569 LECTURE NOTES IN ECONOMICS AND MATHEMATICAL SYSTEMS

Leslie Neubecker

Lecture Notes in Economics
and Mathematical Systems 569

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Strategic Competition in Oligopolies with Fluctuating Demand

Springer

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ISSN 0075-8442
ISBN-10 3-540-29556-9 Springer Berlin Heidelberg New York
ISBN-13 978-3-540-29553-6 Springer Berlin Heidelberg New York

Typesetting: Camera ready by author
Cover design: *Erich Kirchner*, Heidelberg

Printed on acid-free paper 42/3153/DK 5 4 3 2 1 0

Acknowledgements

In writing this book I benefited from discussions with Manfred Stadler, Werner Neus, Alexandra Zaby, Barbara Sender, Jörn Kleinert, Rüdiger Wapler und Stephan Hornig. Their comments and encouragement are gratefully acknowledged. I also would like to thank Christine Hamacher and Viviane Witte for their help in the preparation of the manuscript.

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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.

2

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 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 continuous after the presumed last period. If there is any small probability of continuation, it is a 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 maximizes 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 produce 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 market 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