence of an anticompetitive agreement in the product market.

6.2.3 Demand Cycles Subject to Stochastic Shocks

Until now, we considered uncorrelated shocks and cyclical fluctuations separately. If the demand development is determined by the sum of a deterministic trend and a stochastic component, the resulting expected size of the market in period t indicates an equityholder's assessment of the demand for his firm's product. So it is again sufficient to replace the per-period demand levels in the model with deterministic cyclic development by the corresponding expected values to account for the stochastic shocks. The expected values of the profit streams from collusion and defection then determine the incentive to collude. Since the shocks are uncorrelated over time, the current realization only changes the possible gain from deviation. As in the model with purely

⁶ The case of solvency in the current period is covered by (4.41) in Chapter 4.4. Therefore, we do not reconsider it here.

stochastic shocks discussed in Section 6.2.1, the equityholders have to react to the changing incentive to deviate by expanding the production quotas or lowering the collusive price if the current demand realization is high. On the other hand, they can tacitly agree on a more restrictive agreement than without the additional shock if the actual value of the shock is low (level effect). Furthermore, collusion is again easier if the future expected demand is high (slope effect). The latter is the case in boom periods of the cycle where demand still increases. If the demand level results from a cyclic development with stochastic shocks, the optimal collusive strategy of leveraged firms is a combination of the strategy for cyclical development of demand and the strategy for markets with uncorrelated stochastic shocks as in a situation with full equity finance. Therefore, the finding of less intense collusion between leveraged firms and a more pronounced cyclicity of pricing remains unchanged in the market where both types of demand fluctuations occur simultaneously.

6.3 Discussion

The development of demand determines the equityholders' optimal collusive strategies. With stochastic shocks, pricing is anticyclical. If demand develops in recurring cycles however, the owners of the firms chose a collusive strategy that results in pronouncedly procyclical pricing if they do not place high value on future profits. In the case of perfect collusion and unrestrained competition the price moves exactly in parallel to the demand level over time. Thus, the basic insights of *Rotemberg, Saloner* (1986) and *Haltiwanger, Harrington* (1991), continue to hold if profits from unrestrained competition are positive and the firms are leveraged. In addition, the theoretical analysis shows that debt increases the competitive pressure in long-run competition if the firms face a risk of bankruptcy, but are protected by limited liability. The present framework is not only attractive as a unification of the analyses by *Maksimovic* (1988), *Rotemberg, Saloner* (1986) and *Haltiwanger, Harrington* (1991), but also for the fact that can be easily applied to the case of reinvestments in production. It is sufficient to replace the per-period profits in the present analysis by those gained in the cases of non-cooperative or cooperative investments in physical capital to derive their effect on competition between indebted firms. Therefore, the introduction of leverage leaves the conclusions of Chapter 5 qualitatively unchanged.

Furthermore, the above model provides another example for the unreliability of *Shapiro's* (1989) *topsy-turvy principle*. The investment project is viable only if the firms remain solvent at least in the case of collusion. Therefore, bankruptcy can occur only in the case of *Nash* competition. The financial obligations thus affect the scope of collusion only through their effect on the punishment. Yet, the preceding analysis demonstrates that the harsh punishment by zero profits decreases the scope of collusion. This quite counterintuitive result obtains because the repayments do no longer cancel in the

additional profits from collusion if the firms are insolvent in *Nash* competition. This conclusion however stands in contrast to the reasoning of the *topsy-turvy principle*.

This result of lower collusive profits due to leverage and limited liability is in line with the results by *Brander, Lewis* (1986) who conclude that high financial obligations reduce the profits in one-shot debt-quantity competition. It is contradictory however to the findings of *Showalter* (1995). He shows that leverage is beneficial for firms that meet only once and compete in price. Then, the equityholders can credibly commit to a less aggressive product market strategy by issuing bonds. The resulting profits are higher than with full equity finance. The subsequent analysis by *Wanzenried* (2003) generalizes these results and shows that outside finance increases profitability if the firms compete in strategic complements and decreases it if the product market variables are strategic substitutes. The present framework demonstrates that such a commitment is disadvantageous in price as well as in quantity competition if competition continues infinitely or ends at an unknown date in the future: Due to limited liability of the equityholders, the collusive profit stream is reduced by high repayments in all periods where firms would be bankrupt due to punishment, with the reduction rising in the debt level. Hence, leverage decreases the profitability of dynamic competition, exactly opposite to its positive impact on profits in short-run competition. In sum, leverage has identical effects in short- and long-run quantity competition, but exactly the opposite effects in short and long-run price competition. It is important to keep in mind however that the consequence of indebtedness for the competitive strategy in one-shot competition derived by the literature in the line of *Brander, Lewis* (1986) is driven by the unobservability of the current demand level. In their setting, leverage does not affect the firms' behavior if demand is known before outputs or prices are set. In long-term competition in contrast, the amount of debt determines the product market strategy if the level of current demand is known before the firms interact in the market.

A further important difference between the literature on one-shot competition and the present framework consists in the different purpose of leverage in both settings. In one-shot competition, leverage is chosen strategically to be able to compete more aggressively. In our present supergame analysis in contrast, outside capital is not taken to change the competitive situation, but to finance an initial investment that is indispensable to enter into or remain in the market. Even if the latter financial decision can also be regarded as strategic due to its long-run commitment value, it not strategic in the strict sense of *Fudenberg, Tirole's* (1984) taxonomy.

The theoretical predictions of the present analysis of bond finance stand in contrast to empirical findings on supermarket retailing by *Chevalier* (1995a,b) and on the fiberglass, tractor trailer and polyethylene industry by *Phillips* (1995). These authors conclude that competition is softer after a significant increase in leverage. According to *Phillips* only in the gypsum industry com-

petition was more fierce after the indebtedness of the firm increased. However, he attributes this reversal to low entry barriers and a low level of leverage.

Chevalier, Scharfstein (1995) account for the interaction of debt and demand fluctuations. Using data on 20 U.S. two-digit manufacturing industries they show that leveraged firms reduce prices in recessions. The development of the market price is thus countercyclical. The authors interpret low prices as an effort to create a customer base in a market with switching costs. They argue that this strategy is less attractive if firms are highly leveraged because the trading of current against future sales is less attractive given the risk of bankruptcy. According to *Chevalier, Scharfstein* (1996) the same conclusions apply to the supermarket industry. However, their findings are also consistent with the above model of collusion between indebted firms in a market with uncorrelated demand shocks since it also predicts a countercyclical development of the market price that is more pronounced the higher the firms' financial obligations are.⁷ *Busse* (2002) provides similar evidence from the airline industry. Here, periods of aggressive pricing are more likely to be started by highly indebted competitors. Since the future is less important and defection more attractive if a firm faces a high risk of bankruptcy, this behavior of airlines is in line with predictions of theoretical models of collusion between leveraged firms. Surprisingly however the impact of demand development on pricing is statistically insignificant in this industry if the decision to initiate a price war and the effect of limited liability are explicitly considered.

These econometric studies offer both evidence in favor of more and less aggressive competition between leveraged firms and rarely offer conclusions that allow to reject one of the alternative theoretical explanation for either competitive behavior. To date, the empirical results demonstrate that there is a close link between financial decisions and product market strategies. The mechanisms of transmission in the individual markets however still need to be explored in detail.

6.4 Summary and Policy Conclusions

The preceding analysis demonstrates the impact of outside finance on the competitive strategy of firms in long-run competition. The effect of limited liability, i.e. bankruptcy and the resulting inability of equityholders to repay their debt, proved decisive for the effect of leverage on the intensity of competition in markets with constant as well as with fluctuating demand. If the firms are solvent in unrestrained competition, the repayments are due irrespective of whether equityholders compete, collude or deviate. Hence, the debt level

⁷ *Showalter* (1999) in contrast analyzes the effect of demand uncertainty, proxied by residuals from polynomial trends on the level of debt. Therefore, the results cannot be related to the present analysis that demonstrates the strategic behavior of leveraged firms in a market where the demand level is known before the competitors interact in the product market.

does not change the intensity of competition in the market. In the case of insolvency after a defection, the additional future profit stream from an implicit agreement and thus the potential costs of cheating are lower the higher the repayment is. Consequently, the incentive to collude declines with rising indebtedness. Then, internal financing is the optimal strategy with regard to the viability of collusion.

These considerations demonstrate that outside finance by corporate bonds unambiguously reduces the firms' ability to collude and thus increases the intensity of competition in a market only if limited liability of the equityholders leads to a change in ownership when collusion breaks down. The equityholders then expand output or reduce the price to offset the detrimental effect of leverage on the viability of their implicit agreement. If market prices are lower than those resulting from perfect collusion, this is not necessarily a sign that there is no anticompetitive agreement. Alternatively, the firms could be hindered to attain the maximal degree of collusion by unfavorable development of demand as well as by the need for outside capital. As the equity value of firms is reduced by debt, the equityholders cannot use bond issues strategically to facilitate collusion. Resorting to outside finance can therefore only be explained by other factors such as tax advantages or the impossibility to finance indispensable investments by internal funds.

In connection with limited liability, the degree of product differentiation proved to be another important factor for the impact of leverage on the incentive to collude. If the good is sufficiently differentiated, the profits in the punishment phase are high enough to serve the financial obligations. Indebtedness then does not change the trade-off between collusion and defection. Limited liability of equityholders limits repayments only if the firms are bankrupt due to punishment. The negative impact of leverage on the gains from an implicit agreement is hence higher if goods are fairly homogeneous because the *Nash* profits are lower then.

If the market demand is subject to uncorrelated shocks, a high level of current demand results in a high potential gain from defection, whereas the future gain from continued collusion remains unchanged. For this reason, equityholders are forced to reduce per-period profits from deviation by expanding production or lowering prices if the demand realization is higher than a certain critical level. These reductions of the collusive profit decrease the gain from deviation and stabilize the implicit agreement. As collusion is more difficult if debt levels are high, the critical demand realization that requires such an adjustment is lower the higher the leverage is. The anticyclicity of pricing is hence increased by rising indebtedness of firms. The same argumentation applies if market demand develops cyclically: In this case, the inclination to collude depends on the slope and not on the level of demand. As the potential punishment for defection is lower in times of falling demand, the incentive to cheat on the implicit agreement is higher in such periods. The equityholders have to raise the quotas or decrease the collusive price in these critical periods to offset this effect if their valuation of the future does not allow for the contin-

ual joint monopolization of the market. Pricing is then markedly procyclical. If however the value of future profits is relatively low, the agreement must be adjusted and the resulting price is lower in periods of rising demand, too. Again, the incentive to collude is declining in the debt level. The deviation of the price development from the development of demand is therefore more pronounced in markets where the firms are highly indebted.

Since the financial obligations either reduce the incentive to collude or leave it unchanged, leverage cannot be used to facilitate collusion. In contrast to many other financial decisions, as for example a common banker or cross-shareholdings, a bond issue therefore does not raise antitrust concerns.

Strategic Management Compensation with Fluctuating Demand

Other important factors that determine the scope of collusion and thus the development of prices over time are the decision to delegate the management of the firm and the design of the manager's compensation. In the following sections, we describe the typical components of such compensation contracts and derive the effect of stock-based payments on the incentive to collude in markets with alternative demand development that is determined by stochastic shocks or a cyclical trend. To derive the effect of the demand development on the pricing by managers, we extend the model of time-varying demand presented in Chapter 4 to describe competition between managers. As will be shown, the delegation to managers with stock-based compensation rises the inclination to collude and thus the market price. The analysis suggests that the type of management compensation is a factor that explains alterations in the pricing behavior and thus markup reactions to changes in market demand.

7.1 Stock-Based Management Compensation

The use of stock-based incentive pay grew significantly over the last two decades. Among the different forms of share-price-dependent compensation, the increase in stock option awards was most pronounced. *Balsam* (2002, 41, 205) reports the most recent data on executive compensation. In the data set *ExecuComp* for a sample of firms from the *S&P 500*, *S&P MidCap 400* and *S&P SmallCap 600*, the fractions of the different types of compensation document the substantial increase in stock and option grants. The raise in long-term incentive plans was more moderate. On average, a CEO owned 3.78% of his firm in shares and stock options in 2000.

According to *Unger* (2001) the trend continued despite of the continual fall of share prices in the USA and Europe. After a late introduction of such compensation packages in the mid-nineties, stock-based compensation components also constitute a growing share of top executive compensation in

Table 7.1. Fraction of Firms Granting Long-Term Bonus, Option Grants or Shares (adapted from *Balsam* 2002, 41)

Year	Long-Term Bonus	Stock Options	Stock Grants
1992	0.16	0.50	0.17
1994	0.13	0.64	0.17
1996	0.15	0.67	0.19
1998	0.15	0.71	0.19
2000	0.17	0.79	0.22

Germany (*Schwalbach* 1999, *Conyon*, *Schwalbach* 2000). A study on management compensation in the United Kingdom reports a similar development. In 1997 for example, 67% of the firms awarded stock option grants and 49.5% used long-term incentive plans (*Conyon et al.* 2000, Table 2).

Stock option grants entitle their owner to buy a prespecified number of shares of common stock at a fixed exercise price within a given time span. Usually, a manager forfeits the right to exercise the option if he leaves the firm. According to *Murphy* (1999), there is little variance in the practice of granting stock options across large U.S. companies. The overwhelming majority of the option grants have a strike price at the market value on the award date and can be exercised over the following 10 years.¹ Typically, the options can be exercised only after a specified vesting time, although some option grants vest immediately (*Balsam* 2002, 131). Another popular form of stock option plans are options granted with stock appreciation rights. These entitle the manager to receive the difference between the current share and the strike price as a cash payment. The payment is an alternative to the conventional way to vest the options by first buying the corresponding number of shares at the exercise price and then reselling them at the market price. Thus, stock appreciation rights amount to share-price-dependent compensation payments without an actual sale of shares.

Remuneration components that depend on the current share price are primarily given as an incentive for employees to reach or outperform a target earlier agreed upon. To motivate the executives to pursue long-term goals, firms also use compensation components that are paid out deferred. Since these are usually forfeited if the manager leaves the firm, deferred stock or options grants may be used to keep valuable specific skills and proprietary information within the firm. Such contract components increase the cost of leaving the employer as well as the amount of compensation that needs to be paid to lure the manager away from his firm.

The same objectives, to prevent myopic consideration of short-run profits alone or to tie the manager to the firm for a long time, stand behind other long-term incentive components. Grants of restricted stock, for example, award the

¹ In his sample of 1000 firms only one granted options with a strike price that was tied to the performance of the industry.

manager with a number of shares subject to restrictions on their resale, but not on dividend payments and voting rights. *Kole* (1997) reports an average waiting time of four years before the restriction is lifted for a sample of firms that are listed in the *Fortune 500*. Over the waiting time, a manager thus participates directly in the success of his firm. Typically, restricted stock is also forfeited if a manager is dismissed or quits the firm.

Other examples of remuneration components are long-term bonuses or payouts from pension plans that depend on the performance of the firm over a certain time. Long-term performance-unit plans grant fixed cash awards depending on the extent to which the goal is met. Performance-share plans, in contrast, are tied to the fulfillment of the target and the development of the share price since they are paid in common shares or their cash equivalent. Thus, the latter amount to deferred share-price-dependent payments and deferred stock grants, respectively. Payments from such plans usually depend on the average performance over the last three to five years. In *Kole's* (1997) sample of *Fortune 500* firms, approximately a half of the plans are denominated in common shares, whereas the other half grant a fixed award. *Towers Perrin* (2004) reports a share of stock-based plans of 92% in 2002 that fell to 81% in 2003 for a sample of 483 publicly traded U.S. firms.

Aside from the incentive effect, such compensation contracts may change the competitive strategy of managers and reduce the intensity of competition. Since the beginning of the 1980s, incentive compensation as a strategic variable in product market competition received considerable attention from industrial economists. However, an important shortcoming of the existing literature are neglected demand fluctuations. As *Rotemberg, Saloner* (1986) and *Haltiwanger, Harrington* (1991) and others have shown, the pattern of demand changes plays an important role in determining the inclination of firms to collude. Static, two-stage models of strategic delegation, as those by *Fershtman, Judd* (1987), *Skivas* (1987) and *Reitman* (1993), cannot represent the cyclical and structural dynamics in the markets for goods and services. This chapter in contrast, presents a dynamic model of competition and shows how share-price-dependent compensation packages influence the pricing strategy of managers when the market demand level changes over time. As the effect of such contracts depends on their precise design (cf. *Spagnolo* 2000), we discuss different variants of compensation, i.e. share-price-dependent payments, stock grants and stock options.

7.1.1 Stock Market and Labor Market for Managers

The stock market is assumed to be perfectly competitive. The profit of a firm $\pi_R(a_t)$, $R = \bar{A}, A, D, N$ is distributed as dividends at the end of each period t .² The index R is again added since the profit differs depending on whether

² This assumption simplifies the exposition. In Section 7.1.6 we show that all results continue to hold if an arbitrary fraction of per-period profits is disbursed at the end of each period.

the firm (owner or manager) currently participates in perfect collusion (index $\bar{A}$), in imperfect collusion (index A), defects from the collusive agreement (index D) or competes in unrestrained rivalry (index N). Market participants act rationally with perfect foresight. The price of a share $\mathcal{P}_R$ of firm i at the end of the actual period t , but before payment of dividends is therefore equal to the sum of the actual and discounted future per-period profits divided by the number of shares of the firm φ_i :

$$\mathcal{P}_R(a, t) = \frac{1}{\varphi_i} \sum_{\tau=0}^{\infty} \delta^{\tau} \pi_R(a_{\tau}). \quad (7.1)$$

We denote the market size a and time t as the arguments of the share price to indicate its dependence on the demand level in the current and future periods. For the sake of simplicity, we assume that compensation payments are small in comparison to the stock market value and have no effect on the firm's share price.

A company's dividend policy has a decisive influence on its share price. *Miller, Modigliani* (1961) showed in a stylized model that the decision whether profits are retained or distributed as dividends is irrelevant to investors, as they either receive a share of the profits proportional to their ownership of the firm or gain from a rising share price if profits are retained in the firm and reinvested.³ Nevertheless, firms disburse a significant part of their profits. *Allen, Michaely* (1995, 2001) state that during the 1990s on average 27% of total earnings of U.S. firms were paid out as dividends. But a comparison of the changes in investors' wealth is not the only aspect worth considering when the effects of different dividend policies are to be discussed. An aspect almost totally neglected so far is the effect of the dividend policy on product market competition. *Spagnolo* (2000), for example, only briefly mentions this issue. Thus, it remains to be analyzed whether owners' of firms can use such stock-based compensation contracts as a credible commitment device, if a fraction of the profits is retained in the firm.

With strategic delegation, managers are in charge of each firm in the market. Competition is modeled as an infinite repetition of a basic game consisting of T periods. At the beginning of such a game in period t , all owners choose an incentive contract of the same structure with a common duration T for their manager. These contracts are perfectly observable by all participants.⁴

³ Of course, if their assumptions are relaxed, the *Miller, Modigliani* irrelevance proposition may no longer hold. Since we do not consider the factors that may invalidate their finding, i.e. the role of taxation, asymmetric information, incomplete contracting possibilities or transaction costs, in the present framework, the result applies to our theoretical analysis.

⁴ As larger firms are required to publish the contract conditions, this assumption is usually fulfilled. Moreover, in many cases the shareholders' meeting has to give its consent when an incentive scheme is introduced or changed (*Murphy* 1999, *Weiß* 1999). In the United Kingdom publication of the level and structure of manager

In these T periods, managers interact in the product market. If a manager deviates from a collusive agreement, he will be dismissed at the end of his contract. If an owner does not reappoint his manager even though no deviation occurred, the managers of the rival firms will punish him with unrestrained competition.⁵ Hence, a dismissal of his manager reduces the profits of an owner. We show below that colluding managers can always reach at least the same discounted profit stream as owners. Therefore, owners will always employ a manager and will reappoint him at the end of his contract if he does not deviate from the implicit agreement. This is also true if contracts are not concluded simultaneously or are of different length. The results of the model are therefore not dependent on the assumption of simultaneity or equal duration of the contracts. To be able to focus solely on strategic delegation, we assume that managers and owners have the same information. Moreover, a manager who is indifferent between two alternatives always acts in the interest of his firm's owner. Further, we assume that owners' disutility of managing their firms themselves is always larger than the remuneration payment. Therefore, we do not need to compare the additional gain from more intense collusion with the cost of compensation. To keep the model tractable, we exclude the possibility of managers owning shares of rival firms.

To isolate the influence of stock-based compensation from other kinds of compensation, as for example those depending on sales or relative performance measures, we set boni and wages to zero and consider different share-price-dependent components in turn.

A large part of the stock or stock option grants include stock appreciation rights (65% according to *Kole* 1997). Thus, very often a manager actually

compensation is not legally required. However, after controversial public discussions in the early nineties, more and more firms do publish the details of such contracts (*Conyon, Schwalbach* 2000). In Germany, there is also a trend towards voluntary publication of information on the chief executives' compensation. *Katz'* (1991) and *Bagwell's* (1985) finding that perfect observability is an indispensable condition for contracts to serve as a credible commitment is therefore no impediment for our analysis of management compensation. This is especially true with respect to the main finding that stock-based compensation creates a higher incentive to collude than profit-based remuneration since this result will be shown to hold irrespective of the amount paid.

⁵ In the case of deviation and dismissal, the manager loses his credibility and will therefore not be reemployed. This case gives rise to an infinite punishment by *Nash* competition, i.e. a *trigger* strategy as proposed by *Friedman* (1971). However, there might be managers in other markets who have not yet broken an implicit agreement. The new manager might be considered trustworthy and therefore able to restart collusion. The possibility to hire such a manager after a predetermined number of punishment periods would be an interesting extension of the present model. The length of the competition phase could then be fixed to determine an optimal punishment (cf. *Abreu* 1986, *Abreu et al.* 1986). Since the basic effect of a strategic decision does not depend on the details of the punishment strategy, we exclude this extension from our analysis.

receives a periodic, share-price-dependent cash payment that rises in the current share price $\mathcal{P}_R$ instead of actually buying and reselling the shares. If he decides to vest the options, or if the remuneration consists of a stock or option grant without appreciation rights, the manager receives a number of shares of his firm for a strike price in every period. In the case of immediate compensation, payments are made and grants awarded before profits are disbursed. In order to disentangle the effects of stock-based compensation and stock ownership by managers, we assume that a manager resells the shares immediately to diversify his portfolio if he receives stock or exercises an option. However, empirically an immediate resale is not always possible as some contracts contain a waiting period.⁶ The effect of waiting times and restrictions on resale is discussed in Section 7.1.5. In addition, some compensation contracts specify long-term bonuses that also depend on the stock-market value of the firm. Such contracts are analyzed in Section 7.1.4.

As a reference case, we consider the management of firms by managers with a traditional permanent employment contract that specifies the payment of a constant fraction F of the firm's current profits in each period. We refer to this type as profit-dependent or traditional compensation. It is equivalent to a *Fershtman, Judd-Sklivas* (1987)-type contract that is linear in sales and profits, where sales have weight zero. In this case, a manager maximizes his compensation by maximizing the current profit. Since a multiplicative factor has no impact on this maximization, a manager's incentives are identical to those of an owner who runs the firm himself.⁷

The competitive strategy of managers depends on the design of the incentive contract. In the following, we therefore successively consider the different types of stock-based compensation contracts described so far in our theoretical framework of long-term competition. In addition, we demonstrate that the effect of the compensation on the incentive to collude, and therefore on the development of prices in the market, remains unchanged by a firms' dividend policy as long as a constant fraction of profits is disbursed. The analysis progresses from the simple to the more difficult and begins with a model of management compensation in a market with constant demand that largely reviews some of *Spagnolo's* (2000) results. The effect of a firm's dividend policy however is not considered in the literature so far. Thereafter, we derive the joint effect of stock-based compensation and demand fluctuations on the viability of collusion.

⁶ In an empirical study, *Ofek, Yermack* (2000) conclude that managers of the firms listed in the *Standard & Poor's 500* index, sell a large part of their shares to reduce risk and finance consumption. Within the listed firms, restricted options had a share of 6.1% in total remuneration in 1996 (*Murphy* 1999).

⁷ Technically, the factor F that determines which part of profits is paid as periodic compensation cancels in the conditions for collusion. The incentive to collude in markets with constant, stochastic or cyclic demand are hence given by (4.2), (4.20) and (4.24), respectively.

7.1.2 Share-Price-Dependent Payments

A manager receives the periodic payment $f(\mathcal{P}_R)$ before the current profits are paid out as dividends. The relevant share price depends on the decision of the manager to take part in, or defect from an implicit collusive agreement or to compete non-cooperatively in the market.

$$\mathcal{P}_R = \sum_{\tau=0}^{\infty} \delta^{\tau} \pi_R(a_{t+\tau}) / \varphi_i, \quad R = \bar{A}, A, N \quad (7.2)$$

$$\mathcal{P}_D = \left[\pi_D(a_t) + \sum_{\tau=1}^{\infty} \delta^{\tau} \pi_N(a_{t+\tau}) \right] / \varphi_i \quad (7.3)$$

are the share prices with collusion, *Nash* competition and deviation respectively.

A manager takes part in an implicit agreement as long as this maximizes his remuneration. This is the case if the discounted emoluments gained by collusion are larger than the alternative payment stream gained by defection and during the ensuing infinite punishment. This is the case if the condition

$$V(\pi_A, \delta) = \sum_{\tau=0}^{\infty} \delta^{\tau} f \left[\sum_{\tau=0}^{\infty} \delta^{\tau} \pi_A / \varphi_i \right] - f \left[\left(\pi_D + \sum_{\tau=1}^{\infty} \delta^{\tau} \pi_N \right) / \varphi_i \right] - \sum_{\tau=1}^T \delta^{\tau} f \left[\sum_{\tau=0}^{\infty} \delta^{\tau} \pi_N / \varphi_i \right] \geq 0, \quad (7.4)$$

is fulfilled, where the arguments of the payments are the share prices in the case of collusion, defection and unrestrained competition, respectively. By rewriting the series, the condition simplifies to

$$V(\pi_A, \delta) = \frac{1}{1-\delta} f \left[\frac{\pi_A}{\varphi_i (1-\delta)} \right] - f \left[\frac{1}{\varphi_i} \left(\pi_D + \frac{\delta \pi_N}{(1-\delta)} \right) \right] - \frac{\delta (1-\delta^{T-1})}{1-\delta} f \left[\frac{\pi_N}{\varphi_i (1-\delta)} \right] \geq 0.$$

As the stock-based compensation depends on the infinite stream of future profits, the per-period payments to a manager that will be dismissed at some point in time hinges not only on his behavior, but also on the profits during the punishment phase after his dismissal. Note that the incentive to participate in the implicit agreement, $V(\pi_A, \delta)$, decreases in the duration of the contract irrespective of the type of compensation. Thus, an owner gains by employing the manager on a short-term contract.

As argued above, the incentives of an owner who runs the firm himself are identical to those of a manager who receives traditional incentive compensation that depends on the firm's current profits. Therefore, the conditions for collusion in a market with constant, stochastic or cyclic demand development,

(4.2), (4.20) and (4.24) also apply to collusion between managers with traditional compensation contracts. Compared to a manager with profit-based remuneration or an owner who runs the firm himself, a manager who receives share-price-dependent payments has a higher incentive to collude.⁸

To see this, consider again the implicit agreement between owners or managers with profit-based payments that was discussed in detail in Chapter 4. Suppose the condition for perfect collusion (4.4) holds with equality. This is the case, if the valuation of future profits is just sufficient to make perfect collusion viable, $\delta = \underline{\delta}$. If the valuation of future profits is lower, owners (or managers) take part in imperfect collusion. Then, they maximize their profits by setting the smallest output or the highest price that fulfills the condition for collusion (4.2) with equality given their level of patience. Hence, (4.2) binds for all values of the discount factor $\delta \leq \underline{\delta}$. In all these cases, participation in the implicit agreement and defection followed by competition in the market yield the same discounted profit stream. Consequently, the share price of a firm is also identical in both situations,

$$P_A = \frac{\pi_A}{\varphi_i(1-\delta)} = \left(\pi_D + \frac{\delta \pi_N}{1-\delta} \right) / \varphi_i = P_D. \quad (7.5)$$

Using this equality in the condition for collusion (7.4) we obtain

$$V(\pi_A, \delta) = \frac{\delta}{1-\delta} f \left[\frac{\pi_A}{\varphi_i(1-\delta)} \right] - \frac{\delta(1-\delta^{T-1})}{1-\delta} f \left[\frac{\pi_N}{\varphi_i(1-\delta)} \right] \geq 0 \quad (7.6)$$

as the condition for collusion at any value of the discount factor $\delta \leq \underline{\delta}$ if the manager with share-price-dependent compensation payments sets the same collusive quantities or prices as an owner or a manager who receives profit-dependent payments. Then, the condition (7.6) always holds as a strict inequality independent of the contract length T , because per-period profits from perfect as well as imperfect collusion are always higher than those from *Nash* competition, $\pi_{\bar{A}} > \pi_A > \pi_N$. Compared to defection and punishment, a manager with stock-based compensation will receive a higher periodic payment in all future periods if he participates in the implicit agreement. Evidently, the collusive output and price set by owners or managers with profit-based compensation does not exhaust the scope for collusion between managers with stock-based remuneration. However, a manager maximizes this compensation if he chooses the output and price that just makes the implicit agreement viable. Therefore, managers with share-price-dependent remuneration produce a lower collusive output and charge a higher price so that condition (7.6) is fulfilled with equality.

This effect hinges on the fact that the full stream of future profits enters into the share price that determines the stock-based compensation payment, whereas the profit-based payment depends only on the profit in the current

⁸ This result was shown by *Spagnolo* (2000, Proposition 1).

period. Consequently, managers with any form of share-price-dependent compensation gain more from future profits. Conversely, their loss from a change from collusive to *Nash*-competitive profits after defection weighs more. Thus, punishment is more severe with stock-based than with profit-dependent remuneration. This also applies to option packages, and still more to any type of deferred compensation as managers with such contracts do not gain from the additional profit of the deviation period. Put differently, the scope for collusion is higher if managers with stock-based compensation run the firms. Moreover, an arbitrarily small periodic share-price-dependent payment or a grant that consists of just one share or stock option is sufficient to induce the strategic effect of more intense collusion. The amount of compensation, however, determines the viability of the implicit agreement, i.e. the critical lower bound of the discount factor for collusion.

7.1.3 Stock Options and Stock Grants

A large part of top management compensation consists of stock options (*Jensen, Murphy* 1990, *Yermack* 1995). If a manager receives stock or option grants instead of share-price-dependent payments, he receives the number of shares κ_i for a strike price $\underline{P}_i$ as remuneration. Stock grants differ from option grants only in so far as the managers need not pay a strike price. Stock grants are hence a special case of option grants with a strike price of zero. Collusion is only attractive if the strike price is smaller than the resulting share price $\underline{P}_i < \delta / (1 - \delta) \pi_A / \varphi_i$. Thus, the owner or the compensation committee sets the strike price below this value.

Since the compensation payments are made before profits are distributed as dividends, the condition for collusion between managers who are paid with stock options is given by

$$V(\pi_A, \delta) = \frac{1}{1 - \delta} \kappa_i \left[\frac{\pi_A}{\varphi_i(1 - \delta)} - \underline{P}_i \right] - \max \left\{ \kappa_i \left[\pi_D + \frac{\delta \pi_N}{\varphi_i(1 - \delta)} - \underline{P}_i \right], 0 \right\} - \frac{\delta(1 - \delta^{T-1})}{1 - \delta} \max \left\{ \kappa_i \left[\frac{\pi_N}{\varphi_i(1 - \delta)} - \underline{P}_i \right], 0 \right\} \geq 0. \quad (7.7)$$

Our aim is to demonstrate that the scope of collusion is again higher if the managers' compensation consists in stock options. To this end, we use the fact that the profit streams from perfect collusion and deviation are the same for all values of the discount factor $\delta \leq \underline{\delta}$ if managers with profit-dependent compensation or owners run the firms. As stated by (7.5), share prices are then also the same in both cases. Thus, (7.7) simplifies to

$$V(\pi_A, \delta) = \frac{1}{1 - \delta} \kappa_i \left[\frac{\pi_A}{\varphi_i(1 - \delta)} - \underline{P}_i \right] - \frac{\delta(1 - \delta^{T-1})}{1 - \delta} \max \left\{ \kappa_i \left[\frac{\pi_N}{\varphi_i(1 - \delta)} - \underline{P}_i \right], 0 \right\} \geq 0, \quad (7.8)$$

if a manager who receives option grants sets the same price or output as owners or managers with profit-based payments. As the profits from perfect and imperfect collusion are higher than those from competition, this condition also holds as strict inequality irrespective of the length of the contract. Compared to owners and managers with traditional compensation, managers also have a higher inclination to collude if the stock-based remuneration consists in stock grants or stock options (*Spagnolo* 2000, Proposition 3). Consequently, they set a higher price and lower quota unless perfect collusion is possible irrespective of delegation. As in the case of share-price-dependent payments, the procollusive effect of stock or option grants results because each payment depends on the discounted stream of profits. Therefore, this type of compensation puts a higher weight on the future profits than traditional profit-based compensation contracts. The reason for the higher scope of collusion is thus the same for all types of immediate stock-based compensation.

The strike price can be used as an additional instrument to maximize the manager's incentive to collude (and thereby the firm's return to the owner or owners). Obviously, a manager's gain from the option grant decreases in the strike price $\underline{P}_i$. If it is set at the level of share price that results from *Nash* competition, the manager does not receive any compensation in the periods after defection. The punishment and consequently also the incentive to collude is then maximal. Formally, this can be proved by implicitly differentiating condition (7.7).

Since many incentive contracts also contain a waiting period before the shares can be resold, managers with stock-based compensation actually receive the benefit from stock-based remuneration with a delay. In the following, we derive the effect of such deferred compensation on the scope of collusion in the product market.

7.1.4 Deferred Compensation Components

From the owners' point of view this type of remuneration offers an additional advantage. If this compensation depends on the firm's performance in the period of payment or an average measure of performance over some time span before the payments are due, a manager has an incentive to consider the long-term performance of his firm. Most option grants amount to deferred compensation because the managers typically have to wait at least a year until the options become exercisable (*Kole* 1997, 85). In general, both the stock-market value and the future per-period profits can be used as a measure of firm performance. Thus, all types of stock-based remuneration discussed above can be used as long-term incentive compensation if they are paid deferred, i.e. not in the period where the work is actually performed, but at some later point in time depending on the share price or profit that is realized then. As we will show, the length of the time lag is irrelevant for the scope of collusion in the market.

If a manager receives the payment with a delay of $d = 1, 2, 3, \dots$ periods, the profit of the period the compensation is paid for is already paid out as dividends. Thus, the high defection profit is also disbursed before a manager receives the compensation for his work in the period of defection. The same holds true, if he receives the payment in the same period in which the work is done but not before, but after the profit is paid out as dividends. As managers with such contracts do not gain from the additional profit from deviation, their incentive to participate in perfect collusion in some period t is given by⁹

$$V(\pi_{\bar{A}}, a_t, \delta) = \sum_{\tau=0}^{\infty} \delta^{\tau+d} f \left[\sum_{\tau=0}^{\infty} \delta^{\tau} \pi_{\bar{A}}(a_{t+\tau+d}) / \varphi_i \right] - \sum_{\tau=0}^T \delta^{\tau} f \left[\sum_{\tau=0}^{\infty} \delta^{\tau+d} \pi_N(a_{t+\tau+d}) / \varphi_i \right]. \quad (7.9)$$

Since demand is constant over time, this can be written in short as

$$V(\pi_{\bar{A}}, \delta) = \frac{\delta^d}{1-\delta} f \left[\frac{\pi_{\bar{A}}}{\varphi_i(1-\delta)} \right] - \frac{\delta^d}{1-\delta} f \left[\frac{\pi_N}{\varphi_i(1-\delta)} \right].$$

The expressions in square brackets state the share price in period $t+d$ that determines the payment for a manager's work in the period t . The first summation in both terms accounts for the delay of payments and discounts the future compensation appropriately. Given the same size of the market the profit stream is always larger with collusion than with *Nash* competition, $\pi_{\bar{A}}(a_{\tau}) > \pi_N(a_{\tau})$, so managers with such a contract comply to the implicit agreement irrespective of the discount factor and the contract length. Since the high profits from defection are never relevant for the payment that a manager receives for his work in the period of defection, he always has an incentive to participate in the joint monopolization of the market irrespective of the length of delay d .

If a manager receives stock grants ($\underline{\mathcal{P}}_i = 0$) or stock options ($\underline{\mathcal{P}}_i > 0$) deferred, he cannot gain from defection because the corresponding profits are again disbursed before the compensation is paid out. His incentive to collude is obtained by replacing the share-price-dependent payments by the value of shares or options in the condition (7.9) above. With a strike price $0 \leq \underline{\mathcal{P}}_i < \mathcal{P}_{\bar{A}}$ a manager complies to the implicit agreement on perfect collusion if the inequality

⁹ To avoid a repetition in the analysis of a market with demand fluctuations, we state the condition for collusion in detail accounting for possible changes in the demand levels. The notation used here reflects that demand may not be constant over time.

$$V(\pi_{\bar{A}}, a_t, \delta) = \sum_{\tau=0}^{\infty} \delta^{\tau+d} \kappa_i \left[\sum_{\tau=0}^{\infty} \delta^{\tau} \pi_{\bar{A}}(a_{t+\tau+d}) / \varphi_i - \mathcal{P}_i \right] - \sum_{\tau=0}^{\infty} \delta^{\tau+d} \max \left\{ \kappa_i \left[\sum_{\tau=0}^T \delta^{\tau} \pi_N(a_{t+\tau+d}) / \varphi_i - \mathcal{P}_i \right], 0 \right\} \geq 0 \quad (7.10)$$

is fulfilled. By accounting for the constancy of demand, the inequality can be restated as

$$V(\pi_{\bar{A}}, \delta) = \frac{\delta^d \kappa_i}{1-\delta} \left[\frac{\pi_{\bar{A}}}{\varphi_i(1-\delta)} - \mathcal{P}_i \right] - \frac{\delta^d \kappa_i}{1-\delta} \max \left\{ \left[\frac{\pi_N}{\varphi_i(1-\delta)} - \mathcal{P}_i \right], 0 \right\} \geq 0.$$

This condition always holds strictly irrespective of the contract length, the discount factor, and the number of shares or stock options in the compensation package because the profit from perfect collusion is always larger than the one from *Nash* competition.

Finally, in the benchmark case of traditional payments that consist in a constant fraction F of the firm's current profits, a manager's incentive to collude is simply given by

$$V(\pi_{\bar{A}}, a_t, \delta) = \sum_{\tau=0}^{\infty} \delta^{\tau+d} F \pi_{\bar{A}}(a_{t+\tau+d}) - \sum_{\tau=0}^T \delta^{\tau+d} F \pi_N(a_{t+\tau+d}), \quad (7.11)$$

if he receives the compensation deferred. Again, the condition for collusion (7.11), $V(\pi_{\bar{A}}, a_t, \delta) \geq 0$, is obtained by replacing the share-price-dependent by the profit-based payments in inequality (7.9). Due to the delay of payments the manager does not gain from cheating on the implicit agreement to jointly monopolize the market. Such payments can be interpreted as a stylized description of regular profit-dependent boni that often depend on the average performance during some specified time span. However, to the best knowledge of the author, such deferred boni are not currently used in practice and thus are merely a theoretical extension of the benchmark case of traditional undeferred profit-dependent payments.

The three conditions for collusion (7.9), (7.10) and (7.11), demonstrate that the effect of deferred compensation on the scope of collusion does not depend on the details of the contract design. By deviating a manager lowers his remuneration since the resulting profit is disbursed at the time of payment and does not determine the compensation. Therefore, a manager will always participate in joint monopolization of the market irrespective of all other market and contract conditions if he receives the compensation for his work with a delay.¹⁰ In particular, this strongly procollusive effect of deferred payments is independent of the development of demand over time.

¹⁰ This finding generalizes the results by *Spagnolo* (2000, Propositions 4, 5) for stock-based payments to any type of deferred compensation.

Long-term bonuses from performance-share plans are also frequently part of a manager's compensation package. Since a bonus is denominated in numbers of common shares, these payments also depend on the share price of the firm at the time of payout. However, a manager loses the bonus if he leaves the firm before the award is granted after z periods. If he expects to quit the firm in a period with a probability of $1 - \sigma$, his expected income from the long-term bonus plan that awards a number of shares ψ_i or its monetary equivalent in period $t + z$ amounts to

$$\sigma^z \delta^z \psi_i \mathcal{P}_R(a_{t+z}). \quad (7.12)$$

If κ_i options are awarded the expected bonus is

$$\sigma^z \delta^z \kappa_i [\mathcal{P}_R(a_{t+z}) - \underline{\mathcal{P}}_i]. \quad (7.13)$$

Since the share price is highest in the case of perfect collusion, a manager reaches the maximal remuneration by complying to this agreement until the bonus is paid. This decision is again independent of the discount factor. Afterwards, his incentive to collude depends on the other components of his compensation. If he receives no additional deferred or stock-based payments, his inclination to participate in the implicit agreement is the same as those of owners or managers with profit-based remuneration. Otherwise, the conclusions on the respective type of compensation apply.

7.1.5 Restricted Stock

Up to now we supposed that managers immediately sell the shares they receive as compensation. In fact, this resale is often restricted by contractual or legal requirements. In the United States, for example, the Securities Exchange Act, Section 16b demands a minimal waiting time of six months before options can be exercised or shares sold. In Germany the KonTraG (Gesetz zur Kontrolle und Transparenz im Unternehmensbereich) requires a waiting period of two to three years. If a manager is required to hold the stock he received as a part of his compensation, he becomes a shareholder of his firm. Moreover, he receives a part of his firm's profits as dividends. In this respect, such a restriction is equal to an additional, profit-oriented compensation component. Even with pure stock-based remuneration a manager will consider profits in his objective function according to the amount of shares he holds. In his decision on compliance with or deviation from an implicit agreement, his behavior is more similar to that of an owner. A recent empirical study shows that this behavior indeed results from real contracts (*Conyon, Freeman 2001*). If a manager holds his own firm's stock, his inclination to collude is diminished. The owner's possibility of credibly committing himself to a less fierce behavior in competition by strategic delegation is reduced.

Considering the extreme, procollusive effect of deferred stock-based compensation without restrictions on the resale of shares, owners or compensation

committees should be expected to choose this type of incentive payments. The preceding analysis shows that such incentive payments yield the highest firm value since they induce perfect collusion between the managers. However, the facts on the relative importance of the different types of incentive components stated in the introduction to this chapter indicate that deferred stock-based payments without additional restrictions are not a common form of compensation. This difference between the empirical evidence and the theoretical predictions is caused by the legal restrictions on the accounting and tax treatment of management compensation and the adjustment of compensation schemes to the risk aversion of managers (*Yermack 1997, Balsam 2002*).

7.1.6 Dividend Policy

A firm's dividend policy is characterized by the fraction $1 - g$, $g \in [0, 1]$ of the profits π_R , $R = \bar{A}, A, D, N$ that it disburses at the end of each period. Conversely, the fraction g is retained in the firm. The assumption that the share of per-period profits paid out as dividends is constant reflects the fact that joint-stock companies smooth dividends over time (*Allen, Michaely 1995*). It is not restrictive because the decision whether profits are retained or dividends disbursed is irrelevant to investors under the present assumptions (*Miller, Modigliani 1961*).

Since the fraction g of per-period profits is not disbursed, a firm receives the discounted profits $\pi_R + (\delta g \pi_R)/(1 - \delta)$ in every period. This periodic gain can be rewritten as $G \pi_R$, with $G \equiv [1 - \delta(1 - g)]/(1 - \delta)$. In the case of partial disbursement, the share prices from collusion and defection

$$\tilde{\mathcal{P}}_A = G \mathcal{P}_A, \quad (7.14)$$

$$\tilde{\mathcal{P}}_D = G \mathcal{P}_D \quad (7.15)$$

differ from those for total disbursement of profits (7.2) only by the factor $G \geq 1$ that reflects the effect of the assumed dividend policy. The value and thus the share price of a firm is highest if no dividends are paid at all ($G = 1/(1 - \delta)$), as, for example, is the case in high-growth firms and lowest if all profits are distributed as dividends at the end of each period ($G = 1$) as was assumed so far. The case of infinite retention of all profits is only a theoretical consideration however because shares of such a firm would be worthless for investors in a perfect capital market.

We showed above that the higher incentive to collude implied by stock-based compensation hinges on the fact that the share prices $\mathcal{P}_A$ and $\mathcal{P}_D$ are identical if managers with profit-dependent payments or owners are indifferent between collusion and deviation. Given the same price or output choice by managers with stock-based payments, the share prices in the event of collusion or deviation, $\mathcal{P}_A$ and $\mathcal{P}_D$, are equal because the corresponding discounted profit streams are the same in both cases. This equality holds irrespective

of the dividend policy that is described by the parameter G . Technically, substitution of this equality in the manager's incentive to collude (7.4), (7.7), (7.9) and (7.10) shows that the first payment still cancels in these inequalities. For the same reason, the previous argument also applies if firms distribute asymmetric fractions of profits to stockholders and if demand changes over time.

Hence, the dividend policy does not change the result that a manager's incentive to collude is higher if he receives stock-based instead of profit dependent payments. To verify whether the results are also robust with respect to changes in the demand level we next consider competition between managers in markets with fluctuating demand.

7.1.7 Number of Firms, Market Size and Welfare

Via the share price, the stream of discounted future profits determines the collusive behavior of the managers with stock-based compensation. Thus, all factors that alter this profit stream also affect the implicit agreement in the case of delegation.

Since the number of market participants and the elasticity of demand change the per-period profits in the same way as in the case of competition between owners, the results of Sections 4.7 and 4.8 still apply: A large number of competitors in the market makes collusion difficult and reduces the profits, whereas a high market size increases the firms' profitability.

The analysis of competition between managers also offers conclusions on welfare. The considerations in Section 4.9 demonstrate that the welfare level rises in the firms' quantities. Since stock-based compensation facilitates collusion, it results in a lower market output and reduces the welfare in the market. This detrimental effect is smaller, the larger is the number of firms in the market.

Thus, the results on the number of competitors, the market size and welfare demonstrate the robustness of the present model to extensions and its integrability into a broader framework. The next section will show that the same holds true with respect to different types of demand development over time.

7.2 Demand Fluctuations

The preceding analysis of product market strategies with and without additional financing and investment decisions shows that the development of the market demand over time determines a firm's (i.e. its owner's) inclination to collude. The same is true, if managers run the firms: In the simplest case of traditional profit-dependent compensation, their incentives do not differ from the owners'. In the case of stock-based compensation, the managers' incentives depend on the share price. The share price in turn is determined by the

discounted stream of future profits that results from the current as well as the future expected demand levels. Thus, demand fluctuations also affect a manager's incentives if he is paid depending on the stock market value of his firm.

The collusive outputs and prices therefore change in response to shifts of the demand level irrespective of the decision to delegate and the design of the compensation contract. The development of the market price thus may serve as an indicator of competition or collusion in a certain market if managers run the firms. However, as was shown above, the inclination to collude differs across the types of incentive compensation. Furthermore, the impact of changes in the demand level on competition in the market depends on the details of the time structure of demand. To disentangle the effects of different characteristics of demand in their interplay with delegation of the firms' management, we consider again the market demand patterns introduced in Chapter 4 and analyze the different components of management compensation successively.

7.2.1 Demand Shocks

As before, we start with an analysis of uncorrelated, stochastic shocks on the demand level in every period. In this case, the discounted stream of future profits – and consequently also the share price of the firm – depends on the current realization of the shock and on future expected demand. In period t , it amounts to

$$\mathcal{P}_R(a_t) = \frac{1}{\varphi_i} \left[\pi_R(a_t) + \frac{\delta e[\pi_R(a)]}{1 - \delta} \right], \quad R = \bar{A}, A, N \quad \text{or} \quad (7.16)$$

$$\mathcal{P}_D(a_t) = \frac{1}{\varphi_i} \left[\pi_D(a_t) + \frac{\delta e[\pi_N(a)]}{1 - \delta} \right] \quad (7.17)$$

depending on whether the managers collude, compete or deviate from the implicit agreement. The expected profits from joint monopolization, imperfect collusion and unrestrained competition amount to

$$\begin{aligned} e[\pi_{\bar{A}}(a)] &= \int_{\underline{a}}^{\bar{a}} \pi_{\bar{A}}(a) f(a) da, \\ e[\pi_A(a)] &= \int_{\underline{a}}^{\tilde{a}} \pi_{\bar{A}}(a) f(a) da + [1 - F(\tilde{a})] \pi_A(\tilde{a}) \quad \text{and} \\ e[\pi_N(a)] &= \int_{\underline{a}}^{\bar{a}} \pi_N(a) f(a) da, \end{aligned}$$

respectively. The highest demand level $\tilde{a}$ that is still consistent with perfect collusion between managers with stock-based compensation determines the expected discounted profits and hence the share price in the cases of perfect and imperfect collusion that is given by (7.16).

The discussion of identically, independently distributed shocks in Section 4.3 shows that perfect collusion is possible if the incentive to defect is small due to a low level of demand. If demand is higher than the critical threshold $\tilde{a}$ or $\tilde{\tilde{a}}$, the resulting high incentive to defect and realize the one-shot gain from cheating must be reduced by implicitly agreeing on a quota below or a price above the joint-monopoly equilibrium values to make collusion viable.

Compared to an owner who runs the firm himself or a manager with traditional profit-dependent compensation, a manager who receives any type of stock-based compensation has a higher incentive to collude. Therefore, he participates in perfect collusion if demand is low due to a realization of the shock below the critical value $\tilde{a}$. To demonstrate the effect of management compensation, it is thus sufficient to consider the demand levels that correspond to imperfect collusion between owners. Consequently, we restrict attention to the shock realizations that yield a market size in the interval $(\tilde{a}, \bar{a}]$.

Stock-Based Compensation

A manager takes part in the implicit agreement if the discounted stream of the resulting share-price-dependent compensation payments is higher than the alternative one gained if he defects and competes in the market during the punishment phase. Then, his incentive to collude is positive:

$$V(\pi_A, a_t, \delta) = f \left[\frac{1}{\varphi_i} \left(\pi_A(a_t) + \frac{\delta e[\pi_A(a)]}{1 - \delta} \right) \right] + \frac{\delta}{1 - \delta} f \left[\frac{e[\pi_A(a)]}{\varphi_i (1 - \delta)} \right] \\ - f \left[\frac{1}{\varphi_i} \left(\pi_D(a_t) + \frac{\delta e[\pi_N(a)]}{1 - \delta} \right) \right] - \frac{\delta (1 - \delta^{T-1})}{1 - \delta} f \left[\frac{e[\pi_N(a)]}{\varphi_i (1 - \delta)} \right] > 0. \quad (7.18)$$

The share price in the different situations of collusion, defection and punishment are given by the arguments of the compensation function in the square brackets. The first term above states the payment in the current period, the second the discounted expected future compensation in the case of collusion. The third term gives the payment in the period of defection and the last one the discounted amount earned during the punishment phase. The condition for collusion (7.18) demonstrates that the current realization of the demand shock affects only the share price and compensation in the present period. Due to the independence of the demand levels across time, the future expected discounted compensation is independent of the current market size a_t . The additional compensation that is gained by defection compared to continued collusion in contrast,

$$f \left[\frac{1}{\varphi_i} \left(\pi_A(a_t) + \frac{\delta e[\pi_A(a)]}{1 - \delta} \right) \right] - f \left[\frac{1}{\varphi_i} \left(\pi_D(a_t) + \frac{\delta e[\pi_N(a)]}{1 - \delta} \right) \right],$$

increases in the current market size. Again, there is a critical market size $\tilde{\tilde{a}} \in [\tilde{a}, \bar{a}]$ up to which the condition (7.18) holds with slack even if managers

jointly monopolize the market. If the realization of the shock is higher, however, the compensation payment in the period of defection is very large due to a high demand level. To offset the high incentive to defect from the implicit agreement, managers must reduce the corresponding compensation payment. Since it is set by their firms' owners, they cannot reduce it directly. Yet, due to the fact that the payment depends on the share price, the managers can decrease it by choosing a competitive strategy that yields lower collusive profits. In order to make the implicit agreement viable, they produce quantities that are higher or set prices that are lower than in the case of perfect collusion. Thus, the basic mechanism behind the observation of "price wars during booms" (Rotemberg, Saloner 1986) also works if managers with stock-based remuneration run the firms.

However, the design of management compensation affects collusion in an important way: In a situation where the condition for collusion between owners or managers with traditional compensation is binding, the discounted profit streams, and therefore the share prices of a firm, are identical in the cases of collusion and defection (cf. equation (7.5)). Furthermore, a certain value of the market discount factor then corresponds to an upper bound $\tilde{a}$ of the current market size that is still consistent with perfect collusion between owners and managers who receive profit-based remuneration. This threshold of demand $\tilde{a}$ results in the share prices

$$\mathcal{P}_A(a_t) = \frac{1}{\varphi_i} \left[\pi_A(a_t) + \frac{\delta E[\pi_A(a)]}{1 - \delta} \right] = \frac{1}{\varphi_i} \left[\pi_D(a_t) + \frac{\delta E[\pi_N(a)]}{1 - \delta} \right] = \mathcal{P}_D(a_t). \quad (7.19)$$

Using this equality in (7.18), we see that the current compensation payment cancels in the respective incentive for collusion between managers with share-price-dependent compensation if they set the same prices and output levels as owners or managers with traditional contracts. Therefore, the condition for collusion

$$V(\pi_A, a_t, \delta) = \frac{\delta}{1 - \delta} f \left[\frac{e[\pi_A(a)]}{\varphi_i (1 - \delta)} \right] - \frac{\delta (1 - \delta^{T-1})}{1 - \delta} f \left[\frac{e[\pi_N(a)]}{\varphi_i (1 - \delta)} \right] > 0 \quad (7.20)$$

holds with slack. This is true because the per-period profits and hence the expected compensation payments are always larger if managers participate in the implicit agreement instead of competing in the product market. Further, the inequality (7.20) demonstrates that the collusive strategy of owners or managers with traditional contracts is not optimal for managers who receive share-price-dependent payments. Their discounted compensation is higher if they reduce the quotas or increase the price until the condition for collusion (7.18) holds with equality. As in a market with constant demand, managers with share-price-dependent remuneration produce less and realize a higher price compared to managers with profit-dependent compensation or owners.

Consequently, they are able to monopolize the market at a higher current demand level. The critical threshold of the market size up to which perfect collusion is viable is thus higher if managers receive stock-based instead of profit-dependent compensation, $\tilde{a} > \tilde{a}$. As in a market with constant demand, the inclination to participate in the implicit agreement is increased by stock-based compensation because it puts a higher weight on future profits than the traditional contract. This finding implies that the basic procollusive effect of share-price-dependent compensation is robust to uncorrelated shocks on the market demand.

It is not difficult to verify that the procollusive effect also arises if the remuneration consists in stock or option grants. In a situation where owners or managers with traditional contracts are indifferent between collusion and defection, the equality of the share prices (7.19) yields the following condition for collusion if managers who receive such grants set the same output levels or prices:

$$V(\pi_A, a_t, \delta) = \frac{\delta}{1-\delta} \kappa_i \left[\frac{E[\pi_A(a)]}{\varphi_i(1-\delta)} - \mathcal{P}_i \right] - \frac{\delta(1-\delta^{T-1})}{1-\delta} \max \left\{ \kappa_i \left[\frac{E[\pi_N(a)]}{\varphi_i(1-\delta)} - \mathcal{P}_i \right], 0 \right\} \geq 0. \quad (7.21)$$

For the same reason as before, namely $\pi_A(a) > \pi_N(a) \forall a \in [\underline{a}, \bar{a}]$, the incentive to collude, $V(\pi_A, a_t, \delta)$, is strictly positive. Since managers maximize their discounted remuneration by setting the lowest quantity or highest price that makes the implicit agreement viable, they also produce less and realize a higher price compared to owners or managers with traditional profit-based compensation if they receive stock or option grants.

The preceding consideration demonstrates that all types of stock-based incentive payments that are awarded before profits are disbursed as dividends increase the scope of collusion in a market with uncorrelated, stochastic shocks on the demand level. Consequently, “price wars”, i.e. periods where the price is lower than the price that is consistent with perfect collusion, are observed less frequently compared to a market where owners or managers with traditional employment contracts run the firms. The anticyclicity of pricing is therefore reduced by stock-based management compensation. As is shown in Section 7.1.4 this is all the more true, if managers receive deferred compensation. Since it makes the joint monopolization viable irrespective of the demand development, it eliminates price fluctuations that are caused by imperfect collusion. The market price is thus procyclical and parallels the shifts of demand over time. However, this conclusion is again subject to the qualifications about waiting and holding periods discussed in Section 7.1.5.

7.2.2 Demand Cycles

Since seasonal and other cyclic variations of demand give rise to a characteristic pattern of pricing, we also derive the effect of stock-based management

remuneration on competition in a market with such demand fluctuations. The additional effect of compensation on the development of prices and outputs over time is of special interest because it may serve as an indicator of the scope of collusion in the market. It is thus of specific significance for the antitrust assessment of market power.

If market demand fluctuates, the share price that determines the compensation payment of a manager in period t amounts to

$$\mathcal{P}_N(a_1, \dots, a_{\bar{t}}) = N(t, \delta) / \varphi_i, \quad (7.22)$$

$$\mathcal{P}_A(a_1, \dots, a_{\bar{t}}) = A(t, \delta) / \varphi_i \quad \text{or} \quad (7.23)$$

$$\mathcal{P}_D(a_1, \dots, a_{\bar{t}}) = [\pi_D(a_t) + \delta N(t + 1, \delta)] / \varphi_i \quad (7.24)$$

depending on whether he competes, colludes or defects from the implicit agreement.

To derive the effect of cyclic demand development on competition if managers run the firms, we analyze the different compensation components in turn.

Stock-Based Compensation

We start with an analysis of the simplest case of undeferred share-price-dependent remuneration. In every period, a manager receives the payment $f[\mathcal{P}_R(a_1, \dots, a_{\bar{t}})]$ that rises in the share price $\mathcal{P}_R(a_1, \dots, a_{\bar{t}})$. The relevant share price and hence his inclination to collude now depends on the development of demand over the cycle.

A manager takes part in collusion if the resulting discounted compensation is higher than the one gained by defection and punishment by unrestrained competition thereafter. Thus,

$$\begin{aligned} V(t, \pi_A(a_1), \dots, \pi_A(a_{\bar{t}}), \delta) &= \sum_{\tau=0}^{\infty} \delta^\tau f[A(t + \tau, \delta) / \varphi_i] - \\ f[(\pi_D(a_t) + \delta N(t + 1, \delta)) / \varphi_i] &- \sum_{\tau=1}^T \delta^\tau f[N(t + \tau, \delta) / \varphi_i] \geq 0 \end{aligned} \quad (7.25)$$

states the condition for collusion between managers who receive share-price-dependent payments in a market with cyclic demand.

If the condition for collusion between owners (4.24) is binding due to imperfect collusion or joint monopolization at the critical threshold of the discount factor $\underline{\delta}$, the share prices are also identical if the market demand follows a cyclic trend:

$$\mathcal{P}_A(a_1, \dots, a_{\bar{t}}) = A(t, \delta) / \varphi_i = [\pi_D(a_t) + \delta N(t + 1, \delta)] / \varphi_i = \mathcal{P}_D(a_1, \dots, a_{\bar{t}}). \quad (7.26)$$

By inserting this equality in (7.25), we get

$$V(t, \pi_A(a_1), \dots, \pi_A(a_{\bar{t}}), \delta) = \sum_{\tau=1}^{\infty} \delta^{\tau} f[A(t + \tau, \delta)/\varphi_i] - \sum_{\tau=1}^T \delta^{\tau} f[N(t + \tau, \delta)/\varphi_i] \geq 0, \quad (7.27)$$

as the modified condition for collusion if the managers with share-price-dependent payments choose the same collusive strategy as owners or managers with traditional contracts.

If managers receive stock or option grants instead of share-price-dependent payments, the equality of the share prices (7.26) yields

$$V(t, \pi_A(a_1), \dots, \pi_A(a_{\bar{t}}), \delta) = \sum_{\tau=1}^{\infty} \delta^{\tau} \kappa_i [A(t + \tau, \delta)/\varphi_i - \underline{P}_i] - \sum_{\tau=1}^T \delta^{\tau} \kappa_i \max \{N(t + \tau, \delta)/\varphi_i - \underline{P}_i, 0\} \geq 0 \quad (7.28)$$

as the condition for a viable implicit agreement on the same quotas and prices as they are set by owners or managers with profit-based remuneration.

These conditions, (7.27) and (7.28), are always fulfilled independent of the contract length T because per-period profits from an implicit agreement are always higher than those from *Nash* competition. Compared to owners or managers with profit-dependent remuneration, managers who receive stock-based compensation also have a higher incentive to collude if the market demand fluctuates cyclically. Accordingly, they will exhaust the scope of collusion by setting lower outputs and higher prices than owners or managers with traditional contracts.

With respect to the optimal collusive strategy, cyclic demand fluctuations have the same basic effect as in the case of non-delegation if the compensation payments are made before the dividends are disbursed. Since the stream of future profits is larger in times where demand is still rising, the potential punishment for defection is then higher. Conversely, falling demand yields low future profits and limits the possibility to punish a defector. Thus, collusion is easier in booms than in recessions: Pricing is strongly procyclical. Qualitatively, the analysis presented in Section 4.4 still applies. Furthermore, managers with undeferred stock-based compensation have a higher incentive to participate in the implicit agreement and choose the same collusive strategies as managers with traditional contracts if they put a lower value on future compensation payments. Therefore, the thresholds of the discount factor that mark the boundaries between the different patterns of price development over time are lower if managers receive undeferred stock-based instead of profit-based payments. The corresponding intervals depicted in Figure 4.3 are then shifted to the left. Deferred compensation however gives rise to perfect collusion between managers. Thus, it implies pricing in parallel to the development of demand

irrespective of the value of the market discount factor unless holding periods reduce its procollusive effect (cf. Sections 7.1.4 and 7.1.5).

7.2.3 Demand Cycles Subject to Shocks

If we allow for uncorrelated stochastic shocks on demand within the periods of the cycle, the above model of collusion between managers in a market with deterministic cycles can be applied, if the demand levels of every period are replaced by their expected values. If owners or managers with traditional compensation are indifferent between collusion and defection followed by punishment, the corresponding discounted profit streams and hence the share prices are still identical. Therefore, the finding of a greater scope for collusion with strategic delegation remains unchanged in the generalized model.¹¹

Irrespective of the deterministic trend, the current realization of the demand shock only changes the possible gain from deviation, but not the discounted stream of future profits (level effect). Furthermore, the cyclic trend still yields higher expected profits in times of rising than of falling demand if managers run the firms (slope effect). The basic adjustment of the implicit agreement is hence the same as in a market without delegation. Yet, due to their higher incentive to collude, managers with stock-based compensation expand the output or cut the price at a higher shock realization and lower expected future demand compared to owners and manager with profit-based remuneration. By the same argument, they adjust the implicit agreement if expected future demand is lower. The cyclicity of pricing is therefore less pronounced if the compensation depends on the share price of the firm. Except for this difference, the collusive strategies are identical: If the demand levels result from a cyclical development with stochastic shocks, the output and pricing decision is still a combination of the strategy for deterministic demand cycles and the strategy for markets with uncorrelated demand shocks. If, however, the managers receive their compensation deferred, they always jointly monopolize the market. Then, an adjustment of the implicit agreement to demand fluctuations is unnecessary.

7.3 Discussion

From a theoretical perspective, it is a great advantage that the present framework of collusion between managers with stock-based compensation can be extended to account for additional strategic decisions. The previous analyses of recurring reinvestments and outside financing for example can be integrated in the present model by exchanging the per-period profits that determine the share price by those that result with investments in capital replacement and

¹¹ *Neubecker* (2005) demonstrates that the same result holds if the demand development is stochastically autocorrelated and is described by a *Markov* process.

financing by outside funds. This extension does not change the main finding that stock-based management compensation increases the scope of collusion. It continues to hold because the profit streams gained by collusion or defection are still the same at the critical threshold of the discount factor that is relevant if managers with traditional compensation or owners decide on reinvestments and leverage. Hence, the current payment still cancels in the incentive to collude of a manager with stock-based compensation. The procollusive effect thus does not arise through the impact of stock-based compensation on the punishment. Hence, the design of management compensation is another example where the *topsy-turvy principle* by *Shapiro* (1989) does not apply.

However, the effect of reinvestments in production or leverage on collusion is not a priori clear if managers with stock-based compensation run the firms. Since these long-term decisions determine the periodic profits, they change the share price. The effect of such a change on the managers' remuneration depends on the curvature of the function $f(\mathcal{P}_R)$ that determines the payment on the basis of the current share price. Whether capital reinvestments or outside finance make collusion between managers with stock-based compensation easier or more difficult compared to the benchmark case without these decisions therefore depends on the functional form specified in the contract.

The sparse empirical evidence supports the theoretical results. *Joh* (1999) analyzes compensation schemes and profits of Japanese firms and finds a positive effect of management compensation on industry profit. Since the empirical data does not allow for a precise distinction between the different incentive components that depend on relative performance of the own firm, the current profit and the development of the share price, the positive link between the managers' remuneration and profits may indeed arise from stock-based components. Therefore, the empirical analysis can also be interpreted as weak evidence of a procollusive effect of stock-dependent management compensation.

The closely related study of relative performance compensation in U.S. manufacturing industries by *Aggarwal*, *Samwick* (1999) yields similar results. In this data set, approximately half of the compensation consists of options on unrestricted stock. In addition, a small fraction is composed of grants of restricted stock and of long-term incentive plan payouts. In line with *Joh*'s results, the link between a manager's remuneration and both its own and its rival's performance is positive in most specifications. However, the empirical variables describe the parameters of the relative-performance incentive contract only very approximately. Again, a significant part of the effect may be caused by stock-based components because the positive relationship between profits and compensation is stronger for the total sample than for the short-term components that typically do not depend on the stock market value of the firm. The sensitivity of remuneration to a measure of the own and the competitors' profits is therefore not necessarily due to payments that depend on a firm's relative performance. Hence, the evidence is in line with the prediction of the present model.

The previous theoretical literature proposes very different underlying relationships between compensation and performance. In models of the strategic delegation to managers with a linear contract (e.g. *Fershtman, Judd* 1987, *Sklivas* 1987 and *Aggarwal, Samwick* 1999, *Miller, Pazgal* 2001, *Miller, Pazgal* 2002), the managerial firms are highly profitable only if they compete in strategic complements (i.e. in quantities in a market for a complementary or in prices in a market for a substitutive good, cf. *Bulow et al.* 1985). In the case of strategically substitutive variables in contrast, the profitability of the firms may be reduced by delegation. Notably, in these models of one-shot competition between managers high profits may arise even without explicit or implicit coordination of the product market strategies. In the repeated-game version of competition between managers with a linear contract by *Lambertini, Trombetta* (2002) however, high profits are gained only if owners collude by coordinating their decisions on compensation. In short, the theoretical models offer very different explanations for a high profitability of managerial firms. Yet, the empirical studies published so far are not able to discriminate between those theoretical models that predict higher firm profits and thus higher markups.

Moreover, there are no empirical studies to date that offer conclusions on the collusive effect of deferred compensation since none accounts for the impact of laws on accounting and taxation as well as restrictions on resale. According to the theoretical model, however, the latter factors are important in this context since they prevent managers from jointly monopolizing the market.

7.4 Summary and Policy Conclusions

The above model showed the effects of stock-based management compensation on competition in a market where demand changes over time.

In contrast to traditional compensation that depends only on current profits, all types of stock-based payments depend on the total stream of discounted profits. Stock-based management compensation therefore puts a higher value on future profits than the traditional type of contract.

For this reason, managers with undeferred stock-based compensation gain more by participating in an implicit agreement and have a greater incentive to collude than owners or managers with profit-dependent remuneration. The inclination of managers to comply with a tacit agreement can be strengthened by a shorter contract length because their remuneration after deviation is then lower. If managers receive a deferred compensation, they do not gain from deviation because the one-shot profits from defection are disbursed at the time the payments are made. Therefore, even perfect collusion is stable for all values of the discount factor irrespective of the duration of the contract. Restrictions on the resale of shares however reduce the strong procollusive effect of deferred compensation.

The result of less aggressive competition in the case of delegation to managers with stock-based compensation contracts is robust to changes in the market size. The basic level and slope effect of demand fluctuations also arise in the case of delegation as long as the compensation is paid before the dividends are disbursed. Since managers with stock-based payments have a higher incentive to collude, a smaller adjustment of their implicit agreement is sufficient to make it viable in a market with demand fluctuations. Therefore, the cyclicity of pricing is reduced by stock-based compensation. In the case of deferred payments, the procollusive effect of delegation is much stronger: Then, the managers cannot gain by deviating from the implicit agreement. Consequently, they jointly monopolize the market irrespective of the value of the market discount factor and the pattern of demand development. The corresponding market price changes in parallel to demand over time. If however the contract specifies a holding period for shares, a manager additionally receives a part of the current profit as dividends. Since his incentives are more similar to those of an owner then, a holding period increases the manager's valuation of present profits. As a result, his inclination to collude is smaller and the implicit agreement is viable at a higher value of the market discount factor. All the above conclusions apply irrespective of the dividend policy of the firms.

Since the surge in management compensation, especially in its stock-based components in the nineties, there is an ongoing critical discussion on the structure and level of top executives' remuneration. Whereas the public debate focuses on issues of commensurability and justice, the present analysis demonstrates the considerable collusive potential of stock-based compensation. Although it may be used predominantly for its incentive effect or its advantages with respect to accounting and taxation, the consequent reduction of competition is an additional benefit from a private perspective.

Executives receive a considerable share of their remuneration in the form of stock option grants that usually include a waiting time to exercise. The present study shows that such deferred compensation considerably increases the managers' incentive to collude, whereas holding periods tend to make collusion more difficult. Hence, the regulation of stock-based compensation, especially the requirement of holding periods is not only necessary to prevent insider trading or the abuse of accounting and tax laws, but is also a means to reduce the risk of collusion amongst the managers.

Discussion and Summary

The supergame description of collusion is to date the best developed and researched model of anticompetitive explicit and implicit agreements in oligopoly. In parallel to insights gained from other, complementary approaches, namely differential games and dynamic multiple-agent models in the line of *Ericson, Pakes* (1995) and *Fershtman, Pakes* (2000), it is a reasonable guide for competition policy. To point out its merits, we will first discuss the model from a theoretical point of view, especially in relation to alternative models of dynamic competition. Then, we will consider its usefulness from an antitrust perspective.

8.1 Criticism of the Supergame Approach

The theory of infinitely repeated games offers an explanation of anticompetitive agreements between oligopolists. Moreover, it can be extended to account for details of the market conditions that make it applicable in a wide number of situations. In contrast to the customary, the problem in this case is that the framework even works too well in the sense that it gives rise to a large number of noncooperative equilibria. This is the most obvious point of criticism that entered into the industrial-organization literature under the catch phrase “explaining everything, explaining nothing” coined by *Sutton* (1990, 505). Each supergame has an continuum of solutions and can explain any market outcome between the least profitable *Nash* equilibrium and the most restrictive collusive equilibrium that can be supported at the given value of the discount factor. The theory hence does not predict the market outcome in the case of collusion. However, it shows that such self-enforcing coordination of the competitive strategies is possible and offers an explanation of how it can be achieved.

The multiplicity of equilibria is a drawback of the theory, unless one accepts the notion of a *focal point* of coordination. Given the fact that profit

maximization is one of the fundamental assumptions of microeconomic theory, it is plausible that the firms coordinate on the equilibrium that offers the highest market profit. Since antitrust laws prohibit such coordination, it is likewise plausible to assume that the firms coordinate only on equilibria that can be implemented without incriminating side payments between the participants. If the competitors are identical in all respects, this leaves a single symmetric equilibrium that predicts the market outcome in dependence of the firms' valuation of the future. Most of the industrial-organization literature on collusion, and also the present work, uses these criteria to determine the outcome of long-term competition. The approach is generalized by the concept of *balanced temptation* proposed by *Friedman* (1971) that can be used to select an equilibrium on the *Pareto* frontier in asymmetric situations. The criterion requires that the condition for collusion must be identical for all the participants. Other authors, as for example *Rothschild* (1999) in his analysis of collusion between firms with asymmetric costs, presume specific sharing rules. No other general approach of equilibrium selection has yet been proposed, so that anyone who is not willing to accept the plausibility of the ad hoc assumptions used to limit the number of possible outcomes is still left with the continuum identified by the basic model of the supergame.

Along the same lines, the credibility of the punishment strategy is another issue that may cast doubt on the descriptive power of the theory. Since the participants in collusion cannot commit not to renegotiate, the punishment that follows a defection might in principle be avoided if firms entered into bargaining on the collusive strategy. As is discussed in the Introduction, the criteria proposed by *Farrell, Maskin* (1989) and *Farrell* (2000) single out the renegotiation-proof equilibria that can still be enforced by the firms. However, they require collusive strategies of considerable complexity. The need for coordination, communication and possibly also written documentation of meetings and details of the agreements is therefore higher. Since the numerous case filings at the US- and European antitrust authorities document a close supervision of the markets that offer a large scope of collusion, the firms are not likely to incur the concomitant additional risk of detection. Moreover, renegotiation to avoid the use of the punishment is likely to leave a paper trail that could be used as evidence in antitrust cases. Hence, given effective cartel legislation and supervision, it seems likely that the antitrust authority unintentionally precludes renegotiations (as well as coordination on complex strategies) and enables the firms to collude by using the *grim trigger* punishment as enforcement mechanism. Therefore, the initial version of the model is nonetheless appropriate to analyze collusion in developed, industrial countries.

Another instance where the model is seemingly too effective in explaining collusion is the fact that, according to the model, the firms in the market either participate in the implicit agreement or compete if collusion is not viable. Since they only agree on prices or output quotas that can be enforced in the given situation, the punishment is never actually used. The competitive strategies

of the firms are therefore stationary over time. In its basic version proposed by *Friedman* (1971), the model is thus not suited to explain periodic breakdowns of collusion that result in price wars or other types of price fluctuations. This result is largely due to the assumption of constant market conditions, that is, of course, a stark abstraction from reality.

This stationarity of a firm's competitive strategy and the lack of state variables that describe its strategic investment decisions however only seems to be a disadvantage of the supergame approach. A comparatively simple solution to redress the constancy of the market conditions is the introduction of exogenous shocks, e.g. due to entry, cost shocks or demand changes. The preceding analysis proved that such exogeneous factors can be integrated into the framework and yield time-varying competitive strategies of the firms. However, an endogenous explanation of the market conditions is more elegant. It can be achieved by including additional strategic decisions of the firms. As the survey of the investment-product market games in the Introduction and the detailed analysis of investment decisions in the subsequent chapters demonstrate, it is possible to build a supergame model of competition in a state variable (investment) and a market variable (price or quantity). Due to the (infinite) repetition of the game, the strategies of the firms are again stationary.

On the first glance this may be a poor description of the dynamics of oligopolistic competition. However, it is a great advantage insofar as the market conditions are now determined endogenously. Their stability over time might even be a good description of mature oligopolies where the conditions of competition change most often only due to exogeneous developments. The extensive survey of factors that hamper or facilitate collusion demonstrates that such additional factors can also be integrated into a supergame to achieve a precise description of the characteristics of any special market under analysis.

A last important point of criticism is the fact that the theoretical model always gives rise to a situation where all the firms take part in collusion if their valuation of the future is sufficiently high. However, this feature is the plausible consequence of the assumption that the firms are symmetric in all respects. *Donsimoni* (1985) for example considers competition between asymmetric rivals and shows that only the efficient firms participate in collusion, whereas the inefficient producers form a competitive fringe. Again, the apparent disadvantage is only a stylization that can be removed in a generalized version of the model. Moreover, there is some evidence for *Donsimoni's* conclusion in case filings and other documents on price-fixing conspiracies of the US-Antitrust Division analyzed by *Hay, Kelley* (1974). They report that the fringe most often consisted of the smaller competitors in the cases where not all firms in the market participated in the collusion.

So, despite the points of criticism mentioned above, the supergame theory offers a suitable explanation for anticompetitive, collusive agreements in long-term oligopolistic competition. Its underlying principle of defection and retaliation is intuitively plausible and widely applicable. The survey of empir-

ical work in Chapter 3 documents that there is a great number of econometric studies that find support for the conclusions of the supergame analyses. Once this partial-equilibrium, infinitely-repeated-game description of long-term oligopolistic competition is accepted, a great number of other limitations of the basic version proposed by *Friedman* (1971) can be redressed by extensions of the model. Since the current work analyzes changes in the incentive to collude over time that give rise to fluctuations of the market price in competition that requires additional long-term decisions, we integrate the several extensions into the basic framework.

8.2 Summary of the Main Results

The present work shows that demand fluctuations and long-term investment decisions determine the firms' inclinations to collude. The following overview of the main findings demonstrates their different effects on competition in the product market.

From the outset, the analysis of long-term competition sought to explain price fluctuations in oligopolistic markets (*Stigler* 1964). The present study demonstrates that collusion in the presence of demand changes can explain different patterns of price development over time. Furthermore, the integration of demand fluctuations adds real-world flavor to the theoretical model since both stochastic and cyclic demand changes are characteristic for many markets.

For the purposes of the analysis it is useful to consider these two types of demand development separately. In the case of uncorrelated stochastic shocks on the demand level, colluding firms expand their output or reduce the price in periods of high demand to decrease the gain that is achieved by defecting from the implicit agreement. Thus, collusive pricing is anticyclical. However, modeling the demand development as result of a constant basic level subject to uncorrelated shocks is a considerable abstraction since the future development of demand is typically to some extent determined by its current level. The deterministic cyclic trend is an example of such an autocorrelation. Since the deterministic cyclic trend is a good description of markets for input goods and many consumer goods, its integration into the theoretical model of long-term competition offers further important insights. This type of demand development yields a higher scope for collusion in periods of rising than of falling demand since high future demand yields a more severe punishment for defection, which consists in the loss of collusive profits. Consequently, the firms increase their output or lower the price in times of falling demand if continuous monopolization of the market is impossible. Therefore, a cyclic trend in demand gives rise to markedly procyclic collusive pricing. The parallel occurrence of cycles and shocks is a quite fitting description of the complex patterns found empirically in many markets. In such a setting, the above conclusions

continue to hold: High current demand decreases, but high expected future demand increases the firms' incentive to collude.

The integration of demand fluctuations into the basic model of long-term competition yields an explanation for changes in the market price. According to the theoretical analysis, these result from an adjustment of the implicit agreement to the changing market conditions. If other causes of price fluctuations, as for example cost changes, can be excluded, deviations between the development of the market price and the demand level give evidence of an effective working and not of a breakdown of the collusive agreement. The last consideration demonstrates an additional advantage of the analysis of demand fluctuations. If the demand level is constant over time, the framework can be reinterpreted as a model of changing production costs. A cyclic development of the cost might result for example if a strong factor demand drives up wages and input prices in macroeconomic boom periods.

Whether the considered demand fluctuations or alternative explanations for cyclic pricing, as for example changes in productions costs or consumer search costs, are the explanation for the observed price development in a given market must be determined empirically. Since it is possible to assess the actual relevance of the potential other explanatory factors, it should not be too difficult to judge whether collusion or some other market condition determines the pricing in the market under consideration. Problems arise however if several factors interact. The discussion of the empirical literature on market power and collusion in Chapter 3 demonstrates that it might be very difficult to distinguish clearly between the different causes of price fluctuations. The most prominent case in this respect is the discrepancy in the conclusions of studies by *Porter* (1983b), *Ellison* (1994) and *Vasconcelos* (2004) who analyze collusion by the *Joint Executive Committee*.

We further exploited the versatility of the supergame approach by integrating additional strategic decisions on the capital structure, the organization of reinvestments in production as well as the delegation of the business and the compensation of the managers. The analysis of cooperation in manufacturing demonstrates that individual investments in capital replacement increase, but cooperative investments decrease the scope of collusion in the product market. The necessity to finance an indispensable investment by outside funds is another factor that reduces the likeliness of an anticompetitive agreement. Stock-based compensation in contrast increases a manager's incentive to take part in collusion in comparison to traditional compensation that depends on current profits alone. This is especially true if the remuneration is paid deferred since managers then cannot gain by defecting from an implicit agreement. Hence, the owners of firms in a given market might use stock-based compensation components strategically to gain higher collusive profits. The procollusive effect is reduced however if a manager holds stock in the firm that he runs. Then, the amount gained from dividend disbursement increases his valuation of present profits thereby decreasing his incentive to participate in an implicit agreement. These clear predictions of the pro- or anticollusive ef-

fect of different long-run decisions yield implications for an effective antitrust policy.

8.3 Conclusions with Respect to Antitrust Policy

The theoretical analysis of long-term oligopolistic competition is especially suitable to single out market conditions and business strategies that increase the likeliness of anticompetitive agreements. Since the sum of factors that affect collusion is usually large, the firms frequently rely on written agreements about anticompetitive practices. These are often discovered in the course of judicial investigation in firms that compete in markets that are prone to collusion according to the theoretical appraisal of the competitive conditions. The most recent examples of such cases are given by the filings and summary statements on the internet pages of the US-Federal Department of Justice and the Competition Commission of the European Union. They include cases of price fixing on vitamins, lysine and zinc of international scope, as well as national cases, as for example anticompetitive agreements between cement producers in Denmark and Germany, price fixing in the German paper wholesale sector and many others. The present study derives the pro- and anticollusive effect of different long-run strategies in markets where demand is constant or changes over time. These results can be used to assess whether an anticompetitive agreement is likely to be in place in a specific market. With this information, the resources of the competition authorities can be used economically for the surveillance of markets that are especially prone to collusion.

Based on the findings detailed above, several conclusions for competition policy can be drawn: With respect to its design, a laissez-faire approach to cooperation in capital reinvestment, as it is already incorporated in the U.S. and European antitrust regulation, is advisable. Seeing the beneficial effects of efficiency gains and the reduced likeliness of collusion, the policy agencies should even encourage such cooperation, for example by providing an information platform for prospective participants or subsidies. As outside financing by bonds does not create an additional incentive to take part in an implicit agreement, bond issues do not warrant antitrust regulation. The surge in stock-based incentive components for high-level managers however merits special attention, particularly since waiting times till stock options can be exercised amount to a deferred compensation which results in a very high incentive to collude. As holding times for shares reduce the scope of collusion, their introduction is not only a means to prevent insider trading, but also yields a lower scope for anticompetitive behavior by managers.

With respect to the enforcement of antitrust regulations the following conclusions arise: The comparison of the demand and price development offers a clear indication of the extent of collusion in a given market. If the development of the market demand is dominated by uncorrelated demand shocks, anticyclic pricing points to collusion. If demand cycles are characteristic for

the market considered, pronounced price reductions in times of falling demand are a signal of a collusive agreement. If such a suspicious price development is observed, it is worth to investigate the competitive behavior of the firms more closely to exclude that other factors, as for example changes in the production cost, cause cyclic pricing. If this is not the case, judicial investigation might find documentary evidence of collusion as written agreements or minutes of conspiratorial meetings which facilitate the legal proof of anticompetitive behavior. In addition to considering the pricing of firms, the competition authority should scrutinize their behavior in markets where frequent, noncooperative reinvestments in the physical capital stock or stock-based incentive compensation for managers are an important characteristic. Close supervision of cooperation in the replacement of production equipment or bond issues however is not necessary. By focusing the attention and resources in this way, antitrust regulation can be economically and efficiently enforced. The theoretical and empirical analysis of long-term oligopolistic competition is hence an essential foundation of an effective competition policy.

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List of Tables

4.1	Collusive Quantities in Markets with Demand Shocks	83
4.2	Collusive Prices in Markets with Demand Shocks	83
4.3	Collusive Quantities in Markets with Cyclic Demand	96
4.4	Collusive Prices in Markets with Cyclic Demand	96
5.1	Quantities, Investments, and Profits with <i>Individual Investment</i>	122
5.2	Quantities, Investments, and Profits with <i>Joint Investment</i> . . .	123
5.3	Quantities, Investments, and Profits with <i>Joint Production</i> . . .	124
5.4	Welfare with Different Organization of Production	134
5.5	Prices with Different Organization of Production	138
5.6	Derivatives of Prices with Respect to the Demand Level	138
7.1	Fraction of Firms Granting Long-Term Bonus, Option Grants or Shares (adapted from <i>Balsam</i> 2002, 41)	180

List of Figures

4.1	Cyclic Demand	86
4.2	Critical Period for Perfect Collusion with Cyclic Demand	91
4.3	Collusion with Cyclic Demand	94
4.4	Pricing in the <i>Cournot</i> Duopoly with Cyclic Demand	98
4.5	Outputs in the <i>Cournot</i> Duopoly with Cyclic Demand	98
5.1	Feasibility of Collusion with Different Organization of Production	128
5.2	Per-Period Profits with <i>Individual Investment</i> and without Investments	130
5.3	Per-Period Profits with <i>Joint Investment</i> and without Investments	131
5.4	Per-Period Profits from Collusion and Quantity Competition...	133
5.5	Welfare with Different Organization of Production	136

List of Symbols

- $\bar{A}$ index for perfect collusion
 A index for collusion
 a size of the market
 $\underline{a}$ lowest realization of the market size in the case of demand shocks
 $\bar{a}$ highest realization of the market size in the case of demand shocks
 $\tilde{a}$ highest realization of the market size that is consistent with perfect collusion between owners in the case of demand shocks
 $\tilde{\tilde{a}}$ highest realization of the market size that is consistent with perfect collusion between managers with stock-based compensation in the case of demand shocks
 B index for the organization of production, $B = I, J, P$
 b_l repayment that does not make a firm bankrupt
 b_m repayment that makes a firm bankrupt in a period of low demand
 b_h repayment that makes a firm bankrupt irrespective of demand
 C cost function
 c marginal cost
 D index for defection from a collusive agreement
 d delay of the payment in the case of deferred management compensation
 e parameter of efficiency in capital replacement
 F fraction of per-period profit paid as a traditional management compensation
 f share-price-dependent management compensation payment
 G parameter of the dividend policy
 g retained fraction of the per-period profits
 H profit stream gained by perfect collusion in periods of high cyclic demand
 h profit stream gained by imperfect collusion in periods of high cyclic demand
 I index for individual investment
 i firm index
 J index for joint investment
 j firm index

- k consumer index
 - L profit stream gained by perfect collusion in periods of low cyclic demand
 - l profit stream gained by imperfect collusion in periods of low cyclic demand
 - M parameter of aggregate cost
 - m last recession period of the demand cycle where the market size is at least as high as in a given boom period
 - N index for *Nash* competition
 - n number of firms in the market
 - P index for joint production
 - $\mathcal{P}$ share price if all profit is disbursed at the end of each period
 - $\tilde{\mathcal{P}}$ share price if a part of the profit is disbursed at the end of each period
 - $\underline{\mathcal{P}}$ strike price of a stock option
 - p market price
 - Q market output
 - q individual output
 - R index for the competitive behavior, $R = \bar{A}, A, D, N$
 - r interest rate
 - S indicator function that takes the value 1 until a firm is made bankrupt and 0 thereafter
 - s market share
 - T duration of a manager's contract
 - t current period
 - U utility function
 - V incentive to participate in a collusive agreement
 - W welfare
 - X total capital replacement investment
 - x individual capital replacement investment
 - y choice variable in the adjustment to equilibrium
 - Z parameter of aggregate cost
 - z duration of a long-term bonus plan
-
- β coefficient of the regression function
 - γ slope parameter of the investment cost function
 - δ market discount factor
 - $\underline{\delta}$ critical lower bound of the market discount factor for perfect collusion
 - $\delta_{\text{crit.}}$ critical lower bound of the market discount factor for a collusive agreement that yields profits $\pi_A \in (\pi_N, \pi_{\bar{A}})$
 - $\bar{\delta}$ critical lower bound of the market discount factor for imperfect collusion on the border to *Nash* competition
 - ϵ error term
 - η price elasticity of demand
 - θ probability of the continuation of competition
 - κ number of shares in the stock grant
 - λ conjectural derivative

ξ	proportionality factor in the adjustment to equilibrium
π	individual profit
σ	probability that a manager does not quit the firm in a given period
τ	time index
ϕ	parameter of conjectural variation
φ	number of shares of a firm
ψ	number of shares awarded by a long-term bonus plan

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