This thesis contributes to the literature of industrial organization and competition policy. The main focus of this research is how competition policy and competition policy enforcement can be improved using insights both from theoretical as well as experimental methods in industrial organization. To the field of merger theory and policy this thesis contributes by developing an index to quantify merger efficiencies. The index can be used as a complementary tool in the assessment of merger cases. In the field of cartel research this thesis offers novel results both for theory and policy. First, it gives new insights into the effect of entry on cartel stability. Moreover, it sheds light on how cartels can be 'grown' through sequential entry. Thirdly, the findings presented in this thesis raise doubt about the purported success of leniency program by examining the type of cartels that are broken up by these schemes. Using a theoretical model, it is shown that mainly collapsed cartel may have an incentive to use such self-reporting schemes.

Marie Goppelsroeder has received her bachelor's degree in Economics from the University of Bonn and her Master's degree in Economics from the University of Maastricht. After starting her PhD studies at the Graduate Institute in Geneva, she continued and completed her research as a PhD student at the Amsterdam Center for Law&Economics at the Economics Department of the University of Amsterdam. Her main research interests are industrial organization, experimental economics and competition policy.

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Topics in Market Concentration

Marie-Christine Goppelsroeder

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Assessment, Determinants and Policy Tools

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Für meine Eltern, Rosemarie und Bernd

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Amsterdam, 6 October 2009

Contents

Chapter 1

Introduction

1.1 Motivation

In a perfectly functioning market, there are many buyers and sellers, firms can enter at any time, prices are known to all consumers and producers and products are homogeneous. Under these assumptions, economic theory predicts that the market outcome is both allocatively and productively efficient. In reality, however, an efficient outcome is often not reached automatically. Many firms produce products that are differentiated. Many markets are characterized by barriers to entry. Moreover, information flows are often restricted such that not all consumers are informed about all prices. As a result, competition is not always guaranteed by itself. Firms might interfere with the market mechanism and hamper competition. In order to foster competition in cases where market conditions are such that competition is or might be restricted, there exists a framework of antitrust laws and institutions both at a national as well as at an international level.

The underlying rationale for guarding free competition by installing a regulatory body that monitors market activity is that market players have an incentive to shield themselves from competition that drives down their own profits. They typically do that by engaging in strategic behavior in one form or the other, for example, by excluding entrants through vertical integration, or by abusing their dominant position by engaging in excessive pricing practices. These attempts to hamper competition can hurt consumers in various ways: it might lead to higher prices, less product innovation or less product variety then if competition had been fierce. A competition authority therefore has the mandate to protect consumers by intervening into the market process in order to guarantee that competition is reinstalled or maintained.

A domain that takes up considerable resources of antitrust authorities is merger control, for instance. A merger is the combination of two or more formerly independent economic undertakings. *Ceteris paribus*, a merger leads to an increase in market concentration and, as there are fewer firms competing in the market, the risk of upward pressure on market prices. The task of competition authorities in assessing the effects of this increase in market concentration is a delicate one, as they have to evaluate future effects that may only occur in the long-term and that are therefore hard to predict. What is more, a merger might also bring about efficiencies in the form of lower marginal costs that could ultimately benefit consumers. An example of a merger in which both issues of higher prices due to an increase in concentration as well as cost savings played a role is *Whirlpool/Maytag*, that involved a manufacturer of home appliances for which the US DoJ expected large costs savings that were likely to be passed on to consumers. Overall, pro-competitive and anticompetitive effects have to be weighed against each other to come to an overall conclusion of whether to allow a specific merger.

Another activity in antitrust enforcement which has raised a lot of public interest recently has been the prosecution of cartels. Cartels are based on agreements between firms to act in accordance with each other by for instance fixing market prices or by sharing the market. This may come to the detriment of consumers who possibly face higher prices. The market impact of cartel activity is considerable: some scholars estimate that the total affected sales of cartels that were detected in the period between 1990 and 2008 worldwide was about 16 trillion US Dollars.[1] The price increase that was imposed by these cartels during that period is estimated to be around 17 percent on average.[2] A well-known example of an international cartel is the Vitamins cartel that was active between 1985 and 1999. A total of 21 chemical producers agreed to fix prices for 16 vitamin products over a period of 16 years. In the U.S., the cartel achieved an average overcharge of over 40 percent. After a long-period of investigation across several antitrust authorities worldwide, a total of 7.4 billion US Dollars of fines were imposed between and 1999 and 2005.[3]

The issues of strategic behavior to restrain competition discussed above can be especially problematic in markets that are highly concentrated. This is because each firm in these markets has more influence on the formation of the market price which gives it an incentive to use this power to raise prices. Moreover, it is typically easier for firms in concentrated markets to form, monitor and maintain cartels. The field of industrial organization analyzes the organization of markets and explores the interplay between market institutions, market structure, firm behavior and market performance. In particular, it examines strategic firm behavior in concentrated markets. It adjusts the perfectly competitive model described above by allowing for markets that are characterized by limited information, barriers to entry or transaction costs. It therefore studies the performance of imperfectly competitive markets and the behavior of firms therein. The field started around the turn of the twentieth century. As it sheds light on the functioning and understanding of imperfectly competitive markets, research in industrial organization is of particular importance for antitrust authorities and competition law enforcement. New insights in industrial organization continuously improve competition law enforcement especially since the 1960s and 1970s with the advent of game theory and a greater reliance on econometric techniques. Yet, there are still a number of open issues. This thesis aims to address some of these issues which will be discussed in turn.

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[1]See Connor (2008).

[2]See Connor (2008).

[3]See Connor and Helmers (2006).

One issue is the assessment of efficiencies in the form of cost savings that might be brought about by a merger. Many antitrust authorities allow for the analysis of merger efficiencies in the overall evaluation of the merger. It is difficult to quantify these efficiencies in practice however. This thesis contributes to this question by developing an index that makes it possible to quantify hypothetical merger efficiencies. More specifically, it introduces an index that measures how possible detrimental effects of an increase in market concentration through a merger can be compensated via cost savings of the merged entity. Another open issue are the determinants of cartel formation and the effect of entry in cartelized markets. The thesis examines the determinants of market concentration by analyzing the effects of sequential entry in an oligopolistic market and gives some novel insights into the effect of entry on cartel stability. Lastly, this thesis examines policy tools aimed at detecting collusion among firms, a phenomenon which is typically more likely in concentrated markets. A lot of research in recent years has focussed on the effect of self-reporting schemes in cartel law enforcement in which firms have to option to report their involvement in return for a fine reduction. Different to previous studies, this thesis contributes to this strand of the literature by isolating possible adverse effects of such schemes. To sum up, this thesis analyzes models of strategic interaction of firms in concentrated markets in the light of assessment, determinants and policy tools. It contributes both to merger theory as well as cartel theory in the context of antitrust economics. Moreover, it aims to shed light on the question of how to improve existing competition policy.

Conceptually, one can divide this thesis into three parts. Part I (Chapter 2 and 3) focus on merger theory and merger policy. Part II (Chapter 4 and 5) concentrate on on the determinants of cartel formation and cartel stability in the face of entry. Part III (Chapter 6 and 7) center on cartel law and cartel law enforcement. Chapters 2, 4 and 6 function function as introductory chapters into Chapter 3, 5 and 7, respectively. They give a literature review on each of the respective topics. Chapters 3, 5 and 7 present new insights into merger policy, cartel stability and the interaction of cartel laws and firms' incentives, respectively using both theoretical as well as experimental methods. The following section presents the outline of the thesis in more detail.

1.2 Outline of Thesis

Next to the introductory chapter this thesis consists of six chapters which are organized in three parts. The first two chapters deal with merger theory and policy, the following two chapters deal with cartel theory and the last two chapters deal with cartel policy. Chapter 2 gives an introduction and a literature review into the basic models of merger theory. The first part of the chapter introduces some basic tools of game theory and discusses static games of complete information. Moreover, it presents two applications of static games to oligopoly theory, Bertrand and Cournot oligopoly, and analyzes the effects of mergers within these two settings. The second part of the chapter focuses on policy measures aimed at mergers and discusses recent developments in this area, in particular the introduction of the so-called efficiency defense in merger review, a procedure that allows antitrust agencies to take into account cost savings resulting from a merger. It then explores methods of quantifying efficiencies resulting from the combination of two or more *ex ante* independent firms. Specifically, it reviews advantages and disadvantages of merger simulation models that are used to quantify the potential effects of mergers on a market.

Chapter 3 introduces a novel, alternative method of measuring merger efficiencies. It uses static oligopoly models to measure the cost savings necessary in a merger to keep consumer welfare in a market constant. These required cost savings are aggregated into the so-called Werden-Froeb Index (WFI), to assist in evaluating merger-specific efficiencies in horizontal mergers. The index measures the weighted average reduction in marginal costs required to restore pre-merger equilibrium prices and quantities after the (full or partial) merger is consummated. The WFI is well-defined, objective and robust, and has relatively low information requirements. The index can be used as a natural complement to concentration measures such as the Hirschmann-Herfindahl-index in the assessment of horizontal mergers. Alternatively, this chapter can also be interpreted as a study which focuses on the question under which conditions market concentration can be detrimental to consumer welfare. Moreover, it discusses if and how a socially harmful (from a consumer point of view) increase in concentration can be compensated by appropriate accompanying cost savings.

While Chapter 3 assesses *when* an increase in market concentration is harmful to consumers, Chapter 4 explores *if and how* market concentration changes the behavior of firms. Moreoever, whereas Chapters 2 and 3 of the thesis assess possibly detrimental effects market concentration focusing on consumer welfare, Chapters 4 and 5 look at the producers side and examine firms' incentive to form and maintain a cartel in concentrated markets. Before exploring the theoretical and empirical literature, Chapter 4 starts by introducing the concept of infinitely repeated games. It also introduces the folk theorem. These concepts are important building blocks for the subsequent analysis. Specifically, this chapter builds on the game-theoretic models discussed in Chapter 2 and examines the Cournot and Bertrand game in an infinitely repeated setting. It then analyzes how incentives to collude change with the number of firms both for Cournot and for Bertrand competition. Chapter 4 then explores the determinants of collusion in concentrated markets. Firstly, an overview of the theoretical literature on factors influencing the ability of firms in a market to cooperate is presented. The chapter subsequently compares these findings with the results from the empirical literature on collusion.

To test one of the determinants of market structure and market concentration, namely entry and the accompanying change in the number of firms, Chapter 5 presents some experimental research. The chapter explores the effects of sequential entry on the stability of collusion in oligopoly markets using a laboratory experiment. Experimental research suggests that a larger number of firms makes collusion harder to enforce and that more firms in a market typically erode cartel stability. This literature however focuses on number effects where given market sizes are compared. Chapter 5 takes a different approach in that it addresses whether collusive markets are able to sustain collusion in the face of exogenous entry. We specifically explore to what extent collusion can be sustained when markets start off small and when it is common knowledge that the entrant is informed about the history of her group prior to entry. A second research question relates to two effects that can be attributed to the so-called number effect. First, there is a structural effect that refers to an increase in firms' incentives to deviate from a collusive agreement with more firms in a market. Second, coordination becomes more difficult with more players. With the experimental design we seek to isolate the latter effect. The results show that in markets based on price competition collusion is indeed easier to sustain if players start to interact in smaller markets: average price bids as well as market prices are significantly higher in these markets than in markets that were large from the start. Moreover, the frequency of coordination at the perfectly collusive level is significantly higher in these markets compared to markets that start off large. The results also suggest that entrants joining collusive markets match the behavior of their market post-entry thereby perpetuating collusion. The majority of entrants joining a non-collusive market undercuts after entry, thereby making markets more competitive.

The last part of the thesis consisting of Chapters 6 and 7 concentrate on the interaction of cartel laws and firms incentive to maintain a collusive agreement. Chapter 6 introduces some policy tools aimed at alleviating or compensating detrimental effects of market concentration discussed in the earlier chapters. It starts sketching the rationale for government intervention in the case of cartels. It then discusses US and EU anti-cartel legislation. Particular emphasis is given to the development of the so-called leniency programs which offer reductions in fines to firms that approach the competition authority in order to self-report their involvement in a cartel. This chapter provides a brief history of these programs both for the US as well as the EU jurisdiction. Moreover, it explains how early shortcomings inherent in these schemes were solved in later revisions. Lastly, recent developments in US and EU antitrust enforcement are discussed.

Chapter 7 analyzes measures to detect and break collusive agreements. It presents an analytical model of leniency programs. Corporate leniency programs for cartels are commonly judged a success as they have attracted a large number of applications. In recent years, the vast majority of cartel investigations in these jurisdictions was at least facilitated by self-reporting of cartel members. To be efficient, leniency programs should yield primarily novel cartel cases that would otherwise remain undetected. Recent empirical findings suggest however, that the majority of applications to the European Commission follow on to earlier filings to the US authorities and that some firms even choose to notify cartels that were long terminated. In Chapter 7, we analyze in which stage of the cartel lifecycle applications for leniency are likely to occur. We translate recent policy developments into a stylized model of cartel enforcement with an infinite, discrete time horizon with two unexpected policy changes. In Phase I, there is an increase in the budget of the antitrust division, which leads to an increase in the perceived detection probability, destabilizing a number of cartels. In Phase II, a leniency program is introduced shortly after, in which also collapsed cartels are prone to prosecution by the antitrust authority. The results show that the ratio of collapsed to active cartels that self-report can be substantial for modest detection probabilities and that this effect can be compounded by a budget constrained competition authority. As many of the leniency applications collected are of cartels that already had stopped operating at the time they are being reported, the number of applications cannot be equated with the number of cartels that are broken up as a result of the implementation of a self-reporting scheme. The amount of leniency applications might therefore largely overestimate the direct effectiveness of self-reporting schemes.

1.3 Methods

This thesis analyzes the above-mentioned research topics using two main methods, game theory and laboratory experiments. Moreover, parts of chapters consist of literature reviews.

Game theory studies, using formal and mathematical concepts, how people make decisions in strategic interaction environments.[4] In game theory, decision problems are reduced to its most basic primitives: the players (decision makers), their available actions and the payoffs (consequences) of these actions. One can distinguish between two main branches of game theory: non-cooperative games and cooperative games. We focus on non-cooperative game theory, that is on games in which each agent's optimal decision depends on the beliefs he holds over the decision of the other player(s) in her group. In non-cooperative games agents act in their own self-interest and any cooperation must be self-enforcing. Today, non-cooperative game theory is the basic toolkit of most research in industrial organization as it helps analyzing models of strategic interaction between firms.

Experimental economics studies economic questions using data generated from laboratory experiments or field experiments.[5] They can be used to test i.e. the validity of existing economic theories and to assess the functioning of real market institutions or new market mechanisms. One major benefit of using laboratory experiments is that findings derived from experiments can be verified independently by replicating an experiment. The other vantage point in using experimental laboratory methods is that under laboratory conditions crucial variables can be controlled so as to be able to attribute certain changes in behavior to changes in the laboratory environment.

All chapters use game-theoretic solution concepts widely used in the Industrial Organization literature. Chapter 2 introduces a number of basic concepts of static game theory and reviews merger policy in the EU and US. Chapter 3 is also based on static game theory and contains an empirical example to illustrate the index proposed in this chapter. Specifically, it explores merger efficiencies applying the basic concept of static games with complete informa-

[4]For a thorough introduction into game theory, see e.g. Fudenberg and Tirole (1991), Gibbons (1992) and Osborne and Rubinstein (1994).

[5]See e.g. Davis and Holt (1992) or Camerer (2003) for an introduction into the topic.

tion. Firms in that chapter maximize profit using prices as strategic variables (Bertrand-Nash equilibrium) or using quantities as strategic variables (Cournot-Nash equilibrium). Chapter 4 presents some dynamic concepts of game theory, in particular, infinitely repeated games and the folk theorem. Moreover, it provides a review of theoretical and empirical variables that are important in determining collusion. In Chapter 5 experimental methods are used to study these determinants more closely. Use of the subgame-perfect-Nash equilibrium is also made in that chapter. Chapter 6 graphically discusses the monopoly outcome in a market to explain the rationale for government intervention in cartels and reviews cartel policy. Chapter 7 applies concepts of dynamic games with complete information in order to be able to analyze the effects of leniency programs.

Chapter 2

Horizontal Mergers

2.1 Introduction

This chapter discusses horizontal merger theory and merger policy. As explained in Chapter 1, oligopoly theory is applied to assess market performance when there are only few firms in a market. The two benchmark models of oligopoly theory are the Bertrand model and the Cournot model, representing competition on prices and competition on quantities, respectively.

After introducing some underlying equilibrium concepts in Section 2.2, we present both models starting with the case of duopolies and then extend the analysis to an n-firm setting. This also serves as an introduction to the analysis in Chapter 3 which is analyzing cost savings in a generalized model with n firms. Section 2.3 exemplifies the case of a merger in a triopoly setting analytically and graphically. This is done both for the Cournot oligopoly model and the Bertrand oligopoly model. In Section 2.4, we introduce the relevant horizontal merger policy. We then discuss the efficiency defence in merger policy. This is followed by an assessment on merger simulation models. The last part of this chapter gives an introduction into the index measuring mergers-specific cost reductions which is analyzed in detail in Chapter 3.

2.2 Theory of Static Games with Complete Information

As stated in Section 1.3, large parts of this thesis are based on game theory. This chapter as well as Chapter 3 are based on static games with complete information. One of the most widely applied solution concepts, the Nash equilibrium, is used to analyze these games. This section describes this solution concept.[1] To explore strategic interaction between decision-makers, we introduce the definition of a strategic-form game. A strategic-form game is a game in which each decision-maker (player) simultaneously chooses a strategy which he

[1]See e.g. Fudenberg and Tirole (1991).

commits to. The concept consists of a set of players $i \in \Im$, a pure strategy space S_i for each player i and a payoff function given by u_i that give the players the utility $u_i(s)$ for each strategy profile $s = (s_1, s_2, ..., s_I)$.[2] A strategy is a function which prescribes, for each situation a player might find himself in, which action to take where the action space is given by $A_i \subset \mathbb{R}$. It is therefore a complete plan of action that fully determines the behavior of a player. In the one-shot simultaneous move games we are discussing here, the action space is equal to the strategy space. In Chapter 4, where we introduce repeated games, a player's strategy determines the action the player will take at any stage of the game, for every possible history of play up to that stage. Then the action space and strategy space are different. In the following, we refer to the players other than player i as $-i$. The Nash-equilibrium is now defined as follows.

Definition of a Nash equilibrium in pure strategies:
A profile of pure strategies s^* for which it holds that for every player i

$$u(s_i^*, s_{-i}^*) \geq u(s_i, s_{-i}^*) \text{ for all } s_i \in S_i.$$

is a Nash equilibrium.

A Nash equilibrium is a strategy profile in which each player's strategy is a best response to the other players' strategies. Intuitively, no player has an incentive to unilaterally deviate from his chosen strategy given the strategies of the other players. The profile s^* can therefore only be a Nash equilibrium if no player i has an alternative strategy profile that generates a payoff which he strictly prefers to that generated when he decides to do s_i^* given the equilibrium s_{-i}^* of all other players. In the following, we introduce two classic applications of a pure Nash equilibrium: the Cournot game and the Bertrand game.

2.2.1 The Static Cournot Oligopoly Model

Let's assume that there are two Firms 1 and 2, each producing a single homogenous good. Let q_1 and q_2 be the quantities of these goods and let the industry output be given by $Q = q_1 + q_2$. Let $P(q_1, q_2) = 1 - (q_1 + q_2)$ with be the inverse demand function and let the cost function of each firm be given by $C_{1,2}(q_{1,2}) = cq_{1,2}$ with $c < 1$ so that there are no fixed costs and marginal costs are constant for both firms. The Cournot game is based on competition on quantities. Using the language of game theory, firms in the Cournot game correspond to players in the strategic-form game and the strategy space corresponds to the quantities each firm can choose from. The strategy space of each firm is thus given by $S = [0, \infty)$ as we assume that output is non-negative and continuously divisible. Moreover, firms simultaneously choose their strategy. We also assume that the payoffs are given by the

[2] A mixed strategy is a probability distribution over pure strategies. As this thesis is solely applying pure strategies of players, the discussion here is based on pure strategies.

firms' profits. The payoff function for Firm 1 (and analogously for Firm 2) can be written as

$$\pi_1(q_1, q_2) = [P(q_1 + q_2) - c]q_1.$$

A Nash equilibrium in the two-player Cournot game can be restated as a strategy pair (q_1^*, q_2^*)

$$\pi_i(q_1^*, q_2^*) \geq \pi_i(q_1, q_2^*) \text{ for every strategy } q_1 \in S_1 = [0, \infty) \tag{2.1}$$

The optimization problem for player 1 can then be formulated as follows:[3]

$$\max_{0 \leq q_1 < \infty} \pi(q_1, q_2) = \max_{0 \leq q_1 < \infty} [1 - (q_1 + q_2) - c]q_1.$$

The pair (q_1,q_2) is a Nash equilibrium if it satisfies equation (2.1) for each firm.

For any given output of Firm 2 (Firm 1) the *best-response* function $R_1(q_2)$ ($R_2(q_1)$) determines the profit maximizing output for Firm 1 (Firm 2). The best-response functions can be written as:

$$R_1(q_2) = \frac{1}{2}(1 - q_2 - c), \tag{2.2}$$

and

$$R_2(q_1) = \frac{1}{2}(1 - q_1 - c). \tag{2.3}$$

One can then solve for Cournot-Nash quantities:

$$q_{1,2}^* = \frac{1-c}{3}.$$

Indeed if Firm 2 chooses q_2^*, q_1^* is the best response of Firm 1 and vice versa. The corresponding equilibrium price and profits are given by:

$$p^* = \frac{1+2c}{3} \text{ and } \pi_{1,2}^* = \left(\frac{1-c}{3}\right)^2.$$

2.2.2 The Static Bertrand Oligopoly Model

We now consider a model of price competition. We will show that this difference in strategic variables has important consequences for the outcome of the game and the characteristics of the Nash equilibrium. We assume again that there are two separate Firms 1 and 2, each producing a single but differentiated product. The linear inverse demand function for Firm 1 is given by:[4]

$$p_1(q_1, q_2) = a - b(q_1 + \theta q_2),$$

[3]The optimization problem for player 2 can be formulated analogously.

[4]The functional form of this demand function is taken from Bowley (1924). The inverse demand function for Firm 2 can be written analogously.

where a and b are positive and where $\theta \in [0, 1)$ is the parameter of horizontal product differentiation. The smaller θ, the more distinct the products are perceived. If $\theta = 0$ products would be not competing with each other. As θ becomes larger, products become more substitutable.

The corresponding demand function for Firm 1 is given by:[5]

$$Q_1(p_1, p_2) = q_1 = \frac{(1-\theta)a - p_1 + \theta p_2}{(1-\theta^2)b}.$$

As with the Cournot game, we assume constant marginal costs of $c < a$ for each product and no fixed costs. The payoffs are again denominated in profits. As now prices instead of quantities are the strategic variables, Firm 1 must solve:[6]

$$\max_{0 \leq p_1 < \infty} \pi(p_1, p_2^*) = \max_{0 \leq p_1 < \infty} [p_1 - c] \frac{(1-\theta)a - p_1 + \theta p_2}{(1-\theta^2)b}.$$

The best response functions for Firms 1 and 2 are then respectively given by:

$$R_1(p_2) = \frac{1}{2}((1-\theta)a + \theta p_2^* + c). \tag{2.4}$$

$$R_2(p_1) = \frac{1}{2}((1-\theta)a + \theta p_1^* + c). \tag{2.5}$$

Comparing (2.4) and (2.5) with (2.2) and (2.3), respectively, we can see that reaction functions in the Bertrand game are upward sloping while they are downward sloping in the Cournot game. Under price competition, an increase in the price of a competitor therefore induces an increase in a firm's own price. If a competitor increases his price, a firm can increase his price as well, thereby increasing his profits. Under quantity competition however, an increase in the quantity of a competitor reduces the residual demand and the marginal revenue for a firm, and thereby induces a decrease of the firm's own quantity.

Solving equations (2.4) and (2.5) yields the Bertrand-Nash equilibrium in terms of prices, quantities and profits, which are given by:

$$p_{1,2}^* = \frac{(1-\theta)a + c}{2-\theta}, \tag{2.6}$$

$$q_{1,2}^* = \frac{(a-c)}{(1+\theta)(2-\theta)b} \text{ and } \pi_{1,2}^* = \frac{(1-\theta)(a-c)^2}{(1+\theta)(2-\theta)^2 b}.$$

For the special case of $n = 2$ equations and goods that are very close substitutes ($\theta \to 1$), (2.6) gives:

$$p_{1,2} \to c.$$

The Bertrand game with two firms and very substitutable goods converges to the solution

[5] The demand function for Firm 2 can be written analogously.

[6] The profit-maximization problem of Firm 2 can be formulated analogously.

of a perfectly competitive market. Prices converge to marginal cost and firms almost make zero profits. In price setting markets with hardly any product differentiation it is therefore sufficient to only have two firms to converge to perfect competition.[7] This result is also known as the Bertrand paradox. The intuition behind this is as follows: as goods are viewed as perfectly substitutable for consumers, the firm posting the lowest price will win the entire market demand. This implies that each firm has an incentive to just incrementally undercut the price posted by the other firm thereby gaining the entire market price. Imagine the following example:

$$p_1 > p_2 > c.$$

The equation implies that Firm 2 serves the entire market demand and makes positive profit while Firm 1 sells nothing and therefore makes zero profits. If Firm 1 slightly undercuts the price of Firm 2 charging a price of $p_1 = p_2 - \epsilon$, it obtains the entire market demand $Q(p_2 - \epsilon)$ and makes a positive profit of $(p_2 - \epsilon - c)Q(p_2 - \epsilon)$. In the same manner, given the newly posted price of Firm 1, Firm 2 will in turn have an incentive to slightly undercut the price of Firm 1 by $p_1 - \epsilon$. This undercutting mechanism goes on until the price set by either firm equals marginal cost. The other firm will follow suit and also set a price equal to marginal costs. As firms anticipate this, in equilibrium both firms set a price of $p = c$ and share the market demand, each making a profit of zero.

2.2.3 The Static Cournot and Bertrand Oligopoly Model with n Firms

In this section, we generalize the Bertrand and Cournot model to n firms. For simplicity, we assume again that each firm produces under constant marginal costs of c. Moreover, as in the previous section, each firm produces its own variety and demand is linear. Generalizing the linear demand function given in Section 2.2.2 to n firms yields:

$$Q(p_i, p_{-i}) = \frac{(1-\theta)a - [1 + (n-2)\theta]p_i + \theta \sum_{i \neq j} p_j}{(1-\theta)[1 + (n-1)\theta]b},$$

Cournot Oligopoly Model

As in Section 2.2.1, we solve for the Cournot-Nash equilibrium. The per-firm Cournot-Nash quantity is given by:

$$q_i^* = \frac{a - c}{(2 + \theta(n-1))b}.$$

As n increases, the per-firm output decreases as there is more competition. On the other hand, the more a product is perceived to be differentiated (corresponding to a lower θ), the

[7] This result also holds with $n > 2$.

more a firm will produce.

Equilibrium prices and the corresponding profits are given by:

$$p_i^* = \frac{a + c(1 + \theta(n-1))}{(2 + \theta(n-1))} \text{ and } \pi_i^* = \frac{1}{b}\left(\frac{(a-c)}{2+\theta(n-1)}\right)^2. \tag{2.7}$$

Bertrand Oligopoly Model

The Bertrand-Nash solution with n firms, can be solved to yield prices given by:

$$p_i^* = \frac{(1-\theta)a + [1 + (n-2)\theta]c}{2 + \theta(n-3)}.$$

The corresponding per-firm quantities and profits are given by:

$$q_i^* = \frac{(1 + \theta(n-2))(a-c)}{b[1 + \theta(n-1)](2 + \theta(n-3))} \text{ and } \pi_i^* = \frac{1}{b}\left(\frac{a-c}{2+\theta(n-3)}\right)^2 \frac{(1-\theta)(1+\theta(n-2))}{[1+\theta(n-1)]}. \tag{2.8}$$

If we compare the Bertrand and Cournot solution for a given number of firms and given the degree of product differentiation θ, it can easily be shown that Bertrand-Nash equilibrium quantities are higher and the corresponding prices are lower than in the Cournot-Nash equilibrium. The Bertrand solution is therefore often associated with being more competitive than the Cournot solution. Note that if products are differentiated enough such that demand of the products is completely independent of one another, or $\theta = 0$, the equilibrium outcome in the Cournot model and the Bertrand model are identical. In case of easily substitutable products (large θ), the equilibrium in the Bertrand model converges to the one of a perfectly competitive market.

2.3 Horizontal Mergers in the Cournot and Bertrand Oligopoly Model

In this section, we analyze, using the framework introduced in Section 2.2, what happens when firms in either Cournot or Bertrand markets merge. A merger is a business transaction in which the assets of two or more firms are combined to form a new, united entity. Typically, one distinguishes among three types of mergers: vertical mergers, horizontal mergers and conglomerate mergers. In a vertical merger, an upstream firm unites with a downstream firm, where the upstream firm is the firm that sells an input to the downstream firm which is active in the layer below. The merger therefore takes place across the production or distribution chain of a product or service. Horizontal mergers are mergers in which firms competing on the same production or distribution level combine. Conglomerate mergers are transactions in which firms merge that are active in different business lines and are therefore not in direct competition with one another.

We focus on the analysis of horizontal mergers, that is, mergers between firms that manufacture products that are in direct competition with one another.

2.3.1 Horizontal Merger in the Cournot Oligopoly Model

We build on the framework from Section 2.2.1 and 2.2.2 and begin with a graphical solution for the Cournot game.[8] There are three firms in the market denoted as Firm 1, Firm 2 and Firm 3. We use the assumptions of the model outlined in Section 2.2.2: each firm is producing a single, differentiated product at constant marginal cost of c. The best-response functions are summarized in Figure 2.1. It is possible to depict the combined outputs of Firm 1 and 2 and the output of Firm 3 in a two-dimensional graph which is shown in Figure 2.1. In the following, we refer to the merging firms Firm 1 and Firm 2 as insiders and to the non-merging firm Firm 3 as the outsider.

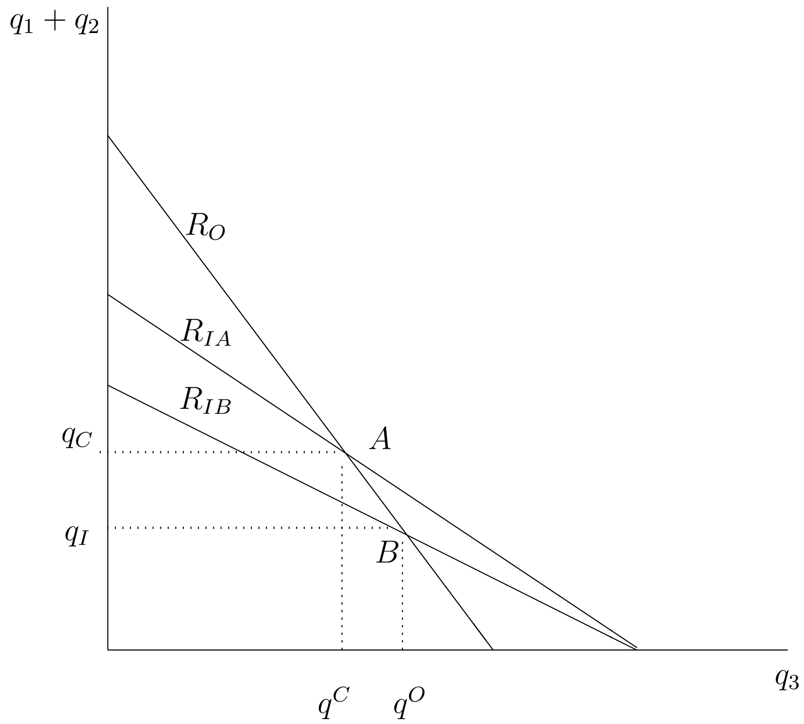

Figure 2.1: Best Response Functions with Strategic Substitutes between three Firms pre- and post-merger.

The best-response functions in the Cournot oligopoly model are downward sloping, because the more its rivals produce, the less each firm wants to produce in reply. The Cournot model can therefore also be classified as a model of *strategic substitutes*. Prior to the merger, the Cournot-Nash equilibrium is given by A at the intersection of the best-reply functions of Firm 3, given by R_O, and the joint optimal production of Firm 1 and 2 given by R_{IA}.

[8] See Salant, Switzer and Reynolds (1983), Perry and Porter (1985) and Reynolds and Snapp (1986).

In the Cournot model, firms do not take into account the negative impact of their own increase in output on their competitors' output levels. This externality implies that each firm chooses an output that exceeds its optimal output from the viewpoint of the industry as a whole. As a consequence, total output will be higher than it would be if the market were controlled by a single dominant firm. The Cournot market price will be lower than it would be under a monopoly regime but higher than it would be under perfect competition.

Assume now that Firm 1 and 2 merge and that there are no associated efficiency gains. Analytically, a merger between two firms in the pool of Cournot competitors is a reduction in the total number of independent players by one. Two firms that previously exerted negative externalities on each other now internalize these. Figure 2.1 illustrates the effect of Firms 1 and 2 merging into a single firm with two integrated divisions. The post-merger reaction curve of the total output $(q_1 + q_2)$ of the merging firm turns downwards to R_{IB}. The direct effect of the merger is that insiders internalize their negative externality upon each other and therefore reduce their joint quantity. Because the merging firms contract output, the outsider increases his output. This leads to a secondary, indirect, effect, where the merging firms decrease output even more. This leads to the equilibrium at point B in Figure 2.1.

Analytically, the best-reply functions pre-merger can be determined as:

$$q_i = R_i(q_j, q_k) = \frac{a - c - \theta b \sum_{i \neq j} q_j}{2b} \text{ for } i = 1, 2, 3.$$

It follows from (2.2.3) and (2.7) that the pre-merger equilibrium for the Cournot case with $n = 3$ is given by:

$$q_i^* = \frac{a - c}{2b(1 + \theta)},$$

$$p_i^* = \frac{a + c(1 + 2\theta)}{2(1 + \theta)} \text{ and } \pi_i^* = \frac{1}{4b}\left(\frac{a - c}{1 + \theta}\right)^2.$$

After the merger, the best-reply functions of the merging firms 1 and 2 change to:

$$q_1 = q_2 = R^I(q_3) = \frac{(a - c)}{2b(1 + \theta)} - \frac{\theta q_3}{2(1 + \theta)},$$

while the best-reply function of the outsider firm 3 remains unaltered at (2.3.1).

Insider firms Firm 1 and Firm 2's price, quantities and profits post-merger are given are given by:

$$p_i^I = \frac{1}{2}\frac{a\,(1 + \theta)\,(2 - \theta) + c\,(\theta(3 - \theta) + 2)}{2 + \theta(2 - \theta)}, \tag{2.9}$$

$$q_i^I = \frac{1}{2b}\frac{(2 - \theta)(a - c)}{(2 + \theta(2 - \theta))} \text{ and } \pi_i^I = \frac{1}{4b}\frac{(1 + \theta)\,(2 - \theta)^2\,(a - c)^2}{b\,(2 + \theta(2 - \theta))^2}. \tag{2.10}$$

For the outsider Firm 3, price, quantities and profits after the merger are given by:

$$p_i^o = \frac{a + c(1 + \theta(2-\theta))}{2 + \theta(2-\theta)}, \tag{2.11}$$

$$q_i^o = \frac{(a-c)}{b\,(2+\theta(2-\theta))} \text{ and } \pi_i^o = \frac{(a-c)^2}{b\,(2+\theta(2-\theta))^2}. \tag{2.12}$$

Proposition 1. *Consider a merger of two firms in the Cournot triopoly model with differentiated goods. Then for all $\theta \in (0,1)$ we have:*

$$p^I > p^o > p^*, q_1^I + q_2^I + q^o < q_1^* + q_2^* + q_3^* \text{ and } \pi^o > \pi^*.$$

Moreover for all $0 < \theta < \theta^* \approx 0.55$ we have $\pi^I > \pi^*$ and for all $\theta^* < \theta < 1$ we have $\pi^I < \pi^*$

Proof. For a proof see Appendix C. □

Proposition 1 shows that a merger is only profitable for the merging firms if the products are sufficiently differentiated. With completely homogeneous products a merger would be unprofitable for the insiders. The intuition behind the adverse effect of a homogeneous products merger in a Cournot oligopoly on the merging firms stems from the fact that the insiders now being merged take into account the detrimental effect of an excess quantity on equilibrium prices. Internalizing this, they reduce their output. As the quantities are strategic substitutes, the outsider, however, increases his output thereby gaining market share. As a result, the outsider's profits increase post-merger. Complementary research has shown however that relaxing the assumption of quantity competition and introducing efficiency gains from the merger can restore the result of merger profitability for the insiders.[9] Moreover, both insiders and outsiders increase their prices. Industry output falls post-merger.

2.3.2 Horizontal Merger in the Bertrand Oligopoly Model

Let us now analyze the effects of a horizontal merger in the Bertrand model discussed in Section 2.2.2.[10] The best-response functions in such markets are upward sloping, as the higher the price a rival firm sets, the higher the price a firm is able to post. Prices in Bertrand competition can therefore also be classified as *strategic complements*. This is illustrated in Figure 2.2. We assume again that there are three firms in the market, Firm 1, Firm 2 and Firm 3, and that the merger involves Firms 1 and 2. Each firm produces a single variety. Assume as above that all firms have identical cost structures. As before, three firms simultaneously and non-co-operatively determine their prices. Figure 2.2 shows the

[9] See Davidson and Deneckere (1985), Williamson (1968) and Farrell and Shapiro (1990).
[10] See Davidson and Deneckere (1985).

best-response functions of Firm 3, given by R_O and the sum of best-responses of Firms 1 and 2, given by R_{IA}. The pre-merger Nash- Bertrand equilibrium is given by A where the best-response functions of Firms 1, 2 and Firm 3 intersect.

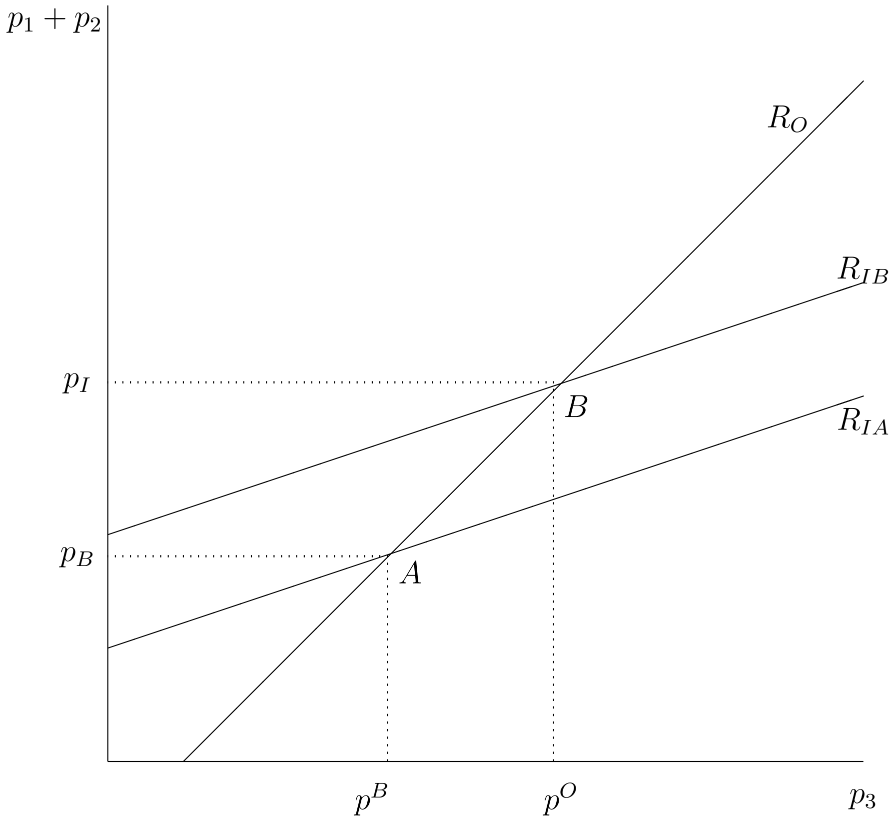

Figure 2.2: Best Response Functions with Strategic Complements between three Firms pre- and post-merger.

Assume now that Firms 1 and 2 merge and that there are no efficiency gains resulting from the merger. As in the Cournot game, each firm in the market imposes an externality on the other firms as it chooses a price which is too low from the point of view of joint profit maximization. After the merger, firms take this negative externality into account and increase their price. As a result, the best response function of the insiders shift upwards. In the new equilibrium denoted by B, prices, both for the insiders as well as for the outsider, have gone up. The price increase of the insider is larger however as the price increase for the outsider which means a reallocation of output in favor of the outsider. The results show that, different to the Cournot case, a merger is indeed always profitable for the insiders in price competition. Note that outsiders profits always increase after the merger irrespective of the mode of competition since they face reduced competition. This is not necessarily the case when the merger leads to efficiency gains.

Analytically, the best-response function pre-merger for all firms is given by:

$$p_i = R_i(p_j, p_k) = \frac{(1-\theta)a + \theta \sum_{i \neq j} p_j + (1+\theta)c}{2(1+\theta)} \text{ for } i = 1, 2, 3.$$

The corresponding equilibrium in terms of quantities, prices and profits pre-merger for the three firms is then given by

$$p_i^* = \frac{(1-\theta)a + (1+\theta)c}{2},$$

$$q_i^* = \frac{(1+\theta)(a-c)}{2b(1+2\theta)} \text{ and } \pi_i^* = \frac{(1-\theta)(1+\theta)(a-c)^2}{4b(1+2\theta)}.$$

Post-merger, the set of best-response functions for the insider and outsider, respectively are given by:

$$R_i^I(p_3) = p^I = \frac{(1+\theta(1-2\theta))a}{2(1+2\theta)} + \frac{\theta p_3 + c}{2}, \tag{2.13}$$

$$R_i^O(p_1, p_2) = p^o = \frac{(1-\theta)a + \theta p_1 + \theta p_2 + (1+\theta)c}{2(1+\theta)}. \tag{2.14}$$

It is easy to verify that insiders price, quantities and profits post-merger are given by

$$p_i^I = \frac{(2+\theta(1-3\theta))a + (2+\theta(3+\theta))c}{2(\theta(2-\theta)+2)}, \tag{2.15}$$

$$q_i^I = \frac{1}{2b} \frac{(2+3\theta)(a-c)}{(1+2\theta)(2+\theta(2-\theta))} \text{ and } \pi_i^I = \frac{1}{4b} \frac{(2+3\theta)^2 (1-\theta)(a-c)^2}{(1+2\theta)(2+\theta(2-\theta))^2}, \tag{2.16}$$

while the outsider's price, quantities and profits post-merger are given by

$$p^o = \frac{a(1-\theta)(1+\theta) + c(1+2\theta)}{2+\theta(2-\theta)}, \tag{2.17}$$

$$q^o = \frac{1}{b} \frac{(1+\theta)^2 (a-c)}{(1+2\theta)(2+\theta(2-\theta))}, \tag{2.18}$$

and

$$\pi^o = \frac{1}{b} \frac{(1-\theta)(1+\theta)^3}{(2+\theta(2-\theta))^2} \frac{(a-c)^2}{1+2\theta}$$

.

Proposition 2. *Consider a merger of two firms in the Bertrand triopoly model with differentiated commodities. Then we have* $p^I > p^o > p^*$ *and* $\pi^0 > \pi^I > \pi^*$*. Total industry output falls after the merger.*

Proof. For a proof see Appendix C. □

Proposition 2 shows that in the Bertrand triopoly both insiders and outsiders gain from the merger. Furthermore, outsiders profit even more as their price increase is lower than that of the insiders and demand shifts to the outsider. As in the merger in the Cournot triopoly model, total quantity falls.

The above analysis shows that absent efficiencies gains, a merger can have different effects on the merging and non-merging firms, depending on the nature of competition. It can be shown that in that framework, a merger leads to losses in welfare. Competition authorities therefore thoroughly examine mergers in real markets. How this is done, is described in more detail in the following section.

2.4 European Merger Policy

The Treaty of Rome (1957) created the European Economic Community and its institutions, among which the European Parliament, the Court of Justice and the European Commission. It also introduced Articles 81 and 82 which condemn anticompetitive agreements between competitors and abuses of a dominant position. Merger control however, was not specifically mentioned in those articles. The need for merger control at the Community level was recognized already in the 1970s as the EC's attempts to apply Articles 81 and 82 to mergers illuminated their shortcomings. The European Commission did not implement a merger control authority until 1989 however. Its enactment was seen as a measure to facilitate the development of a single, integrated European market. The EC Merger Regulation (ECMR) was intended to provide a level playing field and a one-stop shop for the review of mergers with significant cross border effects.[11] The ECMR was amended in May 2004.

Under the Regulation, mergers with a 'Community dimension' are subject to exclusive examination by the European Commission. Article 1 states that a concentration is deemed to have a Community dimension when the two following conditions hold cumulatively. First, the worldwide aggregate turnover of all the undertakings involved is more than 5000 million Euro. Second, the aggregate Community-wide turnover of each of at least two of the undertakings concerned is more than 250 million Euro, unless each of the undertakings concerned achieves more than two thirds of its Community wide turnover within one Member State. Mergers which do not have this Community dimension are subject to national law.

The EC merger investigation is organized in two phases. Phase I starts with the formal notification of the merger and takes 25 working days after which a Phase I decision is issued. Should the merger raise serious doubts, an in-depth investigation is initiated, referred to as Phase II, which must be concluded within 90 working days. Otherwise, the merger is cleared.

In its assessment of a merger, the European Commission employs the substantive lessening of effective competition test ('SIEC test'):

> "A concentration which would significantly impede effective competition, in particular by the creation or strengthening of a dominant position, in the common

[11] See Lyons (2004) on merger control in the EU and Postema et al. (2006) for a study on welfare effects of merger control in The Netherlands.

market or in a substantial part of it shall be declared incompatible with the common market."

The analysis starts with definition of the "affected" markets, which are the relevant product and geographic markets. The Commission then proceeds to assess the possible competitive effects in the affected markets. Moreover, it explores the scope of countervailing factors, and, with the parties', determines whether an agreement can be reached within the decision deadlines.

After the relevant market is defined, the Commission typically proceeds to analyze the level of concentration in the affected markets looking at market shares and concentration levels. To assess the level of concentration, the Commission applies the so-called Herfindahl-Hirschmann index as a first screening devise. The index is defined as the sum of squares of the market shares in percentages of the firms in the relevant market. It can vary between 0 and 10000. The lower the HHI, the more fragmented the market is. A HHI of 10000 is reached when the market consists of a monopoly. The Commission is unlikely to identify horizontal competition concerns in a market with a post-merger HHI below 1000. Moreover, the Commission is also unlikely to identify horizontal competition concerns in a merger with a post-merger HHI between 1000 and 2000 and a *delta* below 250, where delta denotes the differences in HHI pre-and post-merger. The Commission is also unlikely to raise concerns about a merger with a post-merger HHI above 2000 and a delta below 150 except if a number of factors are present which may invalidate the HHI as a first screening devise. To those factors belong, e.g. the involvement of a potential entrant in the market or the existence of significant cross-shareholdings among market participants.

The Commission then begins to assess whether the merger significantly impedes effective competition in a market. In this step, it distinguishes between two different theories of competitive harm. Firstly, the Commission looks into unilateral effects. Unilateral effects arise when a merger creates or strengthens a dominant position of a single firm. The Commission typically assesses whether the merger would have a considerably larger market share than the next competitor post-merger, or whether a merger in an oligopolistic market involves the elimination of important competitive constraints that the merging parties previously exerted upon each other. Moreover, it assesses whether customers would have the possibility to switch suppliers and whether competitors to the merging firms would increase their supply should the merged entity increase prices.

Secondly, the Commission examines the ability of firms to coordinate their actions post-merger, which is also referred to as coordinated effects. Among the factors that are assessed when studying coordinated effects is whether it is easier for firms to reach a common understanding on how coordination can be established. One factor the Commission typically looks into is whether market shares become more symmetric post-merger. Concerning the sustainability of collusion, the Commission examines whether the firms are able to monitor whether each firm sticks to the agreement, so there has to be a sufficient degree of transparency in the market. Moreover, firms must be able to establish a punishment mechanism to deter possible defections from the agreement. Lastly, reactions of outsiders such as entrants should not destabilize the agreement. Chapter 5 examines in detail coordination effects when the number of firms in a market change. Other than stated in the Commission guidelines, we show that entry does not necessarily need to destabilize collusion.

Apart from looking at possible adverse effects a merger can have, the Commission also investigates so-called countervailing effects. To these belong for instance, the existence of buyer power, failing firms or efficiencies created by a merger. Merger efficiencies are a relatively novel factor in the assessment of competitive effects of merger in the EU. How the so-called efficiency defense in horizontal mergers works is discussed and analyzed in the following section.

2.4.1 The Efficiency Defense in Merger Policy

When the analysis is restricted *ceteris paribus* to competition effects, economic theory predicts unambiguously that (partial) horizontal mergers between firms active in the same market lead to unilateral anticompetitive effects and consumer detriment as discussed in Section 2.3. In the IO literature it is well understood that efficiencies can offset the detrimental effects of mergers and result in higher welfare.[12]

Until recently, however, there was little or no regards for weighing any welfare enhancing effects of large mergers in European Commission policy. In the last decade, merger control in both US and EU has opened up to efficiency arguments. They have been admitted in cases to supplement market concentration analyses, typically based on the Hirschmann-Herfindahl-index (HHI). The new Horizontal Merger Guidelines of the European Commission reflect, however, that European merger control is opening up to an assessment of countervailing effects.[13] The amended 2004 guidelines give an explicit opening for mounting a merger defence based on efficiencies that are specific to the merger and passed on to consumers to a sufficient degree. These will be taken into consideration and balanced against anticompetitive effects in the case.

The US horizontal merger guidelines, revised in 1997 on this point, read:

> "[T]he merging firms must substantiate efficiency claims so that the Agency can verify by reasonable means the likelihood and magnitude of each asserted efficiency, how and when each would be achieved (and any costs of doing so), how each would enhance the merged firm's ability and incentive to compete, and why each would be merger-specific. Efficiency claims will not be considered if they are vague or speculative or otherwise cannot be verified by reasonable means." (US Department of Justice and US Federal Trade Commission, 1997, Section 4)

Similarly, the following section was adopted into the 2004 European horizontal merger guidelines:

[12] See for instance Williamson (1968) and Farrell and Shapiro (1990).

[13] European Commission (2004a).

> "The Commission considers any substantiated efficiency claim in the overall assessment of the merger. It may decide that, as a consequence of the efficiencies that the merger brings about, there are no grounds for declaring the merger incompatible with the common market pursuant to Article 2(3) of the Merger Regulation. This will be the case when the Commission is in a position to conclude on the basis of sufficient evidence that the efficiencies generated by the merger are likely to enhance the ability and incentive of the merged entity to act pro-competitively for the benefit of consumers, thereby counteracting the adverse effects on competition which the merger might otherwise have." (European Commission (2004b), Paragraph 77)

This new chapter in European merger control promises to become an improvement over the existing practice, as it allows for a more balanced and complete analysis of economic effects. However, only in very few cases has the efficiency defense played an explicit role in the merger decisions of the European Commission. The first case in which efficiencies were used as an argument in a merger approval decision was *Procter&Gamble* and *Gillette*. [14] The efficiencies gains stemmed from the firms' combined product portfolio in this case. Moreover, in a merger in the cartonboard industry between *Korsnäs* and *AssiDomän*, efficiency gains were one argument to clear a merger in Phase I. They were expected from input cost savings, reduced costs for personnel and also arguments for efficiencies in production and research and development played a role.[15] In the US, merger efficiency arguments have also been acknowledged in actual decisions. In *Whirlpool/Maytag*, a manufacturer of home appliances, for instance, the DoJ expected large costs savings that were likely to be passed on to consumers. In *AmeriSource Health Corporation/Bergen Brunswig Corporation*, economies of scale were named as a major source of merger efficiencies.

Also in some national authorities, the efficiency defense has been applied. A recent case decided by the UK Competition Commission (CC) recognizes the role of efficiencies in the merger of *Macquarie UK Broadcast Ventures* and *National Grid Wireless Group* , two owners of networks of masts for radio television broadcasting.[16] Even though the CC acknowledged the considerable loss of competition as a result of the concentration, they argued that among other things, merger efficiencies counterbalanced this loss. Major efficiencies were grouped into the class of reduction in overhead costs but also rationalizations in duplicate functions were brought forward as an argument for efficiencies.

As a result of the *ex ante* nature of merger control, the balancing of competition and efficiency effects is often complicated in practice. Efficiencies in particular are "easy to

[14] Commission decision, COMP/M.3732, Procter and Gamble/ Gillette, 15 July 2005, paragraph 131. See also some efficiency considerations in Commission decisions, COMP/M.3664, RepsolButano/Shell Gas (LPG), 2 March 2005, paragraphs 33-35; COMP/M.3886, Aster 2/Flint Ink, 25 August 2005, paragraph 22.

[15] Commission decision, COMP/M.4057, Korsnäs/AssiDomän Cartonboard, 12 May 2006, paragraphs 36, 57-64.

[16] See UK Competition Commission, Macquarie UK Broadcast Ventures / National Grid Wireless Group, decided on 11.03.08

promise, yet may be difficult to deliver."[17] The difficulty of including an efficiency defense in actual merger analysis stems from the fact that it is hard to substantiate efficiency claims. This makes the evaluation of notified mergers costly, requiring considerable resources, time and expertise. Competition authorities increasingly employ sophisticated economic analysis, including computer simulation techniques, to assist in the weighing of the various effects of a merger. These methods combine structural oligopoly models with econometric specifications to quantify predicted market reactions following a merger.

2.4.2 Models in Merger Simulation Analysis

To implement the efficiency defense in actual cases one can use quantitative techniques to simulate the effect of a merger on the market. The development of these merger simulation techniques for merger investigations started some ten years ago in US enforcement agencies and academia.[18] Merger simulation analysis today uses as its basis one of two methods. The first, which requires a considerable amount of data, fully estimates a demand model using econometric techniques. Examples of this approach are Hausman et al. (1994) and Pinkse and Slade (2004). The second approach, which is less data intensive, is to calibrate a simulation model using critical features of the industry at hand such as quantities, prices and elasticities. The calibration approach requires a considerable amount of structural specification, such as a choice of the appropriate functional form of demand. This methodology has been applied in Werden and Froeb (1996), as well as in Epstein and Rubinfeld (2001).

Merger simulation models predict post-merger prices in a given relevant market on the basis of pre-merger market conditions and a number of assumptions about the behavior of the firms. A common assumption of these models is that firms compete on prices even though there also exist models based on quantity setting markets or bidding markets. Calibrated models also need an additional set of assumption about the underlying demand model in the relevant market. Popular underlying functional forms used for merger simulation are Logit, AIDS or PCAIDS.[19] Moreover, specific assumptions about the form of supply need to be made. Typically, the models presume constant marginal costs.

Using the calibration approach, the analysis can be split up in two stages. In the first stage, the pre-merger situation is analyzed. This situation is used as the 'but for scenario', in other words it analyzes the benchmark case without the merger taking place. At this stage, the model is calibrated, meaning that the parameters of the model are chosen so as to best reflect the actual pre-merger market situation. The required data for the parameters are typically product prices, quantities and (cross-) price elasticities. Using the pre-merger first order conditions, it is possible to calculate the corresponding profit margins of each firm.

In the second stage, the market situation after the merger would have taken place is analyzed. Here, there is at least one firm less in the market compared to the situation pre-

[17] White (1987), p.18. Fisher (1987) adds that: "Such claims are easily made, and, I think, often too easily believed." (*op.cit.*, p.36). See also Heidhues and Lagerloef (2005).

[18] See Werden and Froeb (1996; 2005) and Bergeijk and Kloosterhuis (2005).

[19] See Hausman et al. (1994), Werden and Froeb (1996), Epstein and Rubinfeld (2001).

merger, and the objective functions of the merging firms have changed. The merged firms are aware of the fact that different from the situation before the merger, sales lost due to price increase are now at least in part diverted to its own division in the new merger entity. In the second stage, one solves for the price changes that create changes in margins, elasticities and shares that are consistent with the altered first order conditions post-merger.

2.4.3 Scope and Limitations of Merger Simulation Models

The debate on the use of sophisticated modeling techniques in merger control is to a large extent still academic. Very little use is made of full-blown simulation modeling in published cases.[20] To our best knowledge, the only supra-national case where in-house developed simulation models have explicitly contributed to decision making, simultaneously by FTC in the US and by DG Competition for the EC, has, in fact, been the *Oracle/Peoplesoft case*.[21] The sensitivity of the analysis to variations in the underlying assumptions of the models makes it difficult to use conclusions based on simulation exercises as evidence.

In Europe, the legal climate for experimenting with these new methods has become friendlier. Analyses in which strategic interaction was assumed to be of the Cournot type was recently done for the iron ore industry by Lyons and Davies (2003), as well as for the Dutch electricity industry in the *Nuon/Reliant* case in the electricity market.[22] Extensive merger simulation analyses based on Bertrand competition were carried out by DG Competition, among others, in *Hachette/Lagardère* and *Volvo/Scania*.[23]

Merger simulation analysis clearly is an open field for further research that is promising for theorists and practitioners alike. Yet, we would like to point to a few limitations of this type of analysis as well.

The modeling techniques that have been applied in these recent merger decisions are, however impressive in their own right, only exploiting a few of the many dimensions for sophisticated tailor-made analyses that economic theory has to offer. Moreover, the debate is focussing on the specification of demand functions.

In addition, the results of simulation studies or other kinds of empirical analyses are often difficult to interpret. This presents difficulties for all involved: parties, competition authorities, outside counsel and often eventually judges. When used as part of the argument in a case, simulation models could therefore be misinterpreted or disregarded by decision makers lacking the experience and knowledge in the field.[24] In fact, Coleman and Scheffman

[20]See Goppelsroeder and Schinkel (2005) for a more extensive critique of the use of simulation models in merger control.

[21]For the EU decision, see Comp/M.3216-Oracle/Peoplesoft. For the US decision, see United States of America v. Oracle Corporation, No C 04-0807 VRW. For an analysis of actual mergers in the airline industry using merger simulation techniques, see Peters (2003). See also Nevo (2000), in which simulation analyses are used to assess actual, as well as hypothetical mergers in the cereal industry. For the use of simulation analysis during an actual investigation by an enforcement agency, even though it was not used in the decision, see Werden (2000).

[22]Case 3386/Nuon-Reliant (2003).

[23]See Ivaldi and Verboven (2005).

[24]See Baker (1999) for the use of econometric evidence and its acceptance in court.

(2005) note for the US practice that econometric evidence in general is often disregarded by judges in antitrust cases when taking the final decision in a case, especially when the different parties come with competing econometric evidence yielding divergent results.

Moreover, merger simulation analyses that go beyond Phase I screening, irrespective of the mix of outside and in-house expertise, typically consume a considerable amount of resources and time. For competition authorities with limited budgets, it is therefore crucial to weigh the costs and benefits of using such complex techniques. On the benefit side surely, and other things equal, enhanced empirical methods can reduce the error margins in assessing mergers and thereby help to contribute to sound interventions.

2.4.4 Alternative Approaches

As a safe route to sail between the Skylla of static *ex ante* HHI thresholds and the Charybdis of costly and uncertain merger simulation methods, the following chapter presents a new measurement tool that captures merger specific efficiency gains, yet does not have all of the drawbacks pointed to above: the Werden-Froeb-index, or WFI. The WFI is based on the concept of Compensating Marginal Cost Reductions (CMCRs), developed in the late 1990's by Werden and Froeb. CMCRs measure merger-specific relative cost savings that are required to just replicate the status quo in terms of prices and quantities that exists prior to the merger, after the merger. As explained in Section 2.3, if two formerly competing firms integrate their pricing or production decisions, prices may rise and market shares of all the firms in the industry will adjust accordingly. When together with the change in firm structure other variables are also properly adjusted, it would be possible to re-establish the pre-merger market equilibrium in terms of prices, quantities and market shares. The CMCRs are based on the decrease in marginal production cost levels – representing efficiency gains – that just offset the competition reducing effects of the merger. Independent of the work of Gregory Werden and Luke Froeb, a similar concept was developed by Lars-Hendrik Röller, Johan Stennek and Frank Verboven, which they called 'Minimum Required Efficiencies' (MREs), in studies for the European Commission. See Verboven *et al.* (1999), and Stennek and Verboven (2003). MREs are defined as the ratio of the anticompetitive price increase as a result of the merger over the rate at which the (claimed) actual merger-specific cost savings are passed on to the consumers. Note also that in a recent paper by Farrell and Shapiro (2008) a test is developed, that serves as a heuristic in determining whether a given merger results in a loss of competition. Their so-called upward pricing pressure measure balances two opposing effects present in many merger cases: an upward pricing pressure due to the loss in direct competition and the potential savings in marginal costs that exert a downward pressure on prices post-merger. The test is simple and can be calculated using information on price-cost margins as well as the magnitude of direct substitution of the merging firms. The following chapter introduces the Werden-Froeb index in more detail and discusses its implementation in merger control.

2.5 Concluding Remarks

This chapter introduced the Cournot and Bertrand oligopoly model, two benchmark models used in oligopoly theory. It has shown that a merger of two firms in a Cournot triopoly market increases prices and decreases industry output. Moreover, a merger in such a market is only profitable for the merging firms if the products are sufficiently differentiated. The outsider, however, always profits from the merger. In a Bertrand triopoly market a merger between two firms leads a different outcome concerning profitability. Both insiders and outsiders increase their profits post-merger. What is more, prices increase and total output contracts. Moreover, the chapter provided an overview on the current European merger policy and recent changes therein. One of the innovations in European merger policy has been the introduction of an efficiency defense. Existing models to quantify merger efficiencies have some drawbacks such as data-intensity and time constraints. In recent years, alternative approaches to measure efficiencies have been introduced. One of these methods will be presented in the following chapter.

Chapter 3

Quantifying the Scope for Efficiency Defense in Merger Control: The Werden-Froeb-Index

3.1 Introduction

In the previous chapter, we presented some of the pitfalls in implementing the merger efficiency defense.[1] In this chapter, we propose an alternative method to assess horizontal merger efficiencies, introducing the Werden-Froeb-index (WFI). The WFI is based on Compensating Marginal Cost Reductions (CMCRs), a concept developed in Werden (1996) and Froeb and Werden (1998). The CMCR of each commodity involved in the merger is the reduction in the commodity's (marginal) production costs after the merger, which is minimally required to obtain the *status quo* in terms of quantities and prices that exists prior to the merger. We derive generalized CMCRs. The WFI is a weighted average of the CMCRs. It is a measure of the relative savings in output-weighted marginal cost of producing the commodities involved in the merger that is required to restore pre-merger equilibrium values. The WFI has a number of attractive features for merger control.

The chapter is organized as follows. In Sections 3.2-3.2.3, generalized CMCRs are established for any number of differentiated goods and firms, of which two or more merge, fully or partially, when competition is either on quantities (Cournot) or on prices (Bertrand). Section 3.3 defines the Werden-Froeb-index. Section 3.4 sets out the index's information requirements. Section 3.5 discusses how to implement the WFI practically in merger control, supplementing established HHI-analysis. Several numerical examples of mergers in a representative market illustrate the power of the measure. Section 3.6 concludes. A short routine in MATLAB for calculating the WFI for mergers in price competition is provided Appendix A.

[1]This chapter is based on Goppelsroeder, Schinkel and Tuinstra (2008). Valuable research assistance was provided by Tashi Erdmann, Benjamin Kemper and Eelko Ubels.

3.2 Generalized CMCRs

The conceptual idea of compensating marginal cost reductions is to establish those efficiency gains that need to materialize in order to exactly off-set a merger's unilateral anticompetitive effects. CMCRs thereby replicate the *status quo* in terms of prices and quantities. Consumers would be just indifferent between the merger being cleared or blocked if these cost savings would indeed result from the merging parties integrating their business. Efficiencies beyond this minimally required level would in principle in part be passed on to the consumers.[2]

In any given industry, the CMCR commodity values depend on specifics like the nature of the (marginal) production costs, commodity characteristics and the type of market competition. Gregory Werden and Luke Froeb developed the concept for a limited number of common settings, involving constant marginal costs and full mergers between two firms. Werden (1996) derives results for Bertrand competition among differentiated substitute commodities. Froeb and Werden (1998) analyses Cournot competition among producers of a homogenous good that differ only in their share of the market.[3] In this section, we generalize these contributions in one integrated setup for the assessment of unilateral effects in horizontal mergers.[4]

First note some limitations of the approach. Conceptually, it abstracts from any post-merger reallocation of production to the more efficient divisions of the merged firm. Although possibly restrictive in the special case of a single homogenous good, it is this assumption that makes the approach generally practical, since it avoids specifying a full structural market model.[5] Furthermore, the *status quo* approach does not take into account that integrated firms may have a post-merger incentive to reconsider their portfolio of products, repositioning them by adjusting their differentiation and extending or possibly discontinuing some of its product lines.[6] We assume these effects away by considering a fixed product spectrum. Finally, the mode of competition is supposed not to change as a result of the merger and we do not consider any coordinated effects of mergers.

Consider a market in which n (possibly only slightly) differentiated products are produced and supplied by $K \leq n$ different firms. Each commodity is produced by only one firm,

[2]The approach therefore is in line with the consumer welfare standard, as further discussed in Section 3.6. It does not recognize efficiency defense arguments based on merger-specific reductions in fixed cost (overhead), which may increase total welfare but are not passed on to consumers (to a sufficient extent). See Farrell and Shapiro (2001).

[3]In Section 4 of Stennek and Verboven (2003), these same basic models are analysed. In addition, the paper considers a merger between two firms out of three, competing on prices in a homogenous commodity produced against different constant marginal cost levels.

[4]In the following, we derive CMCRs in absolute value. In Werden (1996), as well as in Stennek and Verboven (2003), the required marginal cost reductions, and MREs, are expressed relative to original marginal cost levels. In Froeb and Werden (1998), a "proportionate" CMCR is presented that is a special case of the WFI_C—see footnote 20 in Section 3.3.

[5]Stennek and Verboven (2003) includes this post-merger cost-minimizing reallocation of production in their presentation of the MREs for the most efficient firm in the merger only. CMCRs generally overestimate the MREs, as discussed in Section 3.4.

[6]Gandhi *et al.* (2005) develop simulation analyses in which product variety increases with concentration. Berry and Waldfogel (2001) find evidence to the effect in radio broadcasting.

but some firms may produce several commodities.[7] In particular, we assume that firm k produces m_k different commodities, with $\sum_{k=1}^{K} m_k = n$. Without loss of generality, we number commodities such that the first m_1 commodities are produced by firm 1, commodities $m_1 + 1, \ldots, m_1 + m_2$ by firm 2, commodities $m_1 + m_2 + 1, \ldots, m_1 + m_2 + m_3$ by firm 3, and so on. Note that this numbering can always be done in such a way that the first l firms are the merging firms. Also define $n_k = \sum_{j=1}^{k} m_j$. Obviously, $n_0 = 0$ and $n_K = n$.

Demand for product i is given by the demand function $Q_i(\mathbf{p}) = Q_i(p_1, \ldots, p_n)$, where $p_j > 0$ is the price of the j'th product, and $\mathbf{p} \in \mathbb{R}^n_{++}$ is the full price vector. The function $Q_i(\mathbf{p})$ is assumed to be positive, continuous and twice continuously differentiable everywhere. Moreover, we assume $\frac{\partial Q_i(\mathbf{p})}{\partial p_i} \leq 0$. Commodity i is called a substitute for commodity j at $\mathbf{p}$ if $\frac{\partial Q_i(\mathbf{p})}{\partial p_j} > 0$. Mergers may also involve complementary goods previously sold by competing firms—commodities i and j are complements at $\mathbf{p}$, if $\frac{\partial Q_i(\mathbf{p})}{\partial p_j} < 0$—in which case the merger may, in fact, decrease prices.[8] Assuming that the Jacobian matrix associated to $(Q_1(\mathbf{p}), \ldots, Q_n(\mathbf{p}))$ is nonsingular, we know that, by the inverse function theorem, the inverse demand functions exist as the prices that clear the market at the quantities produced. Denote the inverse demand function for product i by $P_i(\mathbf{q}) = P_i(q_1, \ldots, q_n)$ and assume that they are also positive, continuous and twice continuously differentiable.

The costs for firm k of producing the production bundle $\left(q_{n_{k-1}+1}, \ldots, q_{n_k}\right)$ are given by a cost function $C_k\left(q_{n_{k-1}+1}, \ldots, q_{n_k}\right) = C_k(\mathbf{q}_k)$, which is strictly positive, increasing in its arguments, and twice continuously differentiable. By $c_i(\mathbf{q}_k)$ we will denote the marginal costs associated to product i (where $n_{k-1} + 1 \leq i \leq n_k$). Without making any more specific assumptions on the cost functions, we will assume that all equilibria correspond to solutions of the first-order conditions and that second-order conditions for a global maximum are always satisfied. After the first l firms out of the pool of K have merged, the merged entity subsequently faces cost function $\widetilde{C}(q_1, \ldots, q_{n_l}) = \widetilde{C}(\mathbf{q}_1, \ldots, \mathbf{q}_l)$. Again, this cost function is strictly positive, nondecreasing in its arguments and twice continuously differentiable. Note that this setup allows for common costs. Marginal costs with respect to the production of commodity i $(1 \leq i \leq n_l)$ are denoted by $\widetilde{c}_i(q_1, \ldots, q_{n_l})$.

The CMCR values of mergers between firms competing on quantities or prices in otherwise identical market conditions generally differ. In the following two subsections, we derive CMCRs as the absolute marginal costs reductions required to replicate the pre-merger equilibrium in the post-merger market for fully integrating firms in Cournot and Bertrand competition respectively. The section closes with a characterization of CMCRs for partial acquisitions.

[7]We introduce this setup for notational convenience. One way to interpret it is as commodities being (slightly) firm-specific. Yet, for both Cournot and Bertrand competition, in the two subsections below, we also consider the special case of purely homogenous commodities.

[8]Note that by considering complements as well as substitutes, our analysis of efficiencies is not restricted to a single relevant market—which would not contain complements by the SSNIP-test methodology. That is, CMCRs are a (merged) firm-specific measure, and not a market measure, like the HHI is. This issue is further discussed in Section 3.5.

3.2.1 CMCRs in Cournot Competition

Suppose that firms use quantities as their strategic variables and prices adjust in such a way that markets clear. For illustrative purposes, first consider the special case where, before the full merger, each firm produces only one product variety—that is $K = n$, $m_k = 1$ and $n_k = k$ for every k. Firm i, producing commodity i, then chooses q_i by profit maximization

$$\max_{q_i} P_i(\mathbf{q})\, q_i - C_i(q_i).$$

The first-order condition for this problem is

$$P_i(\mathbf{q}) + q_i \frac{\partial P_i(\mathbf{q})}{\partial q_i} - c_i(q_i) = 0, \tag{3.1}$$

for firm i. The vector of Cournot-Nash equilibrium quantities $\mathbf{q}^* = (q_1^*, \ldots, q_n^*)$ is such that (3.1) is satisfied for every firm i. The associated equilibrium prices are given by $p_i^* = P_i(\mathbf{q}^*)$, for $i = 1, \ldots, n$.

Next, consider the effect of a merger between the first l firms. The merged entity's profit maximization problem then becomes

$$\max_{q_1,\ldots,q_l} P_1(\mathbf{q})\, q_1 + P_2(\mathbf{q})\, q_2 + \ldots + P_l(\mathbf{q})\, q_l - \widetilde{C}(q_1, q_2, \ldots, q_l),$$

from which the system of first-order conditions follows as:

$$\begin{aligned}
P_1(\mathbf{q}) + q_1 \frac{\partial P_1(\mathbf{q})}{\partial q_1} + q_2 \frac{\partial P_2(\mathbf{q})}{\partial q_1} + \ldots + q_l \frac{\partial P_l(\mathbf{q})}{\partial q_1} - \widetilde{c}_1(q_1, \ldots, q_l) &= 0 \\
P_2(\mathbf{q}) + q_1 \frac{\partial P_1(\mathbf{q})}{\partial q_2} + q_2 \frac{\partial P_2(\mathbf{q})}{\partial q_2} + \ldots + q_l \frac{\partial P_l(\mathbf{q})}{\partial q_2} - \widetilde{c}_2(q_1, \ldots, q_l) &= 0 \\
&\vdots \\
P_l(\mathbf{q}) + q_1 \frac{\partial P_1(\mathbf{q})}{\partial q_l} + q_2 \frac{\partial P_2(\mathbf{q})}{\partial q_l} + \ldots + q_l \frac{\partial P_l(\mathbf{q})}{\partial q_l} - \widetilde{c}_l(q_1, \ldots, q_l) &= 0,
\end{aligned} \tag{3.2}$$

for the first l commodities. Together with conditions (3.1) for the firms $l + 1$ to n which remain outside the merger, the solution to the post-merger first-order conditions defines the Cournot-Nash equilibrium $(\mathbf{q}^{**}, \mathbf{p}^{**})$.

Typically, post-merger production levels for both the merged firms ($k = 1, \ldots, l$) and the independent firms ($k = l + 1, \ldots, n$) will be different from the pre-merger Cournot-Nash equilibrium levels. However, for given quantities $\mathbf{q}$ and associated prices $\mathbf{p}$ given by $p_i = P_i(\mathbf{q})$, we can explicitly determine marginal costs $\widetilde{c}_1$, $\widetilde{c}_2$, up to $\widetilde{c}_l$ such that the post-merger first-order conditions (3.2) are satisfied for those chosen quantities. The post-merger first-order conditions are thus employed to endogenously determine the marginal costs $\widetilde{c}_i$ that result in a specific output vector $\mathbf{q}$. For an arbitrary output vector $\mathbf{q}$, this is generally problematic. It requires a full understanding of the inverse demand functions at these quantities. Moreover, the first-order conditions for the other firms also change for

$\mathbf{q} \neq \mathbf{q}^*$. The CMCR concept circumvents these difficulties by asking for which values of $\widetilde{c}_i$ the post-merger Cournot-Nash equilibrium quantities $\mathbf{q}^{**}$ are exactly equal to the pre-merger Cournot-Nash equilibrium quantities $\mathbf{q}^*$. The benefit of this *status quo* approach is that the first-order conditions of the nonmerging firms remain the same and can therefore be disregarded in the comparisons.

The necessary absolute marginal cost reductions for each product i to exactly reproduce pre-merger quantities and market prices after the merger follow from combining conditions (3.1) and (3.2), as follows

$$\begin{aligned}
\triangle\, c_i &\equiv c_i\left(q_i^*\right) - \widetilde{c}_i\left(q_1^*, \ldots, q_l^*\right) \\
&= \left(P_i\left(\mathbf{q}^*\right) - \widetilde{c}_i\left(q_1^*, \ldots, q_l^*\right)\right) - \left(P_i\left(\mathbf{q}^*\right) - c_i\left(q_i^*\right)\right) \\
&= -\left[q_1^* \frac{\partial P_1\left(\mathbf{q}^*\right)}{\partial q_i} + \ldots + q_{i-1}^* \frac{\partial P_{i-1}\left(\mathbf{q}^*\right)}{\partial q_i} + q_{i+1}^* \frac{\partial P_{i+1}\left(\mathbf{q}^*\right)}{\partial q_i} + \ldots + q_l^* \frac{\partial P_l\left(\mathbf{q}^*\right)}{\partial q_i}\right] \\
&= -\sum_{j=1, j\neq i}^{l} q_j^* \frac{\partial P_j\left(\mathbf{q}^*\right)}{\partial q_i}.
\end{aligned} \tag{3.3}$$

Some intuition for this specification follows from considering total revenue of the merged firm, $\widetilde{R}\left(\mathbf{q}\right) = \sum_{j=1}^{l} q_j P_j\left(\mathbf{q}\right)$, and revenue of firm i before the merger, which is $R_i\left(\mathbf{q}\right) = q_i P_i\left(\mathbf{q}\right)$. The absolute CMCR for product i can be written as

$$\triangle c_i = MR_{ii}\left(\mathbf{q}^*\right) - \widetilde{MR}_i\left(\mathbf{q}^*\right), \tag{3.4}$$

in which $\widetilde{MR}_i\left(\mathbf{q}\right) = \frac{\partial \widetilde{R}(\mathbf{q})}{\partial q_i}$ and $MR_{ii}\left(\mathbf{q}\right) = \frac{\partial R_i(\mathbf{q})}{\partial q_i}$ are the marginal revenues associated with $\widetilde{R}\left(\mathbf{q}\right)$ and $R_i\left(\mathbf{q}\right)$, respectively. Hence, in order to assure that post-merger quantities equal pre-merger levels, the marginal cost reduction should exactly outbalance the reduction in marginal revenue from an increase in producing more of product i. These reductions in marginal revenue are due to the fact that the negative spill-over effects of an increase of q_i on prices of the other commodities is internalized, which reduces production and increases prices in the absence of marginal cost reductions.

Note that if all commodities involved in the merger are substitutes, the necessary cost reduction is positive, *i.e.*, $\triangle c_i > 0$. If all involved commodities would be complements, $\triangle c_i < 0$. When there is a mixed bundle of substitutes and complements involved in the merger, the sign of $\triangle c_i$ is ambiguous.[9] Finally note that the values of $\triangle c_i$ are uniquely determined at the *status quo* equilibrium, because each commodity's total output remains the same. We do not need to put any restrictions on the shape of the post-merger cost functions outside equilibrium, other than that the second-order conditions for a Nash-equilibrium hold.

Next, we generalize the analysis to cover mergers of any arbitrary number of firms l that each produce an arbitrary number of varieties m_k, with $k = 1, \ldots, l$. Before the merger, firm

[9]Note further that the necessary efficiencies might be so large that the post-merger marginal costs need to fall below zero, in which case $\Delta c_i > c_i$. Even though it is obviously impossible to meet, we do not a priori rule out this requirement on a product-by-product basis, since the WFI deals with it quite naturally, as explained in Section 3.3.

k chooses quantities $q_{n_{k-1}+1}, \ldots, q_{n_k}$ by solving

$$\max_{q_{n_{k-1}+1},\ldots,q_{n_k}} \sum_{j=n_{k-1}+1}^{n_k} q_j P_j(\mathbf{q}) - C_k(\mathbf{q}_k),$$

which returns first-order conditions

$$P_i(\mathbf{q}) + \sum_{j=n_{k-1}+1}^{n_k} q_j \frac{\partial P_j(\mathbf{q})}{\partial q_i} - c_i(\mathbf{q}_k) = 0 \qquad \text{for } i = n_{k-1}+1, \ldots, n_k. \tag{3.5}$$

There is a set of such first-order conditions for every merging firm.

It is convenient to employ some matrix notation from here onwards. Let the following $m_j \times m_i$ matrix collect quantity effects of the products sold by firms i and j:

$$\mathbf{P}_{ij} = \begin{pmatrix} \frac{\partial P_{n_{i-1}+1}(\mathbf{q})}{\partial q_{n_{j-1}+1}} & \frac{\partial P_{n_{i-1}+2}(\mathbf{q})}{\partial q_{n_{j-1}+1}} & \cdots & \frac{\partial P_{n_i}(\mathbf{q})}{\partial q_{n_{j-1}+1}} \\ \frac{\partial P_{n_{i-1}+1}(\mathbf{q})}{\partial q_{n_{j-1}+2}} & \frac{\partial P_{n_{i-1}+2}(\mathbf{q})}{\partial q_{n_{j-1}+2}} & \cdots & \frac{\partial P_{n_i}(\mathbf{q})}{\partial q_{n_{j-1}+2}} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{\partial P_{n_{i-1}+1}(\mathbf{q})}{\partial q_{n_j}} & \frac{\partial P_{n_{i-1}+2}(\mathbf{q})}{\partial q_{n_j}} & \cdots & \frac{\partial P_{n_i}(\mathbf{q})}{\partial q_{n_j}} \end{pmatrix}. \tag{3.6}$$

This matrix is the transpose of the Jacobian matrix of the inverse demand functions of the products supplied by firm i, or $P_{n_{i-1}+1}(\mathbf{q}), \ldots, P_{n_i}(\mathbf{q})$, with respect to the quantities of the commodities produced by firm j, that is, $q_{n_{j-1}+1}, \ldots, q_{n_j}$. Also denote by $\mathbf{q}^{(n_l)} = (q_1, \ldots, q_{n_l})'$ the vector of quantities of the commodities sold by the merging firms, by $\mathbf{p}^{(n_l)} = (p_1, \ldots, p_{n_l})'$ the vector of corresponding prices, and by $\mathbf{c}^{(n_l)} = (c_1, \ldots, c_{n_l})'$ the vector of relevant marginal costs. The pre-merger first-order conditions (3.5) for all merging firms can now concisely be written as

$$\mathbf{p}^{(n_l)} + \mathbf{P}_0 \mathbf{q}^{(n_l)} - \mathbf{c}^{(n_l)} = \mathbf{0}, \tag{3.7}$$

in which

$$\mathbf{P}_0 = \begin{pmatrix} \mathbf{P}_{11} & \mathbf{0} & \cdots & \mathbf{0} \\ \mathbf{0} & \mathbf{P}_{22} & & \vdots \\ \vdots & & \ddots & \\ \mathbf{0} & \cdots & & \mathbf{P}_{ll} \end{pmatrix},$$

collects the quantity effects of all the products involved in the merger.

We use a similar notation for the post-merger situation. The first-order conditions for the merged entity read

$$P_i(\mathbf{q}) + \sum_{j=1}^{n_l} q_j \frac{\partial P_j(\mathbf{q})}{\partial q_i} - \widetilde{c}_i\left(\mathbf{q}^{(n_l)}\right) = 0, \qquad \text{for } i = 1, \ldots, n_l,$$

which can be summarized as

$$\mathbf{p}^{(n_l)} + \mathbf{P}_1 \mathbf{q}^{(n_l)} - \widetilde{\mathbf{c}}^{(n_l)} = \mathbf{0}. \tag{3.8}$$

Here

$$\mathbf{P}_1 = \begin{pmatrix} \mathbf{P}_{11} & \mathbf{P}_{21} & \cdots & \mathbf{P}_{l1} \\ \mathbf{P}_{12} & \mathbf{P}_{22} & & \vdots \\ \vdots & & \ddots & \\ \mathbf{P}_{1l} & \cdots & & \mathbf{P}_{ll} \end{pmatrix}$$

is the transpose of the Jacobian of the inverse demand functions of all merging firms with respect to the quantities of all commodities they supply. This matrix collects all the post-merger quantity effects.

The vector of CMCRs then compactly follows as—with subscript 'C' referring to Cournot competition:

$$\triangle \mathbf{c}_C \equiv \mathbf{c}^{(n_l)} - \widetilde{\mathbf{c}}^{(n_l)} = (\mathbf{P}_0 - \mathbf{P}_1)\, \mathbf{q}^{(n_l)}, \tag{3.9}$$

in which

$$\mathbf{P}_0 - \mathbf{P}_1 = \begin{pmatrix} \mathbf{0} & -\mathbf{P}_{21} & \cdots & -\mathbf{P}_{l1} \\ -\mathbf{P}_{12} & \mathbf{0} & & \vdots \\ \vdots & & \ddots & \\ -\mathbf{P}_{1l} & \cdots & & \mathbf{0} \end{pmatrix},$$

compares pre- and post-merger quantity effects at the *status quo*. [10] Note that the elements of $\triangle \mathbf{c}_C$ are uniquely determined.

The analysis straightforwardly applies to the case of homogenous commodities and different market shares. Homogeneity implies a single inverse demand function, $P(q_1, \ldots, q_n) = P(q_1 + \ldots + q_n)$. Hence, $\frac{\partial P(\mathbf{q})}{\partial q_i} = P'(\mathbf{q})$ for all i. Furthermore, the marginal costs post-merger must be equal for 'each' merged product. Moreover, from (3.2) it follows immediately that for each merging firm i it must be that $\widetilde{c}_i = \widetilde{c} = P(\mathbf{q}) + P'(\mathbf{q}) \sum_{j=1}^{l} q_j$, where l is the number of merging firms. It follows then from equation (3.3) that the compensating reduction in marginal costs for firm i is given by

$$\triangle c_{C\,i} = -P'(\mathbf{q}^*) \sum_{j=1, j\neq i}^{l} q_j^*.$$

Note that our setup can deal with any combination of differentiated and homogeneous commodities as well.

[10] The absolute CMCRs in (3.9) have an interpretation similar to those in (3.4). Denote by $R^{(n_k)}(\mathbf{q}) = \sum_{i=n_{k-1}+1}^{n_k} q_i P_i(\mathbf{q})$ and $\widetilde{R}(\mathbf{q}) = \sum_{k=1}^{l} R^{(n_k)}(\mathbf{q}) = \sum_{i=1}^{n_l} q_i P_i(\mathbf{q})$ the pre-merger revenue of the k'th firm and the post-merger revenue of the merged firm, respectively. The compensating marginal cost reduction for a product i which was produced by firm k before the merger (that is, $n_{k-1} + 1 \leq i \leq n_k$) is then given by

$$\triangle c_{C\,i} = \frac{\partial R^{(n_k)}(\mathbf{q}^*)}{\partial q_i} - \frac{\partial \widetilde{R}(\mathbf{q}^*)}{\partial q_i} = MR_i^{(n_k)}(\mathbf{q}^*) - \widetilde{MR}_i(\mathbf{q}^*).$$

3.2.2 CMCRs in Bertrand Competition

If firms set prices rather than quantities, we can determine the CMCRs along lines similar to the Cournot case. Consider the general case of a pool of firms each producing one or more differentiated goods at varying costs, in which l firms merge. Prior to the merger, firm k chooses prices $\left(p_{n_{k-1}+1}, \ldots, p_{n_k}\right)$ in order to solve

$$\max_{p_{n_{k-1}+1},\ldots,p_{n_k}} \sum_{j=n_{k-1}+1}^{n_k} p_j Q_j\left(\mathbf{p}\right) - C_k\left(Q_{n_{k-1}+1}\left(\mathbf{p}\right), \ldots, Q_{n_k}\left(\mathbf{p}\right)\right),$$

which returns first-order conditions

$$Q_i\left(\mathbf{p}\right) + \sum_{j=n_{k-1}+1}^{n_k} \left(p_j - c_j\left(\mathbf{q}_k\right)\right) \frac{\partial Q_j\left(\mathbf{p}\right)}{\partial p_i} = 0, \text{ for } i = n_{k-1}+1, \ldots, n_k. \tag{3.10}$$

These first-order conditions typically depend on the marginal cost of production of all the merging firms' products. Therefore, in Bertrand competition, matters are slightly more complicated than in Cournot competition. The reason for this asymmetry is that increasing production of one commodity in a Cournot model will also influence the prices of the other commodities, but it will not influence production of the other commodities and hence will leave their costs of production unchanged. On the other hand, increasing the price for a commodity will influence the demand of other commodities and thereby change production and costs for these other commodities, so that these do enter the first-order conditions.[11] The endogenous marginal cost levels that assure any particular Bertrand-Nash equilibrium are therefore more difficult to extract.

In matrix notation, the pre-merger first-order conditions of the l merging firms can be expressed as

$$\mathbf{q}^{(n_l)} + \mathbf{Q}_0\left(\mathbf{p}^{(n_l)} - \mathbf{c}^{(n_l)}\right) = \mathbf{0}. \tag{3.11}$$

Here

$$\mathbf{Q}_0 = \begin{pmatrix} \mathbf{Q}_{11} & \mathbf{0} & \cdots & \mathbf{0} \\ \mathbf{0} & \mathbf{Q}_{22} & & \vdots \\ \vdots & & \ddots & \\ \mathbf{0} & \cdots & & \mathbf{Q}_{ll} \end{pmatrix},$$

is assumed to be an invertible $n_l \times n_l$ matrix with submatrices

$$\mathbf{Q}_{ij} = \begin{pmatrix} \frac{\partial Q_{n_{i-1}+1}(\mathbf{p})}{\partial p_{n_{j-1}+1}} & \frac{\partial Q_{n_{i-1}+2}(\mathbf{p})}{\partial p_{n_{j-1}+1}} & \cdots & \frac{\partial Q_{n_i}(\mathbf{p})}{\partial p_{n_{j-1}+1}} \\ \frac{\partial Q_{n_{i-1}+1}(\mathbf{p})}{\partial p_{n_{j-1}+2}} & \frac{\partial Q_{n_{i-1}+2}(\mathbf{p})}{\partial p_{n_{j-1}+2}} & \cdots & \frac{\partial Q_{n_i}(\mathbf{p})}{\partial p_{n_{j-1}+2}} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{\partial Q_{n_{i-1}+1}(\mathbf{p})}{\partial p_{n_j}} & \frac{\partial Q_{n_{i-1}+2}(\mathbf{p})}{\partial p_{n_j}} & \cdots & \frac{\partial Q_{n_i}(\mathbf{p})}{\partial p_{n_j}} \end{pmatrix}. \tag{3.12}$$

[11] Compare equations (3.5) and (3.10).

Similar to the matrix of quantity effects (3.6), matrix (3.12) represents the transpose of the Jacobian matrix of demand functions of the products produced by firm i, with respect to the prices of the products produced by firm j. $\mathbf{Q}_0$ thus collects all pre-merger price-effects of all the commodities involved in the notified merger.

The post-merger first-order conditions for the fully merged entity are

$$Q_i(\mathbf{p}) + \sum_{j=1}^{n_l} \left(p_j - \widetilde{c}_j\left(\mathbf{q}^{(n_l)}\right)\right) \frac{\partial Q_j(\mathbf{p})}{\partial p_i} = 0 \text{ for } i = 1, \ldots, n_l,$$

which can be written as

$$\mathbf{q}^{(n_l)} + \mathbf{Q}_1\left(\mathbf{p}^{(n_l)} - \widetilde{\mathbf{c}}^{(n_l)}\right) = \mathbf{0}, \tag{3.13}$$

where

$$\mathbf{Q}_1 = \begin{pmatrix} \mathbf{Q}_{11} & \mathbf{Q}_{21} & \cdots & \mathbf{Q}_{l1} \\ \mathbf{Q}_{12} & \mathbf{Q}_{22} & & \vdots \\ \vdots & & \ddots & \\ \mathbf{Q}_{1l} & \cdots & & \mathbf{Q}_{ll} \end{pmatrix}$$

is assumed to be invertible.

Combining equation (3.11) and (3.13), the vector of CMCRs follows as—with subscript 'B' referring to Bertrand competition:

$$\triangle\mathbf{c}_B \equiv \mathbf{c}^{(n_l)} - \widetilde{\mathbf{c}}^{(n_l)} = \left(\mathbf{Q}_0^{-1} - \mathbf{Q}_1^{-1}\right)\mathbf{q}^{(n_l)}. \tag{3.14}$$

Note that under the invertibility assumptions, the elements of $\triangle\mathbf{c}_B$ are uniquely determined.[12]

As a result of discontinuities in demand, the case of Bertrand competition in a single homogenous commodity is not a straightforward special case of the analysis above. Assume that the marginal costs of production are constant. If the firms involved are not equally efficient, the most efficient firm would serve all of the market pre-merger. Naturally, therefore, in determining the CMCR all production remains in that division post-merger. Prices are constrained by the production costs of each commodity's nearest (potential) contestant in terms of efficiency. As a result, it is only mergers involving the two most efficient firms that should raise antitrust concerns in homogenous goods Bertrand competition. Suppose that the differences in efficiency are small enough, so that in the pre-merger equilibrium the most efficient firm prices at the marginal cost level of the second most cost-efficient firm (c_2).[13] The CMCR of the pre-merger most efficient firm then needs to be such that the profit

[12] The results obtained in Werden (1996) follow straightforwardly as a special case with $l = 2$ and constant marginal costs.

[13] We thank a referee for pointing out that there also exist equilibria in which the lowest cost firm sets a price strictly below the inefficient firm's marginal costs. See Blume (2003). However, such an equilibrium requires that the high-cost firm prices below its own costs—in the knowledge that it will not have any sales. Here we assume that no firm prices below costs, which is sometimes referred to as a 'cautious equilibrium'. See Lo (1999).

maximizing price of the merged entity is equal to c_2. That is, for this special case

$$\widetilde{c}_B = c_2 + \frac{Q_i\left(c_2\right)}{Q_i'\left(c_2\right)} \text{ and } \Delta c_B = c_B - \widetilde{c}_B. \tag{3.15}$$

Note that it is still natural here to use pre-merger production levels as a benchmark for the post-merger situation.

3.2.3 CMCRs in Partial Acquisitions

In both the US and Europe, competition authorities may challenge acquisitions of part of one or more firms. Partial acquisitions may raise competition concerns if the integration of mutual interests implies control over a former rival. The relationship between ownership and control is complex in general, but particularly so in the case of partial and asymmetric equity acquisitions. Various combinations of financial interests and corporate control can provide anticompetitive unilateral incentives, ranging from softened competition to joint profit maximization.[14] Partial ownership can imply full control. For this reason, merger regulations recognize the possibility of sole control, even in the case of qualified minority share holdings. In this subsection, we determine CMCRs for general ownership and control structures, following O'Brien and Salop (2000).[15]

Consider an economy with n commodities. Let the profits associated with the production of commodity i be given by π_i. There are K shareholders. Let $0 \leq w_{ik} \leq 1$ be shareholder k's share of business i. The financial interest structure is complete, that is, $\sum_{k=1}^{K} w_{ik} = 1$ for all i. Let $\phi_{ik} \geq 0$ denote shareholder k's corporate control over business i. These control parameters can be exogenously given, but they will typically have some relationship to the ownership shares w_{ik}. Strict majority rules would imply, for example, that $\phi_{ik} = 1$ whenever $w_{ik} > \frac{1}{2}$. In absence of a majority shareholder, ϕ_{ik} will depend on the relative bargaining power of the shareholders.[16]

Shareholder k intends to maximize his total take of profits, which is given as $\sum_{j=1}^{n} w_{jk}\pi_j$. We assume business i determines, given the other prices (or quantities) outside of its control, p_i (or q_i) in order to maximize

$$\sum_{k=1}^{K} \phi_{ik} \sum_{j=1}^{n} w_{jk}\pi_j = \sum_{j=1}^{n} \left(\sum_{k=1}^{K} \phi_{ik} w_{jk} \right) \pi_j = \sum_{j=1}^{n} \varphi_{ij}\pi_j,$$

where $\varphi_{ij} = \sum_{k=1}^{K} \phi_{ik} w_{jk}$ is the 'interest-weight' of firm j in firm i's objective function. This

[14] See Reynolds and Snapp (1986) and Reitman (1994).

[15] O'Brien and Salop (2000) derives a Modified-HHI (MHHI) approach for the assessment of concentration effects in partial acquisitions. In addition, the paper discusses (claimed) post-merger efficiencies in partial acquisitions and joint ventures, which are incorporated in the so-called 'Price-Pressure-Index' (PPI). This index measures how pricing incentives change as a result of (partial) mergers. See O'Brien and Salop (2000), pp.600-601.

[16] Bargaining power can, for example, be measured by the Banzhaf power index or the Shapley-Shubik power index. See Shapley and Shubik (1954), and Banzhaf (1965).

interest weight is high whenever shareholders that have a large stake in firm j are also an important factor in controlling firm i's strategies. We assume that $\varphi_{ii} > 0$ for all i. Without loss of generality, we can then normalize interest weights, such that $\varphi_{ii} = 1$ for all i.

Note that this setup with ownership and control parameters allows for a broad range of possible relationships between financial interests and corporate control. Suppose, for example, that we have $K \geq n$ and $\phi_{ik} = 1$ if and only if $i = k$ and $w_{ik} = 0$ (> 0), whenever $i \neq k$ ($i = k$). In that case every firm i is controlled by a single manager that seeks to maximize π_i, which corresponds to the textbook oligopoly scenario. Alternatively, there may be a subset of firms $i = 1, \ldots, n_l$, with $\varphi_{ij} = 1$ if $i, j \leq n_l$ and $\varphi_{ij} = 0$ otherwise. This structure corresponds to a full merger between the firms producing these first n_j commodities. Finally, consider the case with $K \geq n$ shareholders and $\phi_{ik} = 1$ for $i = k$ and $\phi_{ik} = 0$ for $i \neq k$. This corresponds to the case where there may be 'silent partners' in every firm, that may own part of the firm but do not exert any power over managerial decisions.[17]

Let the commodities that are directly or indirectly affected by the partial acquisition(s) be the first n_l commodities. Consider the $n_l \times n_l$ interest-weight matrix

$$\mathbf{\Phi} = \begin{pmatrix} 1 & \varphi_{12} & \cdots & \varphi_{1n_l} \\ \varphi_{21} & 1 & & \\ \vdots & & \ddots & \\ \varphi_{n_l 1} & & & 1 \end{pmatrix}.$$

We are interested in the change in the ownership and control structures from $\mathbf{\Phi}_0$ to $\mathbf{\Phi}_1$ as a result of the merger—where both structures are normalized such that $\varphi_{ii} = 1$ for all i.

This setup allows for a straightforward expression of CMCRs in partial acquisitions. Consider a market in Cournot competition. Quantity q_i is set as follows.

$$\max_{q_i} \sum_{j=1}^{n_l} \varphi_{ij} \left(q_j P_j \left(\mathbf{q} \right) - C_j \left(q_j \right) \right). \tag{3.16}$$

Note that we have specialized the cost structure to $C(\mathbf{q}) = \sum_{j=1}^{n_l} C_j(q_j)$. That is, we abstract in the following from cross-cost efficiencies, which would typically be very complex to trace in partial mergers.

First-order conditions with respect to commodity i are given by

$$P_i \left(\mathbf{q} \right) - c_i \left(q_i \right) + \sum_{j=1}^{n_l} \varphi_{ij} \frac{\partial P_j}{\partial q_i} q_j = 0, \text{ for } i = 1, \ldots, n_l,$$

which in matrix notation can be written as

$$\mathbf{p}^{(n_l)} + \mathbf{\Phi}_0 \bullet \mathbf{P} \mathbf{q}^{(n_l)} - \mathbf{c}^{(n_l)} = \mathbf{0},$$

[17] More examples are discussed in O'Brien and Salop (2000).

where $\bullet$ corresponds to the *Hadamard* product.[18] Post-partial acquisition, that is, with the interest-weight structure changed from $\mathbf{\Phi}_0$ to $\mathbf{\Phi}_1$, the *status quo* $(\mathbf{p}, \mathbf{q})$ is obtained if

$$\mathbf{p}^{(n_l)} + \mathbf{\Phi}_1 \bullet \mathbf{P}\mathbf{q}^{(n_l)} - \widetilde{\mathbf{c}}^{(n_l)} = \mathbf{0}.$$

Therefore, the unique absolute CMCRs read

$$\triangle \mathbf{c}_C = \left(\mathbf{p}^{(n_l)} - \widetilde{\mathbf{c}}^{(n_l)}\right) - \left(\mathbf{p}^{(n_l)} - \mathbf{c}^{(n_l)}\right) = \left(\mathbf{\Phi}_0 - \mathbf{\Phi}_1\right) \bullet \mathbf{P}\mathbf{q}^{(n_l)}. \tag{3.17}$$

If firms compete in prices, the analogous problem is firm i maximizing profits with respect to p_i. That is,

$$\max_{p_i} \sum_{j=1}^{n_l} \varphi_{ij} \left(p_j Q_j(\mathbf{p}) - C_j\left(Q_j(\mathbf{p})\right)\right), \tag{3.18}$$

which returns first-order conditions

$$Q_i(\mathbf{p}) + \sum_{j=1}^{n_l} \varphi_{ij} \left(p_j - c_j(q_j)\right) \frac{\partial Q_j}{\partial p_i} = 0,$$

or

$$\mathbf{q}^{(n_l)} + \mathbf{\Phi}_0 \bullet \mathbf{Q}\left(\mathbf{p}^{(n_l)} - \mathbf{c}^{(n_l)}\right) = \mathbf{0}.$$

Comparing these to the corresponding first-order conditions after the change in ownership structure at *status quo* quantities and prices,

$$\mathbf{q}^{(n_l)} + \mathbf{\Phi}_1 \bullet \mathbf{Q}\left(\mathbf{p}^{(n_l)} - \mathbf{c}^{(n_l)}\right) = \mathbf{0},$$

the unique absolute CMCRs are found to be

$$\triangle \mathbf{c}_B = \left(\mathbf{p}^{(n_l)} - \widetilde{\mathbf{c}}^{(n_l)}\right) - \left(\mathbf{p}^{(n_l)} - \mathbf{c}^{(n_l)}\right) = \left(\left(\mathbf{\Phi}_0 \bullet \mathbf{Q}\right)^{-1} - \left(\mathbf{\Phi}_1 \bullet \mathbf{Q}\right)^{-1}\right) \mathbf{q}^{(n_l)}. \tag{3.19}$$

Note that equations (3.9) and (3.14) are special cases of equation (3.17) and (3.19), respectively, for appropriately chosen $\mathbf{\Phi}_0$ and $\mathbf{\Phi}_1$.

3.3 The Werden-Froeb-Index

The generalized CMCRs characterized above are commodity-specific and may vary considerably over the products involved in the merger. In complex mergers between multi-product firms with commodities being produced in varying volumes, it is not straightforward to assess these series of individual values. For practical application of the concept in merger control, the Werden-Froeb-Index collects the different CMCRs into an average required marginal cost

[18] The Hadamard, or entry-wise, product $\mathbf{A} \bullet \mathbf{B}$ of two $m_1 \times m_2$ matrices $\mathbf{A}$ and $\mathbf{B}$ gives an $m_1 \times m_2$ matrix for which the (i, j)-element is given by $a_{ij} b_{ij}$.

savings. We define the WFI as

$$WFI = \frac{\sum_{i=1}^{n_l} q_i \triangle c_i}{\sum_{i=1}^{n_l} q_i c_i} = \frac{\triangle \mathbf{c} \cdot \mathbf{q}^{(n_l)}}{\mathbf{c} \cdot \mathbf{q}^{(n_l)}}, \tag{3.20}$$

that is, as the sum of CMCRs, each weighted by the quantity produced, divided by the sum of the product of marginal costs and quantity.[19]

The WFI summarizes the generalized CMCRs in a single statistic by weighing those required efficiencies that need to materialize on the products that have a larger share in total production more than on less important products. It gives an idea of how much more cost efficient the merged firm must produce after the merger for its merger-specific efficiency gains to overcome the merger's unilateral effects. The WFI can be thought of as the average percentage of cost savings required to replicate the pre-merger market outcome.

This interpretation is most fitting if firms have constant marginal costs, since the denominator of definition (3.20) would then be exactly equal to total variable costs. For more general costs of production, the WFI should be interpreted with caution. If marginal costs in- or decrease steeply away from the pre-merger equilibrium, it may be that, even though the minimally required cost reductions on the marginal units at the *status quo* equilibrium are small, multiplied by the total volume they appear large in the WFI. The other way around, parties could have credible evidence of sizeable variable cost reductions that nevertheless have little effect on the marginal cost of the final units produced in the pre-merger equilibrium. The WFI would underestimate such efficiencies.

Using the generalized CMCRs derived above for the case of Cournot and Bertrand competition, the WFI specializes to the following two measures. When firms compete in quantities:

$$WFI_C = \frac{(\mathbf{P}_0 - \mathbf{P}_1)\,\mathbf{q}^{(n_l)} \cdot \mathbf{q}^{(n_l)}}{\mathbf{c} \cdot \mathbf{q}^{(n_l)}} = \frac{\left(\mathbf{q}^{(n_l)}\right)^T (\mathbf{P}_0 - \mathbf{P}_1)^T \mathbf{q}^{(n_l)}}{\mathbf{c} \cdot \mathbf{q}^{(n_l)}},$$

with, using equations (3.17), $\mathbf{P}_0 = \mathbf{\Phi}_0 \bullet \mathbf{P}$ and $\mathbf{P}_1 = \mathbf{\Phi}_1 \bullet \mathbf{P}$, in case of partial acquisitions.[20]

[19] Alternatively, the CMCRs can be weighted by the merger-involved commodities' share in revenue. The behavior of the thus defined index is very similar to the WFI, but is both less natural and not so convenient to apply.

[20] Note that in the case of a single homogenous commodity market

$$WFI_C = \frac{\sum_{i=1}^{l} \triangle c_i q_i}{\sum_{i=1}^{l} c_i q_i} = -\frac{2P'(\mathbf{q}) \sum_{i=1}^{l} \sum_{j=i+1}^{l} q_i q_j}{P(\mathbf{q}) \sum_{i=1}^{l} q_i + P'(\mathbf{q}) \sum_{i=1}^{l} q_i^2}.$$

which, with $\epsilon = -\frac{p}{Q}\frac{\partial Q}{\partial p}$ and $s_i = \frac{q_i}{Q}$, reduces to

$$WFI_C = \frac{2\sum_{i=1}^{l} \sum_{j=i+1}^{l} s_i s_j}{\epsilon \sum_{i=1}^{l} s_i - \sum_{i=1}^{l} s_i^2} = \frac{2 s_j s_k}{\epsilon (s_j + s_k) - \left(s_j^2 + s_k^2\right)},$$

for two merging products j and k. This is exactly "the proportionate reduction in marginal cost necessary to restore the pre-merger price", or equation (4), in Froeb and Werden (1998), p.368.

When competition is in prices:

$$WFI_B = \frac{\left(\mathbf{Q}_0^{-1} - \mathbf{Q}_1^{-1}\right)\mathbf{q}^{(n_l)} \cdot \mathbf{q}^{(n_l)}}{\mathbf{c} \cdot \mathbf{q}^{(n_l)}} = \frac{\left(\mathbf{q}^{(n_l)}\right)^T \left(\mathbf{Q}_0^{-1} - \mathbf{Q}_1^{-1}\right)^T \mathbf{q}^{(n_l)}}{\mathbf{c} \cdot \mathbf{q}^{(n_l)}},$$

in which to replace, using equations (3.19), $\mathbf{Q}_0 = \mathbf{\Phi}_0 \bullet \mathbf{Q}$ and $\mathbf{Q}_1 = \mathbf{\Phi}_1 \bullet \mathbf{Q}$ in case of partial acquisitions.

Since the CMCR values are unique, and pre-merger sales volumes are given, note that the value of the WFI for each type of competition is unique. The relationship between WFI_C and WFI_B values for otherwise identical mergers is not generally uniquely determined. It is essential, therefore, to correctly classify the type of competition in the market under investigation. The two measures are strongly correlated, however, in the numerical examples of common merger discussed below.

The WFI furthermore satisfies several natural axioms regarding proportionality and commensurability. If all relative CMCRs, $\frac{\triangle c_i}{c_i}$, are identical, then the WFI is equal to this relative required reduction. The WFI is independent of the unit of measurement of marginal costs (dollars or euros) or output (pounds or kilos, gallons or liters), as these divide out. The index is determinate in marginal costs and quantities. Finally, the WFI deals quite naturally with required efficiencies that are so large that post-merger production costs would need to fall below zero, since in the event that $\triangle c_i > c_i$, the value of the WFI is high.

3.4 Information Requirements

The WFI is a local measure and therefore independent of the specific functional forms of market demand and cost of production. By construction the measure does not require any information on the products that remain outside the merger. The reason for this is that conserving the *status quo* for the merging firms implies that none of the rivals that remain outside the merger has an incentive to change its price and production strategies. With the outside product volumes and prices as a given, the merging firms behavior depends only on their own choice variables. Furthermore, the WFI is based on measurements taken in the pre-merger equilibrium. Calculating the index therefore only requires local information on the products involved in the proposed merger at the pre-merger market equilibrium.

More specifically, apart from the proposed changes in ownership and control, the following information is required: the quantities of the products offered by the firms involved in the merger prior to the merger ($\mathbf{q}^{(n_l)}$); their sales prices ($\mathbf{p}^{(n_l)}$); and the matrix of the affected commodities' quantity-effects ($\mathbf{P}_1$ in the case of Cournot competition) or price-effects ($\mathbf{Q}_1$ in the case of Bertrand competition), evaluated at the pre-merger market equilibrium. Matrices $\mathbf{P}_0$ and $\mathbf{Q}_0$ follow straightforwardly from $\mathbf{P}_1$ and $\mathbf{Q}_1$ by setting all appropriate elements equal to zero.

The denominator of the index uses the marginal cost of production. It is not necessary to separately obtain this information, however, as the marginal costs of production are implied by the first-order conditions (3.8) for Cournot competition and (3.13) for Bertrand competition. The different marginal production cost levels can therefore straightforwardly be recovered, given sales prices and traded volumes.[21] Although (variable) costs of production as stated by the parties could be used as a proxy for the base instead, firms may have an incentive to overstate pre-merger production costs in an attempt to decrease the WFI value for their merger.[22]

It is common practice in merger control to obtain and evaluate demand elasticity matrices, rather than just the derivatives and cross-derivatives of (inverse) demand. Regular demand elasticities premultiply price over quantity by the partial derivative of demand with respect to price. The information on $\mathbf{Q}_1$ necessary to establish CMCRs in a market in Bertrand competition can therefore be recovered from standard demand elasticity information, using information on $\mathbf{q}^{(l)}$ and $\mathbf{p}^{(n_l)}$.[23] It is not equally straightforward to determine $\mathbf{P}_1$ on the basis of regular demand elasticities. That would require separate specific information on the 'inverse demand elasticities', which is not a common concept.[24]

Demand elasticities may be estimated econometrically on the basis of structural models. Often, however, they are set on the basis of surveys and questionnaires on (hypothetical) switching, marketing studies, and other documentary evidence. Moreover, certain proportionality assumptions may apply that allow to construct the full Jacobian from limited information. In Epstein and Rubinfeld (2001), for example, a full approximate demand-elasticity matrix is constructed using information on the firms' market share, the industry elasticity of demand plus one own-price elasticity, on the assumption that substitution between products is according to relative market shares. Such structural assumptions greatly reduce the number of parameters that needs to be estimated.

Alternatively, information may be available on diversion ratios, a concept advanced in Shapiro (1996) and Werden (1996). The diversion ratio d_{ji} measures the fraction of the lost

[21] This is identical to using the Lerner-index for this purpose. See Dansby and Willig (1979).

[22] Alternatively, if there is some indication of pre-merger marginal costs levels, the mode of competition (Cournot of Bertrand) could be derived from first-order conditions (7) and (11).

[23] That is, given the $n \times n$ elasticity-matrix

$$\mathbf{\Omega} = \begin{pmatrix} \varepsilon_{11} & \varepsilon_{12} & \cdots & \varepsilon_{1n} \\ \varepsilon_{21} & \varepsilon_{22} & & \\ \vdots & & \ddots & \\ \varepsilon_{n1} & & & \varepsilon_{nn} \end{pmatrix},$$

where

$$\varepsilon_{ij} = \frac{\partial q_i}{\partial p_j} \frac{p_j}{q_i},$$

and given prices $\mathbf{p} = (p_1, \ldots, p_n)$ and quantities $\mathbf{q} = (q_1, \ldots, q_n)$, the matrix of price-effects $\mathbf{Q}$ can be recovered as

$$\mathbf{Q}^T = D(\mathbf{q})\, \mathbf{\Omega}\, [D(\mathbf{p})]^{-1},$$

where $D(\mathbf{q})$ and $D(\mathbf{p})$ are diagonal matrices, in which the (i,i)th element is q_i or p_i, respectively.

[24] Alternatively, information may be available on either the full $n \times n$ Jacobian matrix of price-effects or the full $n \times n$ Jacobian matrix of quantity-effects. In that case, the one follows directly as the inverse of the other. In most instances, only a small subset of price- or quantity effects in the relevant market is necessary to compute the WFI. Section 3.4 offers some discussion on mergers in which this may not be the case.

output of product i that is taken up by product j when the price of product i increases as

$$d_{ji} = -\frac{\varepsilon_{ji} q_j}{\varepsilon_{ii} q_i} = -\frac{\frac{\partial Q_j}{\partial p_i}}{\frac{\partial Q_i}{\partial p_i}}.$$

The WFI can straightforwardly be formulated in terms of diversion ratios. Define the $n \times n$ matrix of diversion ratios as

$$\mathbf{D} = \begin{pmatrix} -1 & d_{21} & \dots & d_{n1} \\ d_{12} & -1 & & d_{n2} \\ & & \ddots & \\ d_{1n} & d_{2n} & & -1 \end{pmatrix}.$$

Furthermore, let $\mathbf{Q}$ be the $n \times n$ matrix with $\frac{\partial Q_j}{\partial p_i}$ as its (i,j)'th element and let $\mathbf{Q}_D$ be a $n \times n$ diagonal matrix with $\frac{\partial Q_i}{\partial p_i}$ as its i'th diagonal element. Let $\mathbf{D}_1$ ($\mathbf{Q}_D^{(n_l)}$) be the $n_l \times n_l$ (diagonal) matrix consisting of the first n_l rows and columns of $\mathbf{D}$ ($\mathbf{Q}_D$). Finally, let $\mathbf{D}_0$ be a $n_l \times n_l$ matrix with its (i,j)'th element equal to d_{ji} if product i and j are produced by the same firm pre-merger and zero otherwise. We then have

$$\mathbf{D} = -\mathbf{Q}_D^{-1}\mathbf{Q} \text{ or } \mathbf{Q} = -\mathbf{Q}_D\mathbf{D},$$

and similarly $\mathbf{Q}_1 = -\mathbf{Q}_D^{(n_l)}\mathbf{D}_1$ and $\mathbf{Q}_0 = -\mathbf{Q}_D^{(n_l)}\mathbf{D}_0$.

The CMCRs for the case of Bertrand competition can now be expressed in terms of diversion ratios as[25]

$$\triangle\mathbf{c}_B = \left(\mathbf{Q}_0^{-1} - \mathbf{Q}_1^{-1}\right)\mathbf{q}^{(n_l)} = \left(\mathbf{D}_1^{-1} - \mathbf{D}_0^{-1}\right)\left(\mathbf{Q}_D^{(n_l)}\right)^{-1}\mathbf{q}^{(n_l)}.$$

For CMCRs in Cournot competition, the matrix $\mathbf{Q}_D$ and the full matrix of diversion ratios $\mathbf{D}$ are required. Using $\mathbf{PQ} = \mathbf{I}$ and $\mathbf{D} = \mathbf{Q}_D^{-1}\mathbf{Q}$ we find that $\mathbf{P} = \mathbf{D}^{-1}\mathbf{Q}_D^{-1}$. From this, the matrices $\mathbf{P}_1$ and $\mathbf{P}_0$ as defined above follow, so that $\triangle\mathbf{c}_C$ can be determined. Hence, the WFI's can also be calculated from the matrix of diversion ratio's and the own price elasticities of demand of the products involved in the merger.

3.5 The WFI in Merger Control

The WFI has a number of benefits for application in merger control. Apart from its relatively low information requirements, the index provides a well-defined single statistic that can supplement established market concentration analyses. In their assessments of horizontal mergers, competition authorities have committed to the use of the Hirschman-Herfindahl-

[25]Note that if all merging firms produce only one commodity prior to the merger, we have $\mathbf{D}_0 = -\mathbf{I}$, where $\mathbf{I}$ is the $n_l \times n_l$ identity matrix, and compensating marginal cost reductions reduce to $\triangle\mathbf{c}_B = \left(\mathbf{I} + \mathbf{D}_1^{-1}\right)\left(\mathbf{Q}_D^{(n_l)}\right)^{-1}\mathbf{q}^{(n_l)}$.

index (HHI) as a measure of market concentration. Merger regulations and guidelines in both the US and the EU specify threshold values of the HHI for the purpose of self-assessment. As long as the combination of the absolute value of the HHI and the change in its value, ΔHHI, remains below specified critical values, it is unlikely that competition authorities will find horizontal competition concerns.[26] Only if either of these measures, or both, surpass the thresholds is the merger referred to a deeper Phase II investigation.

The use of the HHI for the purpose of assessing whether a merger can be expected to lead to a "substantial lessening" or "significant impediment" of effective competition is not without problems, however. The measure can be deceptively straightforward and miss the competitive discipline of potential entrants, for example, or rivals in bidding markets. The HHI does not discriminate perfectly between detrimental and socially desirable mergers. In particular, HHI analysis is of little assistance in assessing merger-specific efficiency gains. Instead, efficiencies only come into consideration in a full and costly Phase II inquiry. It is presently difficult, therefore, for firms to self-assess their possibilities for a successful efficiency defense. The WFI can supplement merger control by providing guidance in this. The index can be used to extend the *de minimus* doctrine to include efficiency claims, along the following lines.

As a matter of standard procedure, firms could be required to submit the value(s) of the WFI(s) for their proposed merger—along with documented calculations.[27] This could be either directly with the notification of the horizontal merger for the purpose of an initial Phase I investigation, or, if this is impractical because of time or information constraints, in an early stage of a Phase II investigation if the merger is referred. The submitted value complements the more general argumentation that efficiency gains can indeed be expected to materialize as a result of the merger. The burden of proof therefore remains on the parties proposing the merger. The validity of the submitted analysis is to be assessed by the competition authorities and can be challenged.

The merger guidelines would specify threshold values of the WFI, possibly in combination with critical HHI values. If the WFI of the merger remains below this threshold, the merger would in principle be allowed, even when it does raise competition concerns. That is, a sufficiently low (and credible) WFI value can compensate an HHI or ΔHHI value over and above the safe-haven thresholds. A (deeper) Phase II investigation will only be initiated if compensating cost reductions higher than the thresholds are necessary to overcome the anti-competitive effects of the merger. Alternatively, a second and upper-bound critical (Δ)HHI value may be specified, such that the merger is automatically referred to a full Phase II inquiry when it surpasses this upper-bound threshold, irrespective of the WFI value, but not

[26]In the US, this is formally so for all mergers for which the HHI remains below 1000 and all for which ΔHHI remain below 50, as well as for any combination of HHI, ΔHHI below 1800 and 100—see Section 1.5 of US Department of Justice and US Federal Trade Commission (1997). In the EU, critical values are HHI=1000, ΔHHI=150, and combinations below 2000 and 250—see paragraphs 19 and 20 of European Commission (2004b). In practice, a cruder criterion may apply, distinguishing between so-called '4 to 3' and '3 to 2' mergers.

[27]Appendix *A* provides an algorithm in MATLAB for this purpose. See http://wfi.acle.nl for a user-friendly online version.

for values below.

What the proper threshold values for the WFI in future horizontal merger guidelines should be is a policy matter—no different in principle from the specification of the present HHI safe-haven boundaries. It is difficult to say what would be reasonable to ask. Perhaps anything below 5% is acceptably low, or maybe 10%. One possible way to substantiate a threshold departs from the following observation. In the past two decades of merger control, a number of mergers initially challenged were eventually cleared after a Phase II investigation or by a court inquiry–with or without divestitures. Apparently, despite raising competition concerns, these mergers satisfied an implicit standard of merger-specific benefits. Using these past decisions, the implied value of the WFI could be backed out to provide some guidance in this policy matter. Although in principle possible, we have so far not been able to compile a complete data set of sufficiently many cases to do this robustly. We leave the idea for further research.

To illustrate the proposed application of the WFI and its power in supplementing HHI analysis, consider a hypothetical representative pre-merger market in which eight firms compete, each producing a single commodity. Table 1 specifies regular prices, quantities and demand elasticities of each of these commodities.[28] These eight substitute products together constitute a relevant market by a 10% SSNIP-test in the numbered order.[29] The HHI and the WFI are defined, therefore, over exactly the same set of commodities.

#	Price	Volume	1	2	3	4	5	6	7	8
1	400	36.0	-1.500	0.010	0.001	0.150	0.045	0.020	0.125	0.425
2	450	15.0	0.001	-1.500	0.005	0.211	0.061	0.015	0.110	0.425
3	410	100.6	0.050	0.020	-2.900	0.020	0.090	0.100	0.100	0.200
4	483	25.7	0.230	0.095	0.001	-1.500	0.045	0.013	0.201	0.415
5	375	33.1	0.085	0.029	0.006	0.050	-2.400	0.035	0.010	0.515
6	390	10.0	0.010	0.010	0.300	0.100	0.100	-3.300	0.200	0.100
7	365	93.6	0.085	0.035	0.150	0.065	0.010	0.100	-2.450	0.100
8	400	161.8	0.045	0.015	0.300	0.036	0.065	0.035	0.100	-1.400

Table 3.1: Prices, Sales Volumes (in thousands) and Elasticities in representative relevant Market.

Suppose the market is in Bertrand competition. Between the eight firms, there are twenty-eight different complete two-party mergers possible. For all these potential combinations, Figure 1 plots the WFI_B versus ΔHHI.[30] Two vertical lines mark the lowest threshold values of ΔHHI= 50 for US merger regulation, and ΔHHI= 150 for EU merger control. As

[28]The elasticity matrix is so defined that, for example, entry $(1, 2)$ represents the elasticity of the demand for commodity 1 with respect to changes in the price of commodity 2, that is, $\epsilon_{12} = \frac{\partial q_1}{\partial p_2}\frac{p_2}{q_1} = 0.01$.

[29]These values are constructed, but they were inspired by an actual merger. They are consistent with structural model specifications. If competition is in prices, the (rounded) implied marginal costs are $133, 150, 161, 219, 216, 114, 269, 272$, respectively. If competition is in quantities, these values are $117, 144, 138, 210, 208, 92, 264, 271$, respectively.

[30]These examples are generic in the sense that the qualitative effects are robust to small but significant changes in the underlying data. The reader is invited to work with the example, or any other set of merger data, using the MATLAB routine in Appendix *A*.

explained above, below these values, mergers are likely not to be challenged, independent of their absolute HHI value. A potential threshold value for the WFI_B is drawn in at 10%.

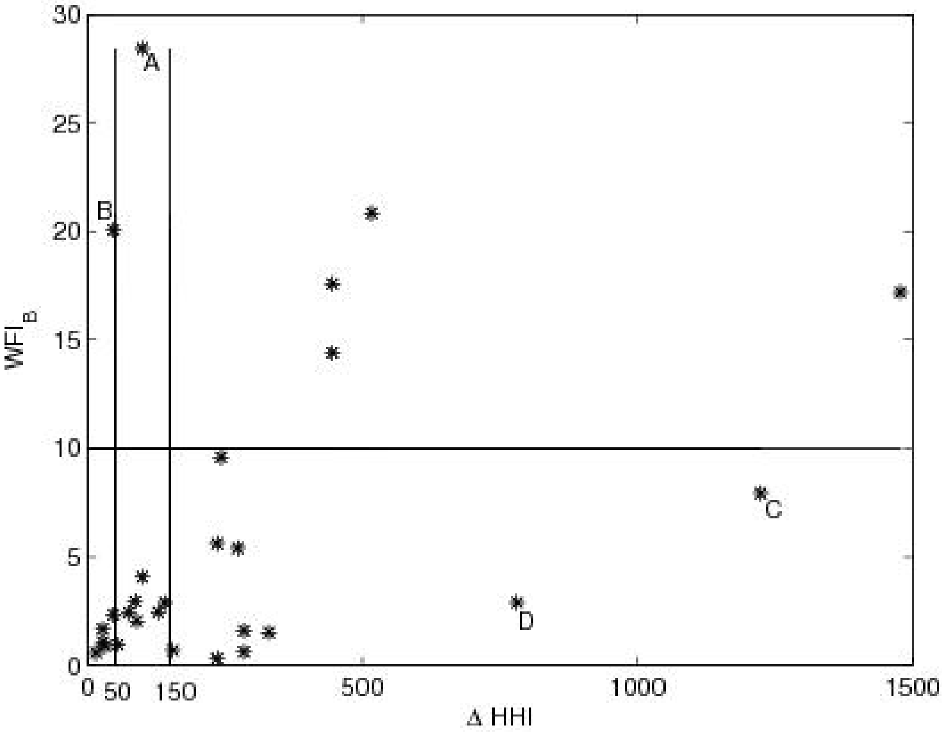

Figure 3.1: WFI_B versus ΔHHI for representative Mergers.

Figure 3.1 reiterates the weak relationship between CMCRs and HHI or ΔHHI also pointed out by Werden and Froeb in their papers. The mergers that are grouped in the lower-left corner of the figure remain below the EU and/or US threshold values for ΔHHI and require only relatively low efficiency gains as measured by the WFI_B. Allowing these mergers to be consummated on standard HHI assessment alone is in principle correct. Yet, a number of mergers involve high levels of either ΔHHI or WFI_B. Consider the merger labelled A in Figure 1, which is between firms 1 and 4, which are both relatively small with respective market shares of 7.6% and 6.5%. The HHI increases through this merger from 2114 to 2213, that is, ΔHHI= 99. The merger's WFI_B value is 28.4%. By relying on HHI-analysis alone, without quantifying efficiency gains, this merger would in principle pass European (albeit not US) merger control without remedies, even though it requires considerable merger specific efficiency gains to overcome its anticompetitive effects.

Merger B, as another example, has a ΔHHI= 47 and would therefore probably not be challenged in either jurisdiction. It is a merger of firm 2 with firm 4. Firm 2 has a market share of 3.6%, which is smaller than that of firm 1. In addition, the cross-price elasticity of firm 4's commodity with respect to the price of commodity 1 is roughly 2.5 times that of commodity 4 with respect to the price of commodity 2. As a result, the WFI_B is substantially lower, yet still as high as 20.1%, which may be too much to expect to materialize as a result of the merger. Relying only on standard HHI analysis, without a proper assessment of merger specific efficiencies, therefore poses a risk of Type II error, that is, of allowing a merger that should have been blocked from the point of view of consumer welfare.

An example of a merger with the opposite danger is merger C, which is between firms 7 (market share: 18%) and 8 (market share: 34.1%). Here, the HHI increases to 3339, that is ΔHHI $= 1225$, as a result of the substantial market shares of the two firms involved in the merger. Yet, $WFI_B = 7.9\%$. Even though the merger would certainly be challenged, trigger an in-depth investigation, and quite possibly be blocked under both European and US merger regulations, the efficiencies minimally needed for this merger to be welfare enhancing are relatively low. Therefore, Phase II investigation costs could be saved if our proposal to include WFI analysis in merger regulation would be adopted. Indeed, supplementing merger control with WFI analysis has the largest potential for saving on enforcement costs in this category. Mergers that stay below a set WFI threshold value and an additional ΔHHI threshold (e.g. ΔHHI$= 250$) need then not enter into a (deeper) Phase II investigation, whereas they would under the present merger criteria.[31]

If the market above were in Cournot competition instead, a series of WFI_C-values for all different combinations of two firms merging follows. This series is strongly correlated with that of the WFI_B-values, with correlation coefficient $\rho = 0.98$. All WFI_C-values are higher than the WFI_B-values. This reflects the fact that, with the same level of product differentiation, quantity competition typically leads to higher prices and profits across the board than price competition.[32] The anticompetitive effects of mergers in Cournot competition are often larger than in Bertrand competition, other things equal, so that greater efficiencies are required to compensate them.

The relationship between WFI_B and WFI_C does not generalize straightforwardly, however, as can be seen from the case of a merger to monopoly. In this case the WFI_C is always strictly lower than the WFI_B. The reason for this is that the post-merger equilibrium is identical for both types of competition, so that more efficiencies are required to restore pre-merger equilibrium in Bertrand competition than in Cournot competition. The same four examples of mergers with low (high) ΔHHIs and high (low) WFI values discussed above are valid in Cournot competition, however—albeit that merger C with $WFI_C = 12.9\%$ is above the threshold value of 10%. Although it remains important for the interpretation of the Werden-Froeb-index to properly classify the nature of competition in the market analyzed, the qualitative insights obtained with the Werden-Froeb-index are often comparable.

All the above examples are full mergers between two firms. Partial acquisitions typically imply lower WFI values. Note that the WFI can therefore in principle be used to explore the allowable limits of partial acquisitions. That is, given a set threshold WFI value for which a partial acquisition can in principle be cleared, it is possible to design that partially

[31]This second ΔHHI threshold value would have to be established on the basis of systematic research. Note also that, at a threshold WFI-value of 5%, there remains a Type II error candidate: merger D between firms 7 (18%) and 3 $(21,7\%)$, which returns a ΔHHI$= 781$, yet the $WFI_B = 2.9\%$.

[32]See Hathaway and Rickard (1979).

integrated ownership and control structure that just meets that critical value. Analogously, the WFI can advise on divestitures. If a full merger would imply a prohibitively high value of the WFI, parties or the agency can propose to sell part of their business to an extent that is tailored to the WFI threshold. In fact, the WFI for partial acquisitions will typically allow for determining a whole range of interest-weight matrix changes that just meet any given efficiency requirement. Any one of these combinations of financial interest and corporate control would in principle take away the competition concerns in divestment negotiations with the competition authorities.

The described use of the WFI in merger control has a number of benefits. The WFI is an exact and well-defined measure that requires information that can be collected in the market as it is relatively straightforwardly. The measure is easy to interpret and standardizes the submission of evidence for an efficiency defense. As a single statistic, the index can be published without publicly revealing the underlying data, which are often confidential.[33] The WFI is independent of the functional form of demand and costs, and not as sensitive to other model specifics as merger simulation analyses often are. It does not rely on costs as reported by the parties.

These characteristics greatly reduce the possibilities for presenting overly rosy efficiency claims. The minimally required efficiencies are compared to a fixed target that is specified in the guidelines. Firms are not asked to argue specific efficiencies in relation to their merger.[34] In fact, the WFI is best be thought of a measure of anticompetitive effects, rather than of efficiencies. As a result, the proposed use of the WFI can avoid excessive lobbying, complex and expensive litigation and administrative procedures.

It is nevertheless important to understand the limitations of the WFI in order to carefully use the index in merger control. To begin with, the merging parties may try to manipulate the WFI downwardly. Like all standardized tests, the WFI can be tricked when applied unintelligibly. Notifying firms can attempt to manipulate the matrix with estimates of quantity- or price-effects. By overstating their own-elasticities and understating the cross-elasticities between the products involved in the merger, firms give the impression of more competition for their products generally, and less competition between the commodities involved in the merger. As this reduces the anticompetitive effects of the merger, the WFI value will be lower.

In addition, it is important to carefully interpret the WFI in mergers in which not all of the commodities involved in the merger are in the same relevant market. In such mergers, efficiencies in other markets may importantly influence the WFI value. To see this, consider a

[33]In some cases, for example when there are relatively few products involved in the merger, the proposed weighted sum of CMCRs may be less informative than the vector of individual CMCR values. Still, in order to make an assessment of the relative value of each CMCR, some measure of their relative weight is required. The output of our software separately reports each product's absolute CMCR value, as well as the implied pre-merger marginal cost of production, with each price-quantity combination.

[34]Note that any claimed actual merger-specific variable cost savings do not obviously compare to the CMCRs or the WFI, because the actual savings will change the post-merger equilibrium—unless they are all exactly equal to the CMCRs. Instead, a full post-merger equilibrium analysis would be required to assess the welfare effects of (claimed) actual efficiencies.

merger between two firms. The first firm produces a number of substitutes and complements to the products of the second firm. Let the substitutes all be in the same relevant market. The CMCRs of those products are positive. However, for the complement commodities of the first firm, the CMCRs will typically be negative and therefore decrease the WFI-value of the merger. This is in line with the efficiency defense, which allows merger-specific marginal cost efficiencies on all products to be counted. Furthermore, cost savings on complements are good for welfare. It is nevertheless important to realize that the WFI is a (merged) firm-specific measure, whereas the HHI is a (relevant) market measure.

Focussing on the *status quo* market equilibrium, rather than actual post-merger equilibrium, implies that a WFI screen as suggested is open to enforcement errors of both Type I and Type II. These relate to the more global efficiency effects of mergers that the WFI abstracts from, discussed above. When cost functions in- or decrease steeply away from the pre-merger equilibrium, consumer prices in the post-merger equilibrium may be higher than without the merger, despite materialized efficiency gains that meet the WFI. Likewise, local efficiencies may be much higher than globally required under certain special structures of the market.[35] In addition, as discussed above the measure does not take efficient reallocations of production into account, nor possible increases in product variety and fixed cost synergies. It furthermore ignored possible long-term benefits that may result from the pooled IPRs and product R&D efforts of the merging firms. For these reasons, the WFI is likely to overestimate the truly required marginal cost reductions that compensate consumers for the anticompetitive effects of the merger.[36]

Mechanical application of the WFI can lead to a false assessment of mergers in which the above mentioned aspects are important. Only if the local characteristics of the pre-merger equilibrium are a good enough approximation of the relevant global market structure around the merger, is the proposed WFI analysis reliable. Hence, care should be taken in the assessment of mergers that are expected to lead to large shifts in production in and across plants. In such mergers, relatively small claimed efficiencies on variable costs may affect the post-merger equilibrium enough to compensate the antitrust concerns, even when the WFI for the merger comes in quite large. Our proposal to apply the WFI firstly as a screen to (deeper) Phase II investigations partly remedies these problems, as it will be an upper-bound requirement that is biased towards the error of referring mergers to a (deeper) Phase II investigation that will eventually be cleared on efficiency grounds.

Finally, the definitions above assume a clean competitive model pre- and post-merger, whereas in real markets there are such problems as imperfect and asymmetric information, various degrees of buyer power, (tacit) collusion and coordinated effects. As a result, it may not be obvious to classify competition as either of the Bertrand or Cournot type. Calculating

[35] Alternative approaches, such as the Price-Pressure-index (PPI) developed in O'Brien and Salop (2000), could perform better in such circumstances. Obviously, they require considerably more structure and information.

[36] This is conceptually comparable to the Laspeyres price index overestimating the true-cost-of-living index. See Fisher and Shell (1998), Chapter 2.

the implied equilibrium costs picks up some of these effects, but certainly not in a structurally identifiable way. The approach furthermore abstracts from post-merger entry and exit, the possibility of a failing firm defence, and monopolization strategies by sequential acquisition. Where it is clear that the models underlying the WFI do fundamentally not apply to the market, the index should be interpreted with caution.

3.6 Concluding Remarks

The stakes in merger control are high and merit a full weighing of all the likely consequences of notified mergers and (partial) acquisitions before deciding to clear, modify or block them. Even more so than a merger's effects on competition, merger-specific efficiencies claimed by the merging parties are hard to substantiate and difficult for the authorities to verify. The WFI assists in this assessment. The measure trades off concentration and efficiency effects, and asks what average percentage of output-weighted marginal cost savings need minimally materialize as a result of the merger to compensate consumers for the merger's anticompetitive effects. If the WFI is low, the burden of proof on the proponents of the merger can be lower than when considerable compensating efficiencies are required. A threshold value can be set, below which no extensive investigation is required. The WFI is a point measure that is straightforward to implement, exact, informationally efficient, well-behaved and natural to interpret. It standardizes the efficiency defense in horizontal merger procedures.

The WFI is inherently based on the consumer welfare standard, which is the principle criterion for both US and EU competition policy.[37] If the compensating marginal cost reductions indeed materialize, consumer welfare will remain constant. The merging firms will be better off, producing at lower costs yet selling against the same prices as before. Therefore, total welfare increases by the total amount of cost savings—which is the numerator of the WFI—in the *status quo*.

An unambiguous *de facto* welfare analysis with the actual post-merger efficiencies is not obvious, however, since such comparative statics requires a structural model and global information on the market. Yet, presumably the merging firms would not integrate their businesses if they would not expect to profit from it.[38] Any merger-specific gains that will materialize over and above the minimally required levels are likely to lead to more output and lower consumer prices in the post-merger equilibrium. In addition, rivals that are not

[37] What the proper and actual objectives of competition policy are is a long-time subject of debate. Protection of competition as a process, for example, arguably includes a total welfare element in the US as well as Europe. The consumer welfare standard can be interpreted as a 'tough standard' commitment device for the agencies against the merging firms' strong lobby. See Neven and Roeller (2005). We thank a referee for pointing out that our proposed use of the WFI preempts an efficiency lobby, at least in Phase I, and may thus allow a total welfare standard. Note, however, that the WFI is conceptually exclusive to the consumer welfare standard.

[38] In Cournot competition, the intention to merge is indeed a signal that the parties expect cost-efficiencies—unless the merger is close or equal to a merger to monopoly. See Salant, Switzer and Reynolds (1983). Yet, in Bertrand-competition, anticompetitive effects may fully drive the merger. See Davidson and Deneckere (1985).

party to the merger typically benefit from the competition reducing effects of the merger. Although, therefore, it is possible to construct examples of post-merger markets in which this is not true, in general post-merger total welfare increases for sufficiently high values of the WFI.

Given that competition law enforcement is time-consuming and costly, the WFI can reliably enhance merger control by facilitating a standardized two-tier efficiency defense. Obviously, the proposed use of the WFI as a quick-screen in merger control does not relieve the competition authorities from their obligation to carefully review every merger. Bearing in mind its limitations, the Werden-Froeb-index can provide assistance in assessment and priority setting. It further gives legal guidance to self-assessment of efficiency arguments. This implies considerable potential for private and public savings in merger enforcement.

Chapter 4

Cartels: Theory and Evidence

4.1 Introduction

Collusion denotes agreements between firms that have the goal of increasing their respective profits by restricting competition. This can take place for example in the form of fixing prices or sharing the market. Collusion can be both explicit or tacit or a combination of the two. In explicit agreements, firms negotiate directly with one another. In tacit collusion, firms do not communicate directly but agree implicitly on a common conduct via which they can increase their profits. Tacit collusion can develop when firms interact repeatedly. They may then be able to maintain higher prices by tacitly agreeing that any deviation from the collusive path would trigger some form of punishment. In order to make an agreement sustainable, punishment must be sufficiently likely and costly to outweigh the short-run benefits from cheating from the collusive path. These short-run benefits, as well as the size and probability of retaliation, depend in turn on the determinants of the industry. We therefore extend the concepts developed in Chapter 2 and Chapter 3 by introducing dynamic games in which the one-shot game is repeated a given number of times.

Static models of oligopoly introduced in Chapter 2 and Chapter 3 of this dissertation involve only a single period of play. We now focus on dynamic oligopoly models, in which firms are assumed to interact repeatedly over time. It is necessary to introduce repeated games in this chapter in order to explain how collusion can arise as the collusive equilibrium is not a Nash-equilibrium of the one-shot games we introduced in Chapter 2. When the games are repeated however, it is possible to show that the collusive outcome indeed may become an equilibrium outcome. Intuitively, as the game is repeated infinitely many times, collusion can be established whenever players use the right punishment mechanisms for deviating players. We will see that players will collude under these circumstances, whenever the profit made from colluding in the future is higher than defecting from the collusive agreement and being punished by the other firms thereafter.

An early contribution to dynamic oligopoly models has been given by Chamberlin (1929). His findings indicated that in a market where a homogeneous good is produced, firms realize their interdependency and are therefore able to sustain the monopoly price. This form of collusion without explicit agreement, *tacit collusion*, was further developed and formalized by Friedman (1971) in his theory of supergames. Before discussing Friedman's theorem, we introduce some basic elements on the theory of repeated games. We then analyze the relationship between the number of firms in the market and the critical discount factor to sustain collusion.

The first part of the chapter adds to the game-theoretic concepts introduced in Chapter 2 and discusses the incentive structure of firms necessary to make collusion sustainable. The second part of the chapter, starting with Section 4.4, reviews some determinants of collusion. The discussion in this part of the chapter distinguishes between structural and behavioral determinants affecting cooperation and looks into factors such as entry conditions and demand conditions as well as transparency of a market and coordination. Chapter 5 will then provide an experimental study into these different effects.

4.2 Theory of Dynamic Games

4.2.1 Supergames

In this section, we introduce infinitely repeated games in which players repeatedly interact with each other. A primitive of a repeated game is called the *stage game* which denotes the game that is played in each period.[1] Assume that each stage game, e.g. the one-shot Bertrand or Cournot oligopoly game, consists of a simultaneous move game with a finite number of players given by I and an actions space given by A_i. Let $G = (A_1, ..A_n; u_1, .., u_n)$ denote a static game of complete information in which players simultaneously choose actions $a_1, .., a_n$ from the action space $A_1, .., A_n$ and payoffs for players are given by $u_1(a_1, .., a_n)$ to $u_n(a_1, .., a_n)$. An infinitely repeated game given by $G(\infty, \delta)$ is a game in which the stage game G is repeated forever and in which each firm has a common discount factor of $\delta \in (0, 1)$. The discount factor can be thought of as a rate of time preference. The closer δ gets to 1, the more patient a player is. Alternatively, it can also be interpreted as the continuation probability of a game. The lower δ, the higher the probability that the game stops at the end of each period.

A repeated game is defined by the action space of each player and by the respective payoff functions. In an infinitely repeated game a strategy for each player specifies the action the player will take in each stage game, for each possible history of actions in the preceding periods. The strategy space is therefore not identical to the action space as this is the case in the one-shot simultaneous move game. We assume that each player can observe the realized actions at the end of each stage before the next stage begins. Furthermore, the payoffs of each player in the infinitely repeated game are represented by the present value of the players' payoff from the infinite sequence of the stage game given by $\sum_{t=0}^{\infty} \delta^t u_{it}$. We normalize the payoffs $\sum_{t=0}^{\infty} \delta^t \pi_{it}$ by a factor $(1 - \delta)$ in order to measure the payoffs in the

[1] See Fudenberg and Tirole (1991) and Rubinstein and Osborne (1994).

repeated game in identical units of 1 util= 1 per period as we can then directly compare the discounted payoffs from the supergame to those in the stage game.

Note also that each stage begins with its proper subgame. Intuitively, a subgame is the part of the game which still needs to be played, which starts at a point where the complete history of the game so far is common knowledge to all players and which includes all the moves that follow that part in the original game. It is a notion used in the solution concept of subgame perfect Nash equilibrium and a refinement of the Nash equilibrium that eliminates non-credible threats. The key feature of a subgame is that it, when seen in isolation, constitutes a game in its own right. In the infinitely repeated game $G(\infty, \delta)$, each subgame starting in period $t+1$ is original to the entire game $G(\infty, \delta)$. There are as many subgames at for instance stage $t+1$ of $G(\infty, \delta)$, as there are possible histories of play until stage t. A Nash-equilibrium can then be defined as subgame perfect if the player's strategy constitute a Nash-equilibrium in each subgame. This also includes the subgames which are not reached when the equilibrium is played.

4.2.2 The Folk Theorem

In this section we explore the set of outcomes that can be supported as Nash equilibria in repeated games. We will show that in the infinitely repeated game, not only outcomes that constitute the repetitions of the equilibria of the stage game can be an equilibrium, but that the set of equilibria is much wider. In fact, a multitude of outcomes can be supported, given that players are prevented from deviating, which is enforced by means of a punishment mechanism. One can think of many different punishment mechanisms but one that is widely used in the economics literature are the so-called *trigger* strategies. Trigger strategies are strategies in which a player initially cooperates but punishes opponent players if a specific level of defection by these players (the so-called trigger) is observed. In the equilibria that are studied in this section this type of punishment mechanism is applied.

An informal example of how such a trigger mechanism can enforce cooperation among Bertrand oligopolists is given in the following. Imagine that there are two firms with identical technologies that play an infinitely repeated Bertrand game and set prices for a homogeneous good in each period simultaneously. Assume that both firms have the following strategy. In the first period, they charge the monopoly price and continue to do so in every following period, given that the other firm also charged the monopoly price in the preceding period. Otherwise, the firm sets a price equal to the marginal costs forever. These so-called *grim trigger* strategies punish a single deviation forever and put a stop to cooperation should one firm undercut the monopoly price. We show below that the strategy not to undercut the monopoly price and to collude forever constitutes a Nash equilibrium, for sufficiently patient firms. Friedman's results formalized the notion of tacit collusion. It is remarkable that collusion can be sustained in this manner through a purely non-cooperative mechanism. If firms collude, they receive the monopoly profit divided by the number of firms. If they defect, they gain the difference between the whole monopoly profit minus their usual cartel profit at the expense of merely getting the competitive profit in all future periods following deviation. As stated above, this is not the only equilibrium in this game. A range of outcomes can be supported given that the players are patient enough. Moreover, the equilibrium of the stage game also constitutes an equilibrium of the repeated game. In this case, each firm would simply ask a price equal to the marginal cost in each period.

Define the minimax value $\underline{v_i}$ as the lowest payoff the other players can inflict on player i, that is:

$$\underline{v_i} = \min_{\alpha_{-i}}[\max_{\alpha_i} u_i(\alpha_i, \alpha_{-i})] \tag{4.1}$$

Equation (4.1) is the lowest payoff with which the opponents of player i can punish him by any choice of α_{-i}, assuming that player i correctly predicts the actions of the other players and plays a best response to that. Let m^i_{-i} be a strategy for the other players that force the minimum of equation (4.1). m^i_{-i} is then the *minimax* profile against player i. Denote m^i_i as the profile of player i for which $u_i(m^i_i, m^i_{-i}) = v_i$. Note also that player i's payoff is at least $\underline{v_i}$ in the static equilibrium and it is also the payoff in any repeated Nash equilibrium of the repeated game, independent of the discount factor. $\underline{v_i}$ can therefore be interpreted as some lower bound on payoffs or reservation utility. Moreover, we assume that the set of payoffs $(u_1, .., u_I)$ is feasible in the stage game G if they are convex combinations of the pure strategy payoffs of G. The Folk Theorem can then be stated as:

Folk Theorem (Friedman): *Let G be a static game of complete information. Let α^* be a static Nash equilibrium with payoffs e_i. Then for any feasible payoff of G given by $v \in V$ with $v_i > \underline{v_i}$ for any players, there exists a $\underline{\delta} \in (0, 1)$ such that for all $\delta > \underline{\delta}$ there exists a subgame-perfect equilibrium $G(\infty, \delta)$ with average payoffs of v.*

The Folk Theorem in repeated games states that if players are patient enough, so for discount factors that are close to 1, any feasible payoff can be implemented as an equilibrium. Intuitively, when players are sufficiently patient any gain made from a one time deviation is compensated by the loss in utility in every future period after the defection period. With trigger strategies a player who defects will be punished forever after by other players playing the minimax strategy on him.

4.3 The Folk Theorem applied to the Cournot and Bertrand Oligopoly Model

Now that we have a general description of the Folk theorem, this section applies the concept to Cournot and Bertrand games with n firms that are infinitely repeated and in which firms employ grim trigger strategies. We thereby extend the analysis on static Bertrand and Cournot games developed in Chapter 2. We first present the collusive payoffs and the deviation payoffs in both models. More specifically, our approach in this section is to take a closer look into the relationship between the number of firms and collusion within the framework of these oligopoly models. In particular, we solve for the critical discount factor to sustain collusion for a given number of firms. As before, we assume that firms use grim trigger strategies. The discount factor δ is then the lower bound of the range of discount factors over which a trigger strategy will support non-cooperative joint profit maximization.

We discuss the Bertrand and Cournot game as introduced in Chapter 2 in which we assume that the number of firms in the market is given by n. Recall that as in Sections 2.2.1 and 2.2.2, we assume that the n firms in the market each produce their own variety at constant marginal costs of c and that they face a linear demand given by (2.2.3). Firms play an infinitely repeated game where they can either play the Nash solution, collude or deviate from a collusive agreement. We then do comparative statics on the discount factor.

We will first solve for the prices, quantities and profits when firms collude and when firms deviate. In Sections 4.3.1 and 4.3.2 we will calculate the critical discount factor to sustain collusion both for Bertrand and Cournot, and analyze how it changes with the number of firms in the market.

4.3.1 The Perfectly Collusive Outcome

In the collusive outcome, firms act as a single entity, jointly maximizing overall profits. We assume perfect collusion, so that firms are able to reproduce the monopoly outcome. Again, products are differentiated and each firm is producing a single variety. Firms share the monopoly profits equally so the profit per firm is simply the monopoly profit divided by the number of firms n. The results are identical whether firms maximize over prices or over quantities. If they are maximizing over quantities, the joint objective function is given by:

$$\max_{q_1,..,q_n} (p_1 - c)q_1 + (p_2 - c)q_2 + .. + (p_n - c)q_n.$$

Using the demand function in (2.2.3) it follows that:

$$\begin{aligned}
a - c - 2bq_1 - b\theta \sum_{i \neq 1} q_i + (n-1)q_1 &= 0 \\
a - c - 2bq_2 - b\theta \sum_{i \neq 2} q_i + (n-1)q_2 &= 0 \\
&\vdots \\
a - c - 2bq_n - b\theta \sum_{i \neq q_n} q_i + (n-1)q_n &= 0.
\end{aligned}$$

The symmetric solution can then be solved to be:

$$q_i^{coll} = \frac{(a-c)}{2b(1+\theta(n-1))}, \tag{4.2}$$

$$p_i^{coll} = \frac{a+c}{2}. \tag{4.3}$$

$$\pi_i^{coll} = \frac{1}{4b}\left(\frac{(a-c)^2}{1+\theta(n-1)}\right), \tag{4.4}$$

where the superscript $'coll'$ indicates the collusive outcome. In the following section, we compute the payoffs if a firm deviates from this collusive solution.

4.3.2 Cheating by Firms: Deviation from Perfect Collusion

If a firm deviates in a given period, it gains the difference between deviation profits and collusive profits in the period it deviates and thereafter only gains a per-period profit equal to the profit in the Nash equilibrium. We now calculate the deviation profits, both under price and quantity competition. We first calculate the payoffs from defection of a firm active in a Cournot market and then do this analogously for a firm defecting in a Bertrand market.

Deviation Outcome in Cournot Oligopoly

We now turn to the profits of a deviating firm under Cournot competition. Analogous to Bertrand competition, the best response function of a deviating firm can be written as:

$$R_i(q_i) = \frac{1}{2}(a-c) - \frac{1}{2}\theta\sum_{i\neq j} q_j, \tag{4.5}$$

By plugging the collusive quantities of the other players given by (4.2) into the reaction function in (4.5) one can derive the quantity for the defecting firm in the Cournot market:

$$q_i^d = \frac{(a-c)(2+\theta(n-1))}{4b(1+\theta(n-1))}.$$

the corresponding price and profits are then given by:

$$p_i^d = \frac{1}{4}\frac{a(2+\theta(n-1)) + c(2+3\theta(n-1))}{(1+\theta(n-1))} \text{ and } \pi_i^d = \left(\frac{(2+\theta(n-1))}{4(1+\theta(n-1))}\right)^2 \frac{(a-c)^2}{b} \tag{4.6}$$

where the superscript $'d'$ stands for the deviation outcome.

Deviation Outcome in Bertrand Oligopoly

In Bertrand competition, a defecting firm maximizes profits along its best response function given by:

$$p_i = R(\mathbf{p}) = \frac{(1-\theta)a + \theta\sum_{i\neq j} p_j + [1+(n-2)\theta]c}{2[1+(n-2)\theta]}.$$

At the same time the colluding firms will set prices according to the monopoly outcome as discussed in Section 4.3.1 given by:

$$p_j = \frac{a+c}{2}.$$

Given this, the price, quantity and profits for the defecting firm can be calculated as :

$$p_i^d = \frac{a[2+\theta(n-3)] + c[2+\theta(3n-5)]}{4[1+(n-2)\theta]},$$

$$q_i^d = \frac{2+\theta(n-3))}{(1-\theta)[1+(n-1)\theta]}\frac{(a-c)}{4b},$$

$$\pi_i^d = \frac{1}{b(1-\theta)}\frac{[2+\theta(n-3)]^2}{[1+(n-2)\theta][1+(n-1)\theta]}\frac{(a-c)}{4}^2. \tag{4.7}$$

4.3.3 Critical Discount Factor to Sustain Collusion with Trigger Strategies

This section derives the discount factor necessary to sustain collusion when firms employ trigger strategies. As discussed in Section 4.2.2, grim trigger strategies imply that the respective Nash outcome is played in every period by the remaining firms. These unrelenting strategies constitute a Nash equilibrium provided that:

$$\sum_{t=0}^{\infty} \delta^t \pi_i^{coll} \geq \pi^d + \sum_{t=1}^{\infty} \delta^t \pi_i^n, \tag{4.8}$$

where the left-hand side are the profits when a firm sticks to the cartel agreement and the right hand side are the profits from deviating. This gives $\pi^d > \pi^{coll}$ in the period of defection and $\pi^n < \pi^{coll}$ in all remaining periods. Using $\sum_{t=0}^{\infty} \delta^t = \frac{1}{1-\delta}$, we can write (4.8) as:

$$\frac{1}{1-\delta}\pi^{coll} \geq \pi^d + \frac{\delta}{1-\delta}\pi^n \Rightarrow \pi^{coll} \geq \pi^d - \delta\pi^d + \delta\pi^n. \tag{4.9}$$

Solving equation (4.9) for δ gives:

$$\delta = \delta^* = \frac{1}{1+r} \geq \frac{\pi_i^d - \pi_i^{coll}}{\pi_i^d - \pi_i^n}, \tag{4.10}$$

where r denotes the critical discount rate. The denominator can therefore be interpreted as the gain from deviating from the collusive agreement. The denominator depicts the difference between deviation profit and the per period continuation profit after deviation has occurred. A firm has an incentive to adhere to the cartel, if the discount factor is slightly larger than δ^* in equation (4.10). Solving this for $\frac{1}{r}$ yields

$$\frac{1}{r} \geq \frac{\pi_i^d - \pi_i^{coll}}{\pi_i^{coll} - \pi_i^n}. \tag{4.11}$$

In the following, we calculate (4.11), both for the case of Cournot competition as well as for the case of Bertrand competition.

Critical Discount Rate to Sustain Collusion in the Cournot Oligopoly

The corresponding expression for (4.11) in the case of Cournot can be found by plugging the profits given in (2.7), (4.4) and (4.6) and into (4.11) and simplifying. This yields:

$$\frac{1}{r} \geq \frac{\pi_i^d - \pi_i^{coll}}{\pi_i^{coll} - \pi_i^n} = \frac{[2 + \theta(n-1)]^2}{4(1 + \theta(n-1))}.$$

Solving for the discount rate r yields:

$$r \leq \frac{4(1 + \theta(n-1))}{[2 + \theta(n-1)]^2} \equiv r^{*c},$$

where r^{*c} is the upper limit of the range of discount rates over which collusion can be sustained. Note that r^{*c} falls as the number of firms n increases:

$$\frac{\partial r^{*c}}{\partial n} = \frac{-4\,(n-1)\,\theta^2}{(2 + n(n-1))^3} < 0, \tag{4.12}$$

which implies that the critical discount factor δ increases in n. In other words, as the number of firms in the market increases it becomes more difficult to sustain collusion. As the market becomes more competitive with more players, the Cournot profits are decreasing and the incentives to deviate are increasing.

Critical Discount Rate to Sustain Collusion in the Bertrand Oligopoly

Doing the corresponding exercise for a Bertrand model by plugging the profits given in (2.8), (4.7), (4.4) and into (4.11) and rearranging yields

$$\frac{1}{r} \geq \frac{\pi_i^d - \pi_i^{coll}}{\pi_i^{coll} - \pi_i^n} = \frac{1}{4(1-\theta)} \frac{(2 + \theta(n-3))^2}{[1 + (n-2)\theta]}.$$

Solving for the discount rate yields:

$$r \leq \frac{4(1-\theta)[1 + (n-2)\theta]}{(2 + \theta(n-3))^2} \equiv r^{*b}. \tag{4.13}$$

The derivative of r^{*b} in equation (4.13) with respect to n yields

$$\frac{\partial r^{*b}}{\partial n} = \frac{\theta^2\,(\theta - 1)\,(n-1)}{4\,(2 + \theta(n-3))^3} < 0, \tag{4.14}$$

which implies that collusion becomes more difficult as the number of firms in the market increases. Comparing the disount rates r in the Bertrand oligopoly with the Cournot oligopoly, it can be shown that the critical disount rate in Bertrand competition is lower than in Cournot competition. In other words in order to sustain collusion in the Bertrand oliopoly, firms have to be more patient than in the Cournot oligopoly *ceteris paribus.* That is:

$$
\begin{aligned}
r^{*b} &< r^{*c} \\
\frac{4(1-\theta)[1+(n-2)\theta]}{(2+\theta(n-3))^2} &< \frac{4(1+\theta(n-1))}{[2+\theta(n-1)]^2}
\end{aligned}
$$

which can be simplified to

$$\theta^3 (n-1)^2 (2+\theta(n-2)) > 0$$

which holds for any $n > 1$. Intuitively, *ceteris paribus* Bertrand markets are more competitive than Cournot markets all else equal as a higher discount factor is needed to sustain a collusive agreement among participating firms. To sum up, in this simple framework we show that the critical discount factor increases in the number of firms in a market. The upshot of this is that collusion typically becomes more difficult to sustain once there are more firms in the market.

The previous sections have established how collusion becomes harder to adhere to as the number of firms in the market increases, which holds both for quantity and price setting markets. In the following sections, we examine which other factors play a role when firms are engaging in a collusive agreement. We isolate a number of determinants taken both from the theoretical literature and discuss them in turn.

4.4 Factors determining Collusion among Firms

Section 4.3.3 has shown that collusion can be established in a dynamic environment in which firms employ the correct punishment mechanism. Furthermore, the short-run benefits from cheating must outweigh the present value from staying in the cartel. These profits in turn depend on various industry characteristics, some of which will be discussed in this section. In general, when firms try to cooperate, they face two prime problems. On the one hand, there is a structural effect related to the fact that firms engaging in a cartel face an incentive problem.[2] The incentive problem refers to the phenomenon that cartel members may find it profitable to defect from the collusive agreement once it has been established. The coordination effect refers to the problem of succeeding in coordinating on a common equilibrium. In the following sections, we will discuss factors that fall in either category in more detail starting with the theoretical literature.[3] We ordered these factors as structural and *behavioral* factors.

[2]See Dolbear et al. (1968), Motta (2004, pp.142) and Whinston (2006, p. 21).

[3]Please note that this list is non-exhaustive. For a more comprehensive discussion on these factors, see Tirole (1988), Church and Ware (2000) and Motta (2004).

4.4.1 Theoretical Literature

Structural Factors

1. *Market concentration and the number of firms*
   The notion that market concentration may facilitate collusion was discussed early on by Bain (1956). Indeed, if there are fewer firms in the market and the firms are symmetric, one can show that the incentives to defect decrease. As has been discussed in Section 4.3.3, the critical discount factor needed to make collusion attractive for a firm increases with the number of firms in the market. The interval of discount factors on which collusion can be sustained therefore shrinks with the number of firms. A simple example illustrates this. Imagine that there are only two firms in a market which form a cartel. Each firm receives half of the monopoly profits in each period. If one firm would deviate in a given period, it would gain half the monopoly profit in the period of deviation but thereafter only receive the competitive profits. The loss through foregone profits from collusion would be substantial. The incentives to cheat are much higher in a perfectly collusive market with many firms: in each period, each firm receives only a small share of the monopoly profit. By deviating, a firm would receive the entire monopoly profit. This gain might be large enough to overcompensate the foregone collusive profits during the punishment phase.

2. *Entry conditions*
   In markets with low barriers to entry, it is harder to maintain collusive prices. Entry in these markets is attractive and this tends to break cartel agreements for the following reasons. Firstly, it could be that the entering firm undercuts the collusive price therefore taking away market share from the existing cartel. Secondly, the threat of entry may force a cartel to set a price close to the competitive one, thereby making cartelization less attractive. Porter (1985) and Vasconcelos (2004) extend the Green and Porter (1984) model of price wars under demand fluctuations for entry. Their theoretical predictions show that entry leads to more competitive pricing. Using the data set of the railway cartel JEC that operated in the late 19th century, they both find that cartel stability is inversely related to the number of firms. In Chapter 5, exploring the effect of entry on collusion in an experimental setting, we show that entry does not necessarily have to destabilize an existing cartel agreement.

3. *Demand Factors*
   A second important factor is the stability of market conditions. This implies that demand remains stable over time or that orders from consumers come in on a regular basis. An unexpectedly high order in a given period, for instance, would increase firms deviation profits thereby raising the incentives to undercut. The effect of market fluctuations on sustainability of collusion was examined in Rotemberg and Saloner (1986). They demonstrate the existence of price wars during booming demand in a

model of stochastic demand.[4]

4. *Symmetry of firms*
   Symmetry in terms of product characteristics as well as in terms of firm size and firms' technology are crucial in creating and maintaining a collusive agreement. For instance, if the cost conditions between firms differ, it is harder for firms to agree on a common price making collusion less stable. Moreoever, cheating might be harder to punish if it has to be done by a smaller firm, which may not have the means to do so. Compte, Jenny and Rey (2002) model a market where firms produce a homogenous good and have equal costs but different capacities. They show that the largest firm (in terms of capacities) has the highest incentive to deviate and the smallest firm has problems to punish a deviator. They also show that, as capacity levels among firms become more symmetric, problems in terms of cheating and punishing are eventually alleviated and collusion becomes more stable.[5]

5. *Multimarket contact*
   If the same firms are active on more than one market, existing collusive agreements are typically easier to sustain. The rationale behind this is as follows: if firms co-exist in several markets, then deviation in one market would trigger the punishment of the other firms in all remaining markets. This argument is incomplete, however, as one can also make the reverse argument that multimarket contact destabilizes collusion, too. Deviation in such an environment is more profitable as a firm can deviate in all markets simultaneously. In particular, Bernheim and Whinston (1990) show that multimarket contact with perfectly symmetric firms may not change the incentive to collude.

Behavioral Factors

1. *Transparency*
   Market transparency is of central importance to collusion. If price cuts cannot be detected, mechanisms such as grim trigger strategies are harder to enforce. This in turn makes collusive agreements harder to set up. Green and Porter (1984) show that, if prices are unobservable collusion can nevertheless be sustained. The mechanism is then such that firms stick to a higher, agreed price (not the perfectly collusive price) as long as the firms face a high level of demand. If demand falls all firms revert to the competitive price for a finite number of periods. After the punishment phase is over, firms go back to the collusive price.

2. *Coordination*
   When it comes to coordinating collusion, several factors play a role. Firstly, there is the issue of multiple equilibria as discussed in the theory of supergames in Section

[4]See also Porter (1985).
[5]See also Kuehn and Motta (1999) showing a similar result in a different framework.

4.2.1. This theory however does not offer an explanation regarding how equilibrium selection takes place. Let us assume that a cartel chooses Pareto efficient collusion at the monopoly equilibrium. It remains unclear what happens should one of the cartel members defect. Even if firms agreed on grim trigger strategies in period two, they have an incentive to renegotiate after the deviation to prevent the long punishment phase. Farrell and Maskin (1986) and van Damme (1986) discuss supergames with a possibility of renegotiation. Another strand of theory that tries to explain equilibrium selection problems is the literature on cheap talk.[6] Cheap talk is non-binding communication that does not directly affect players' payoffs. A player can interpret cheap talk by another player about his intended actions as being meaningless. An additional implication of cheap talk on intended actions may be however that the other players believe it and act favorably to it. In this sense, cheap talk can facilitate coordination.[7] Another factor is that coordination problems on an equilibrium aggravate the more players are involved. As the number of fellow players increases, the uncertainty about the choices of the other players increases as well, making it more difficult to coordinate on an equilibrium.[8]

In Section 4.4.2, we discuss the empirical evidence for each determinant presented in this section. For ease of discussion, we again divided this section into structural and behavioral factors.

4.4.2 Empirical Literature

Extensive empirically literature has tested the theoretical findings which we have discussed in Section 4.4.1. In particular, numerous case studies and cross-section studies have been exploring the determinants of cartel stability. For ease of comparison, we categorized the empirical literature using the same list of factors as in Sections 4.4.1. We also illustrate the empirical evidence using information from case studies.

Structural Factors

1. *Market Concentration*

   The empirical literature on the effect of concentration provides support for the theoretical findings of an inverse relationship between market concentration and the success of a cartel. Levenstein and Suslow (2004) build a meta-study in which they examine cartel success determinants pooling five previous cross-section studies.[9] Most of the

[6]See Crawford and Sobel (1982) and Farrell and Rabin (1996).

[7]Experimental literature on the effect of cheap talk on collusion is mixed. See Holt (1993) and Crawford (1998) for a survey.

[8]See Crawford (1995).

[9]The studies examined where by Eckbo (1976), Griffin (1989), Suslow (1991), Marquez (1994) and Dick (1996).

studies they review find that cartels are more likely to occur in concentrated industries. Eckbo (1976) and Griffin (1989) both find in their cross-section analysis that cartel profits are increasing in market shares. Also Hay and Kelley (1976), Dick (1996) and Suslow (1991) find that cartel duration increases in market concentration.[10] There is however also some research pointing to a negative relation between cartel stability and the degree of concentration.[11] Several reasons could explain these contradictory findings. Firstly, there might be an inherent selection bias by looking only into cartels prosecuted by the US Department of Justice. Many of these cartels often involved trade associations or involved many members and were therefore easier to detect. Moreover, cartels with very few members could be stable through tacit collusion without having to resort to communicate explicitly.

2. *Entry*
Entry conditions are also a determining factor for cartel success. Griffin (1989) identifies entry as the second most important reason for cartel breakup. Moreover, Levenstein and Suslow (2006) find that the most common cause for cartel breakdown in their sample of case studies was entry which lead to cartel breakdown in over a third percent of the cases investigated. In the US, for instance, the salt industry succeeded in creating the first known price-fixing cartel in the nineteenth century. This was achieved by creating a common pool for the salt industry. The pool had two main functions. Firstly, it induced complete participation by producers to forego the problem of free-riding. Secondly, the pool had to prevent secret cheating. Stable collusion however, could not be established as cartel members were unsuccessful in creating barriers to entry high enough to keep new firms out of the market.[12] In addition, Levenstein and Suslow (2004) find that in thirty percent of their cross-section sample studied, entry caused cartel breakdown. Note also however that there are case studies indicating that entry can be accommodated. See for instance Levenstein and Suslow (2004, p.38) who show that in industries such as bromine, diamonds, mercury, ocean shipping, oil, potash and sugar the cartel included the entrant.

3. *Demand Factors*
Theoretical results on demand factors and market stability on cartel formation are also in line with empirical findings. Eckbo (1976) shows that firms' ability to raise price crucially depends on a sufficiently low demand elasticity and on the fact that in the short-run, not many substitutes are available. Dick (1996) finds that demand instability has a significant negative effect on cartel duration. Marquez (1994) confirms an inverse relationship between the rate of demand growth and cartel duration. However, this relationship is not significant. Suslow (1991) also finds a significant negative effect between these variables. In particular, she finds that the rate of demand growth is the

[10] See also Levenstein and Suslow (2006) and Whinston (2006, p.43) for an overview.
[11] See, for instance Dick (1996).
[12] See Levenstein (1995).

most relevant single explanatory variable for cartel duration.

4. *Symmetry of Firms*
The empirical literature on the effects of symmetry of firms suggests that this factor has a positive effect on cartel profits. Eckbo (1976) and Griffin (1989) find that the more homogeneous firms in a cartel are, the more successful the cartel is. Eckbo (1976) shows that successful cartels seem to consist of firms that have a similar cost structure. Moreover, Griffin (1989) concludes that cartels consisting of small, equal sized firms are more successful in increasing prices. In a case study on the pasta industry in the US in the 1930s, Alexander (1997) posits that it was the dissimilar cost structures that eventually made it impossible for the maccaroni manufacturers to agree on a common price even in the era of the US NIRA Act when many other firms were able to collude.

5. *Multimarket Contact*
The effect of links across markets seems to have a positive effect on cartels. Dick (1996) investigates the effect of side agreements of firms in other industries by looking at twelve cartels that were acting under the Webb-Pomerene Act. He analyzes whether side agreements affected the duration of industry export agreements and finds a significant positive effect between multimarket contact and cartel duration. In particular, cartels that included side agreements in several markets lasted on average three times longer than firms that did not have such agreements.

Behavioral Factors

6. *Market Transparency*
Case studies as well as cross-section studies show that cartels often used joint sales agencies to monitor adherence to the cartel agreement by their members. These were used in the bromine cartel and the salt cartel, for instance.[13] Levenstein and Suslow (2006) find that seven out of nineteen cartels in the examined case studies used sales agencies. Another means of disseminating information were industry associations. Between twenty five to fifty percent of the cartels in the cross section studies examined by Levenstein and Suslow (2006) involved industry associations. The sugar cartel that started in 1927 is a nice illustration on how transparency can be achieved through the governance structure of a trade organization. Genovese and Mullin (2001) show that this cartel implemented a meticulous system of rules that implicitly severely restricted the scope of each cartel member to secretly undercut prices. It is noteworthy that throughout its 10 year existence, the cartel never directly fixed prices or market shares but solely relied on rule fixing to enforce cartel stability. Part of these rules required that members had to post prices openly and that contract terms were publicly

[13]See Levenstein (1993) for the bromine cartel and Levenstein (1995) for the salt cartel.

announced. Moreover, the sugar cartel imposed strong contractual restrictions on factors such as rebates and freight rates. Both of these measures increased transparency, thereby making it very difficult for each member to make secret price cuts.

7. *Coordination*
Levenstein and Suslow (2006) point to the importance of bargaining problems as a cause for cartel breakups. These coordination problems were relevant in all cartels in their sample. About twenty-five percent of their cartels examined collapsed due to so-called bargaining price wars. These bargaining price wars occurred due to multiple collusive equilibria that differed in the distribution of rents among cartel members. Levenstein (1996) argues that in these cases a cartel member might start a price war to achieve a new equilibrium consisting of a profit distribution that is more favorable to him. She identifies that at least two of the price wars of the bromine cartel, which was active in the late nineteenth century in the US, namely the ones occurring in 1887 and 1891, can be defined as bargaining price wars. They were instigated with the express intention of redistributing the rents among cartel members. Moreover, Gupta (1997) finds evidence of bargaining price wars in the Indian tea industry and Lamoreaux (1985) finds evidence of bargaining price wars in the US steel industry. In the latter case, this phenomenon took place in the steel rail price war in 1896 in which one of the cartel members, Illinois Steel, cut prices heavily following a period of long cooperation during the depression years. Illinois believed that the industry pool had a too low estimate of the actual demand elasticity and therefore suggested a price decrease as this would increase profits. As the cartel did not respond to Illinois Steel's demands, they openly slashed their prices forcing the remaining cartel members to follow suit.[14]. A system to coordinate actions has successfully been implemented by the sugar cartel mentioned in the discussion on transparency above.[15] The trade association implemented a dual system of a Code of Ethics on the one hand, which consisted of a set of rules restricting business practices of each cartel member. Complementary to that, there existed a Code of Interpretation, that, similar to a commentary in law, contained interpretations of the rules. The latter was constantly amended by decisions that governed newly occurring business practices. This system of checks allowed tight accordance of cartel behavior to the cartel rules and thereby enhanced cartel stability.

4.5 Concluding Remarks

The discussion in Section 4.2.2 shows that if firms interact repeatedly, a multitude of possible equilibria exists. The incentives of firms to opt for collusion also depend on the profits of deviation in comparison to the present value of sticking to the agreement. Only if the cartel is sufficiently profitable, deviation profits are not too high, and the firms are relatively

[14]See Levenstein (1996), p. 116.
[15]See Genovese and Mullin (2001).

patient, will a cartel be stable. Moreoever, the analysis in Section 4.3.3 establishes that an increase in the number of firms typically makes collusion harder to sustain and that collusion is also affected by the mode of competition. In particular, the theoretical analysis shows that quantity-setting market seem to be more prone to collusion than price-setting markets. However, the theoretical and empirical literature presented in Section 4.4 indicates that there are many other factors that are crucial to set up a successful cartel such as symmetry among firms, market transparency or stability of demand. One major determinant that can be singled out in affecting the stability of collusion is entry. The findings in Levenstein and Suslow (2006) show that this factor is the most common cause for a cartel break-up in their sample with 30 percent of cartels in their sample collapsing due to entry.

One can isolate two factors playing a role here. On the one hand, the number of firms increases triggering the effects discussed in Section 4.3.3. With the change in incentive structure defection becomes more profitable. On the other hand, coordination becomes more difficult as there are more players having to agree on a common strategy and there is more uncertainty regarding the other players' choices. The point of coordination is also highlighted in the existence of the bargaining price wars discussed in the empirical literature. It shows that the existence of multiple collusive equilibria can make collusion harder to enforce. The following chapter aims to shed light on the question of entry and coordination in an oligopoly game. It uses a laboratory experiment with three subjects to explore the effect of entry in repeated homogeneous Bertrand games.

Chapter 5

Three is still a Party: An Experiment on Collusion and Entry

5.1 Introduction

As established in Chapter 4, oligopoly theory predicts that cooperation becomes more difficult to sustain as the number of firms involved in collusion is higher.[1][2] Intuitively, with a growing number of firms incentives to defect and costs of coordination, communication, and monitoring rise, making it more difficult to maintain a stable cartel. How the number of players in a market alters the behavior of firms has been studied extensively. Theoretical as well as empirical research on entry discussed in the previous chapter has shown that firms joining a cartelized market may disrupt collusive agreements. In particular, theoretical research on entry in oligopolistic settings has mainly explored the extent of collusion using a free-entry condition in a quantity-setting framework.[3] Moreover, numerous purely empirical cross-section studies as well as case studies have shown how entry can disrupt collusion.[4]

In this chapter, we test the effect of sequential entry on firm behavior in an oligopolistic market, using an experimental setup. Our objective is to address to what extent markets are able to sustain collusion in the face of entry. In particular, our experiment is designed to examine the effect of entry on groups that start off small and that interact in that same configuration for some time prior to entry. We hypothesize that this gives them the possibility to create a culture of cooperation in the small group which they are able to transfer to the enlarged group, once entry has taken place.

The experimental setup we use is the following: firstly, two players play the Bertrand-duopoly game with fixed matching. An additional player then enters the market within a predetermined time interval. Prior to entry, this player observes the choices of her group. The fact that the entrant observes her group is common knowledge. We compare this setup

[1]This chapter is based on Goppelsroeder (2009).
[2]See also for instance Bain (1956), Tirole, ch.6 (1988).
[3]See Harrington (1991), Friedman and Thisse (1994) and Vasconcelos (2008).
[4]See Section 4.4.2.

to a second treatment in which players are matched in groups of three from the very start of the session. In order to test our conjecture, we compare the post-entry rounds of the entrant treatment with the baseline treatment. Higher levels of collusion in the post-entry rounds of the entrant treatment than in the baseline treatment would be consistent with the conjecture that collusion can be nurtured provided that groups start off sufficiently small.

There are a number of experimental studies related to our work. Experimental literature on number effects has established an inverse relationship between market prices and the number of firms in a market. Since Fouraker and Siegel's (1963) seminal book, many experiments have focused on studying Cournot type markets. Huck, Normann and Oechssler (2004) review the existing literature and present a new experiment. They find that the cutoff point between collusion and competition lies somewhere between two and four firms. Whereas collusion regularly occurs in duopolies it becomes increasingly rare with triopolies and quadrupolies.

Moreover, many experimental studies looking into price-setting models have shown that a larger number of firms typically leads to more competitive outcomes. Using a homogeneous Bertrand game, Dufwenberg and Gneezy (2000) confirm a similar trend as Huck, Normann and Oechssler (2004) for Cournot games. Using random matching and constant marginal costs in markets with three and four firms, they find that prices rapidly converged to the Nash levels. In the duopoly markets however, prices remained considerably above competitive levels for most rounds.

Abbink and Brandts (2009) explore the extent to which experimental price setting duopolies are able to achieve collusive outcomes in growing versus shrinking markets. They show that in contrast to theoretical findings, duopolists tend to collude more in shrinking markets. The authors conjecture that participants have an incentive to coordinate early as profits melt away quickly in the future.

The main difference between the study presented in this chapter and the experimental literature on number effects is that the latter compares groups of fixed sizes. It is not clear however, what such a number effect is caused by. When studying the consequences of a larger number of firms in a concentrated market, two main effects can be discerned. On the one hand, there is a change in incentives to defect due to a higher number of firms in the market. This effect we denote as the structural effect. Typically, incentives to cheat are higher with more firms involved as individual deviation becomes more profitable relative to the cartel profit. On the other hand, when there are more firms in a market it is harder to coordinate choices. This effect we label the coordination effect.

Empirical literature on cartels has shown that overcoming coordination problems is paramount for cartel stability. Levenstein and Suslow (2004) show that in over twenty-five percent of the cartel cases studied, cartel breakdown occurred because of bargaining problems. Moreover, an early experimental study discerning both mechanisms has been conducted by Dolbear et al. (1968) who find that, by controlling for the monetary incentives, it is mainly the coordination effect causing the number effect.[5] Using sequential entry, our chapter proposes an alternative approach to isolate the coordination effect. By comparing the post-entry rounds of the treatment with entry with the post-entry rounds of the treatment with a fixed group size, differences between the treatments can mainly be attributed to this effect. An alternative interpretation of our work is therefore that sequential entry helps to shed light on the question whether a coordination effect exists.

There are only very few experimental studies specifically looking into entry. Sonnemans, Schram and Offerman (1999) explore the extent of cooperation in a public goods game where subjects are assigned in groups of four and where the composition of these groups changes throughout the experiment. In pre-determined rounds at most one subject leaves a group and will be replaced by another subject. The authors show that subjects contribute more in the first round in their new group than in the last round in their old group and that subjects condition their contributions on expected cooperation by their fellow group members. An important difference with our work is that even though the group composition changes, the size of the group is fixed in their experiment.

A public goods experiment that does allow for growing groups through endogenous entry is Guerek, Irlenbusch and Rockenbach (2006). The study shows that larger groups not only reach high levels of contribution but *a fortiori* that the larger the group, the higher the contributions.[6] In much of the same vein as our conjecture, the study highlights that groups can develop a culture of cooperation by slowly growing into a larger group. As entry in our study is predetermined and not chosen by the subjects themselves, we expect that cooperation will be harder to enforce and sustain than in Guerek, Irlenbusch and Rockenbach (2006).

The closest study to ours is Weber (2006), who looks into group cooperation within the framework of a minimum effort coordination game. In a number of different treatments, participants start off in small group sizes which are eventually enlarged following a predefined growth path up until the group reaches a size of 12 participants. The subjects that enter the treatment groups differ with respect to the information they have: in a history treatment, entrants observe the choices of the group they are entering into. In a no-history treatment, entrants do not know anything about the behavior in their group. Weber (2006) compares these treatments with a fixed size control group that starts playing from the beginning with 12 participants. The results show that only in the history treatments, efficient coordination was possible. Weber's results provide support for our conjecture, as he shows that both information conditions of the entrant and starting in small groups are crucial factors to reach efficient coordination.

One important dimension where our chapter differs with respect to the work of Weber is that we study entry in an oligopoly setting in which the Pareto-efficient outcome does not coincide with the Nash equilibrium. Coordination on that outcome might therefore be

[5]Moreover, case studies have pointed out the coordination problem of cartels. See for instance Levenstein (1996) for a study in the bromine cartel, Gupta (1997) for the tea industry.

[6]Even though incentives are such that cooperation in smaller groups is easier than in larger ones.

harder to achieve. In the minimum effort coordination game, there is strategic uncertainty as to which of the seven symmetric Nash equilibria will be chosen by the other player(s) but there is no monetary incentive to defect from these equilibria.

To our knowledge, this is the first experimental study that specifically examines the effects of sequential entry on collusion in an oligopoly game. We find support for the conjecture that collusion can be sustained provided that groups start small and that starting small may help to overcome coordination problems inherent in the larger groups.

The remainder of this chapter is organized as follows. In Section 5.1, we discuss the experimental design. Section 5.3 presents aggregate results, Section 5.4 individual results. Section 5.5 concludes with some policy implications and directions for further research.

5.2 Experimental Design

5.2.1 The Game

Subjects play a Bertrand game with a homogenous good, inelastic demand and no costs. In each round, a buyer will purchase the good at a constant quantity of one unit up to a given maximum price. This type of demand schedule is also known as box demand.

In each round each seller posts an integer price bid from the strategy space $[1, .., 100]$. In the treatments, subjects are either playing in duopolies or in triopolies. The seller posting the lowest price will sell the good and gets profits equal to the price she posted. The other seller will make zero profits. Should the players post an identical price in a given round, profits will be shared equally. Given the price of the other seller(s) it is always profitable to slightly undercut the minimum price.

The subgame-perfect Nash equilibrium in the triopoly is to set a price equal to the lower bound of the price interval given at $p = 1$. The corresponding profits at this equilibrium for each player are 1/3. The collusive equilibrium is at the upper bound at $p = 100$ with corresponding profits of 33 1/3 for each player.

In the duopoly game, the subgame-perfect Nash equilibrium is given by players setting a price of $p = 1$ which implies that each players receives profits of 1/2. Note however that due to the discretization of the strategy space, a second Nash equilibrium exists at p=2 where each of the players get a profit of 1. By undercutting the Nash equilibrium at $p = 2$, a player would also gain a profit of 1.

5.2.2 Sources of a Number Effect

As discussed in Chapter 4, there may be several reasons why collusion is more difficult to enforce in larger markets. Firstly, the incentives to defect from the collusive agreement increase with a higher number of players in the Bertrand game which we refer to as the *structural effect*. Secondly, with more players, there is more strategic uncertainty about the choices of the other players which makes it harder to coordinate on a common price bid. This we refer to as the *coordination effect*. In our experiment we aim to explore this coordination effect using the following two treatments.

- **Entrant Treatment**: Subjects start playing the Bertrand duopoly game. At a given point, a third player enters and the group plays the Bertrand triopoly game.
- **Baseline Treatment**: Subject play the Bertrand triopoly game during the entire experiment.

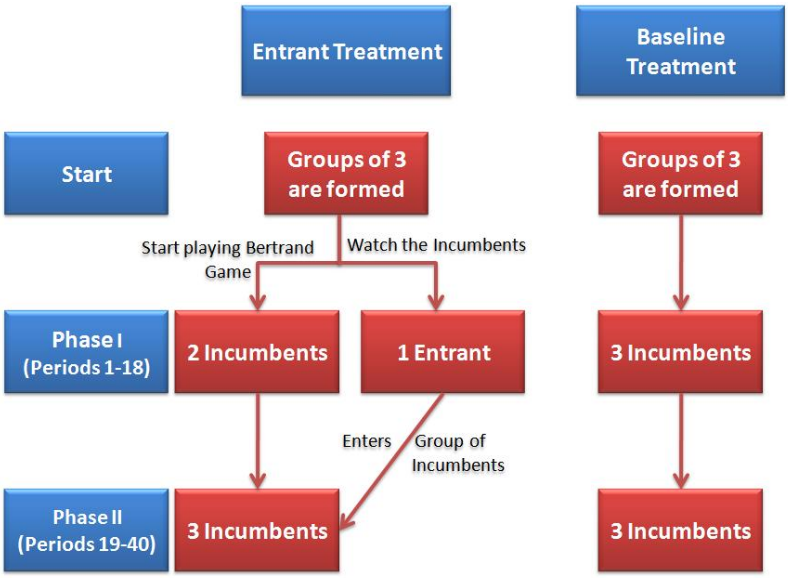

Figure 5.1: Design of the Experiment.

Figure 5.1 presents the main features of the experiment. In both treatments players are informed that they play for 40 rounds. In the Entrant Treatment, players are randomly matched in groups of three. Two players are randomly selected and start playing the Bertrand game explained above from the beginning of the experiment while the third group member observes their choices via a computer screen. The fact that the entrant observes their groups prior to joining them is common knowledge. It is also common knowledge that entry takes place between round 15 and 25. We impose entry in all sessions in round 19. After entry occurs, players play the same game in groups of three until the end of the experiment. In the Baseline Treatment, subjects play the same Bertrand game in groups of three throughout the entire experiment. In the following, we will refer to the pre-entry rounds (rounds $1-18$) as the first subsession and the post-entry rounds (rounds $19-40$) as the second subsession in both treatments.

In both treatments the informational feedback subjects receive consists of their own prices and profits as well as the individual prices posted by the other firm(s).[7] Prior to

[7]We chose not to reveal the profits of the fellow group members to subjects as some studies have shown that these induce imitation and lead to competitive outcomes. See for instance Huck et al. (1999) and Offerman et al. (2002) for a discussion on this. Note however that they can easily be inferred from the price bid of the other group members.

entry, entrants are given the task of predicting the choices in their group. In each round, entrants observe the prices chosen by each group member and guess the minimum price for the following round. We chose for this setup as we wanted to incentivize entrants to pay attention to choices in their group and to learn about the group behavior.

If entrants' guess is within 20 percent of the actual winning bid, they receive profits equal to the average profits of their group members for that round. In case the estimate falls outside that bound, entrants receive zero profits. For fairness considerations, we decided to tie the entrant's profit before entry to the average group profits.

When there a more players in a group, there is more uncertainty about the choices of others, which makes it harder to coordinate. The fact that the groups start in a smaller configuration reduces the initial level of strategic uncertainty, thereby facilitating coordination. Moreover, we conjecture that once cooperation is established, it is possible to transfer it to the enlarged group especially if the entrant is informed about the group's prior choices. This implicitly rests on the assumption that subjects are able to build a set of self-enforcing rules with fewer group members that they are able to transfer to the larger group. This conjecture is also consistent with the findings in Weber (2006).

Theoretically, incumbents should set a price of one or two in equilibrium prior to entry. After entry has taken place, both incumbents and entrants should set a price of one. The collusive benchmark predicts that incumbents set a price of 100 both before and after entry and that entrants also price at 100.

In line with the above discussion, we expect that subjects that start off as duopolists and whose groups are extended to triopolies are closer to the collusive benchmark in the triopoly game than subjects that initially start playing in a triopoly constellation. In order to test this, we compare the triopoly in subsession two in the Entrant Treatment with the subsession one of the Baseline Treatment. One might argue that this approach has some limitations as subjects in the Entrant Treatment in subsession two already have some experience in playing the Bertrand-Nash game whereas players in the Baseline Treatment in subsession one do not. We therefore impose an additional, more stringent test by comparing both treatments in subsession two.

5.3 Aggregate Results

5.3.1 Subject Pool

The experiment is computerized and the program is written using the ZTree software package from Fischbacher (2007). A transcript of the instructions can be found in Appendix B. The experiment was conducted at the CREED laboratory of the University of Amsterdam in June and September 2008. There were 138 undergraduate students from different disciplines participating in the experiment, with 26 groups in the entrant treatment and 20 groups in the baseline treatment.

For both treatments, subjects were assigned randomly and anonymously in groups of three at the beginning of the experiment. Communication between subjects was not allowed. Moreover, we used a neutral frame to make the game as simple and clear as possible for the participants.[8] Before the start of the experiment, subjects read the instructions on the screen and answered three test questions. They were also handed out a paper copy of the instructions at the beginning of the experiment.[9]

Subjects received a five Euro show-up fee and where paid based on performance for the 40 rounds. The experimental currency was given in points. For each 100 points subjects earned they received Euro 1.50. The average payment for subjects was 22 Euros for one hour.

5.3.2 Average Market Prices

Table 5.1 shows the average winning bid per group for the Entrant Treatment and Baseline Treatment for the two subsessions. In the first subsession, it is not surprising that average winning bids are higher in the Entrant treatment than in the Baseline treatment as we are comparing duopolies with triopolies. Comparing the overall averages of the second subsession, it is clear that in the Entrant Treatment the bid is higher than in the Baseline Treatment (66 compared to 50). In line with previous literature on number effects, the averages are higher in duopolies than triopolies (comparing column three and column four) but it is striking that they remain higher even after entry occurred. In the following sections, we analyze this difference in more detail, by disaggregation the data over time and over groups.

5.3.3 Impact of Entry on Pricing Decisions in Concentrated Markets

In this section, we explore the pricing behavior across our two treatments. When examining the evolution of collusion, one can focus on two different indicators. On the one hand, one can analyze how the *level* of collusion evolves in each treatment by looking at average price bids, average market prices or medians. We present the results of this part of the analysis in this section. On the other hand, one can look at measures of *variance* of collusion such as the fraction of coordinating groups. These latter results will be presented in the Section 5.3.4.

Figure 5.2 shows the price bids in a given round averaged over all groups in a given treatment. Figure 5.3 is constructed the same way for average market price. We start by comparing the prices levels in period one, as subjects at this moment do not have any experience and have not yet learned anything neither about their group nor about the game. It is clear from both of these figures that the Bertrand-Nash equilibrium is not achieved in

[8]Note that studies provide mixed results concerning the question whether neutral or economic frames induce more cooperative outcomes. See also Huck et al. (2004).

[9]A copy of the instructions can also be found in Appendix B.

Average Winning Bids				
	Rounds 1-18		Rounds 19-40	
GroupNr	Entrant	Baseline	Entrant	Baseline
1	100	80.56	93.00	97.68
2	95.10	44.72	90.41	6.77
3	67.44	98.61	88.14	99.95
4	76.11	48.78	61.23	25.23
5	97.11	47.78	86.23	25.50
6	69.94	26.22	18.64	23.10
7	90.55	71.94	99.36	41.04
8	97.17	19.22	99.50	2.95
9	100.00	37.06	91.86	55.82
10	67.00	96.22	26.23	97.68
11	65.83	47.67	77.45	25.41
12	92.39	54.17	51.04	44.05
13	17.33	8.61	5.27	6.45
14	67.17	25.17	28.64	16.27
15	32.56	26.56	22.82	18.00
16	98.10	60.83	77.36	55.05
17	100.00	69.056	76.32	27.95
18	100.00	77.11	99.95	92.36
19	75.44	80.833	29.23	83.00
20	95.61	45.44	94.77	89.45
21	66.28		32.18	
22	96.11		47.86	
23	95.56		66.64	
24	94.50		98.04	
25	93.10		95.45	
26	75.94		57.45	
Overall Average	81.78	53.78	65.95	50.13
Bertrand Benchmark	1	1	1	1
Collusive Benchmark	100	100	100	100

Table 5.1: Average Winning Bid per Group in the Entrant Treatment and the Benchmark Treatment.

the first period in any treatment. Average price bids are at 71 and 60 in the Entrant and Baseline Treatment, respectively. Looking at the convergence of average prices as well as average market prices in later rounds, we can see that prices tend to increase in the first subsession in both treatments. In the second subsession this trend seems to be reversed for both treatments, an effect which seems stronger when looking at market prices. Moreover, prices do not converge to the Bertrand-Nash equilibrium, a result which is consistent with the findings of Dufwenberg and Gneezy (2000).[10] Looking at market price in Figure 5.3, they oscillate at collusive levels of over 80 for most periods in the Entrant treatment and then drop after entry revolving at a level around 70. In the baseline treatment, prices are typically between 50 and 60 if we disregard the beginning and the end periods.

Let us now compare the treatments in more detail. If collusion is easier to maintain in groups that start off small, as we conjecture, we should observe a higher degree of collusion

[10]Note however, that in their setup subjects played the Bertrand game with random matching.

post-entry in the groups of Entrant Treatment than in the Baseline Treatment. Also if there exists a coordination effect, we should see higher prices in the Entrant Treatment in subsession two. Indeed the results point into this direction.

Looking at the whole 40 rounds, it is clear that average prices are higher in the entrant treatment than in the baseline treatment. This is not surprising for the first subsession, as we are comparing duopoly markets in the Entrant Treatment with triopoly markets in the Baseline Treatment. What is striking however is that this considerable difference in price bids remains after entry has taken place, providing support for our conjecture.

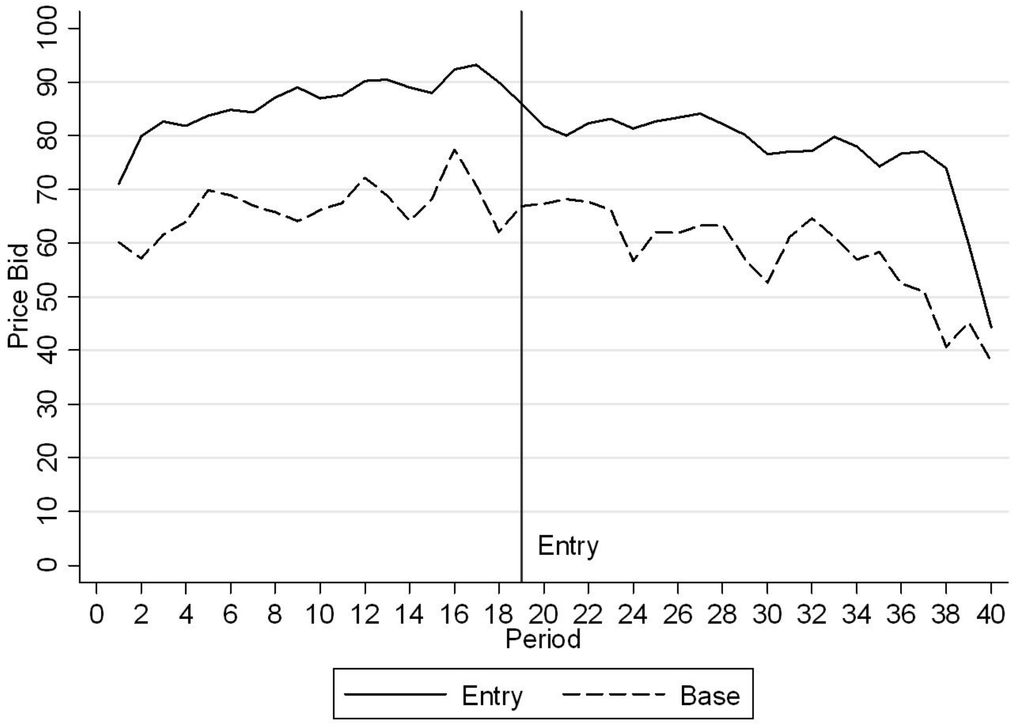

Figure 5.2: Average Price Bids in Entrant Treatment and Baseline Treatment.

To test for the differences in treatments statistically, we calculate the average price bids per group over the entire forty periods. The differences in treatments are significant according to the Mann-Whitney-U test (MWU test) (p=0.09). We also compare the average price bids per group over the second subsession to test for the coordination effect. As we compare equal sized groups, differences in treatments cannot be due to structural differences and can therefore be attributed to the coordination effect. Indeed, there is a significant difference in treatments in this subsession, pointing out to the importance of coordination problems as a source of the number effect (MWU test, p=0.06). Finally, we compare the post-entry price bid averages of the Entrant treatment with the pre-entry price-bid averages of the Baseline treatment (rounds $1-18$). Also this test yields significant differences according to the MWU test (p=0.04) .

To get a more complete picture of the bidding behavior, it is insightful to look at the evolution of the market prices per group in both treatments depicted in Figure 5.3. Differences in market prices across treatments would give even stronger support for our hypothesis as they present the minima of the bids in each group.

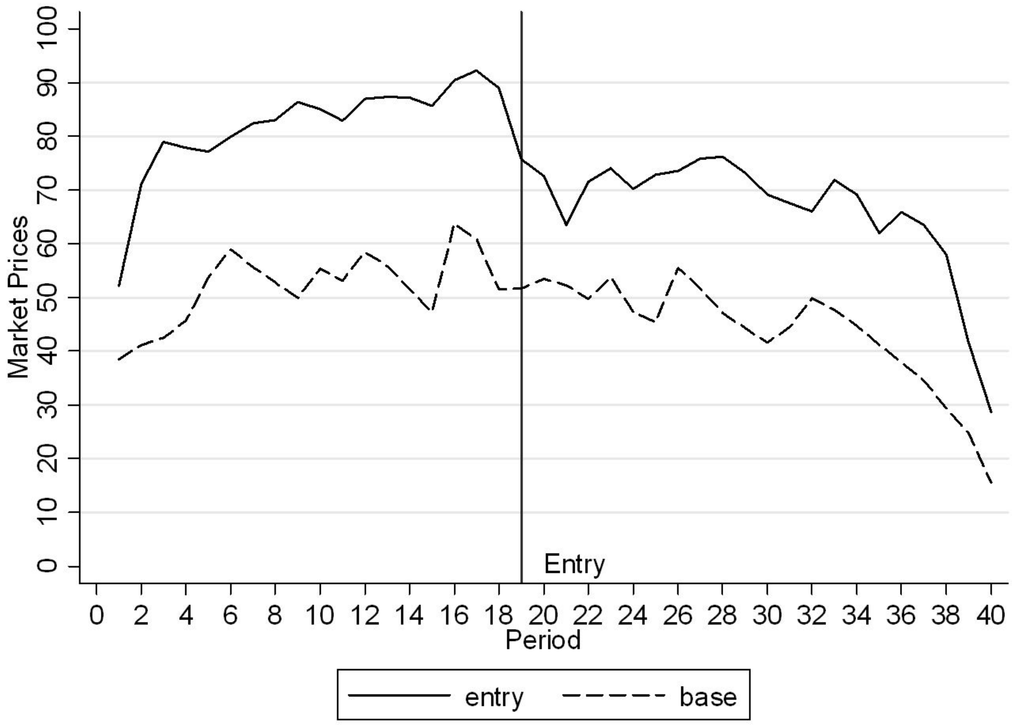

Figure 5.3: Average Winning Bid in Entrant Treatment and Baseline Treatment.

The pattern displayed in Figure 5.3 shows that market prices remain considerably higher in the Entrant Treatment in subsession two. As with the the price bid analysis above, we calculate the average winning bids per group over the entire 40 periods, periods $19-40$ and periods $1-18$, respectively. Comparing the overall averages and the post-entry averages yields significant differences across treatments according to the MWU test (p=0.01 and p=0.06, respectively). Comparing the pre-entry round averages of the Baseline treatment with the post-entry round averages of the Entrant treatment also yields significant results (p=0.07). These results provide further support for our conjecture of a coordination effect being present.

Note however that prices drop considerably in comparison to the pre-entry levels. This drop in market prices is mainly caused by groups were collusion could not be established pre-entry. In these markets, both entrants and incumbents undercut strongly the pre-existing market prices thereby bringing down the overall pricing level. In the groups that collude pre-entry the average winning price drops by nine percent from 100 to 91. In the groups unable to establish collusion however average winning prices drop by 27 percent from a market price of 75 to 55. We discuss the dynamics of individual group behavior, in particular the pattern of undercutting in more detail in Section 5.4. The sharp drop in market prices is in line with the findings in Porter (1985) and Vasconcelos (2004) discussed in the introduction that show that actual entry leads to more competitive pricing.

Furthermore, there is a negative trend in prices after entry occurs.[11] Note that even though the decrease in market prices after entry is substantial, prices still remain considerably higher than predicted by the Nash equilibria.

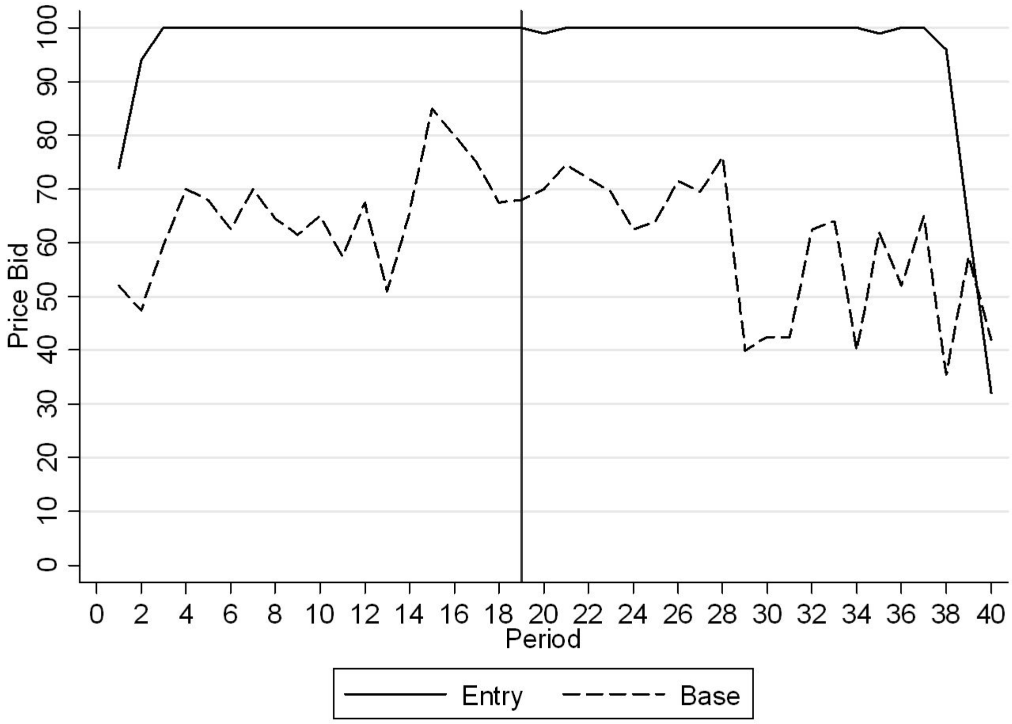

Figure 5.4: Median Prices in Entrant Treatment and Baseline Treatment.

Figure 5.4 depicts the median price bids per round per treatment over the 40 rounds. The median has the advantage of being more robust to outliers in the data. Over 50 percent of the bidders in the entrant treatment bid at the perfectly collusive level if we disregard the beginning and the end periods. In the baseline group on the other hand, median price bids remain much lower and vary strongly, oscillating between price bids of 40 up to 85. As for the average price bids and the winning price bid, we calculate the median winning price per group for periods $1 - 40$, periods $1 - 18$ and periods $19 - 40$. The differences between treatments are significant according the MWU test for entire session (p=0.01). Comparing the post-entry group medians (second subsession), the differences are marginally insignificant (p=0.13). Lastly, comparing the post-entry medians of the Entrant Treatment with the pre-entry medians (first subsession) of the Baseline treatment, the differences are significant (p=0.03). The above findings are summarized in the following observation.

Observation 1 *Market Prices in the Entrant Treatment remain significantly higher than in the Baseline Treatment. This supports our conjecture that it is easier to collude in groups that started off small. Moreover, we find evidence for a coordination effect.*

[11] This effect is significant at the 10 percent level.

5.3.4 Impact of Entry on Cooperation

In this section, we concentrate on measures of variance of collusion. In particular, we explore the degree of cooperation among groups. One way to do this is to look at the frequency of common price bids across treatments. A higher fraction of coordination in the second subsession of the Entrant Treatment than in the Baseline Treatment would provide evidence in favor of our conjecture. Figure 5.5 shows the frequency of coordination on a common price

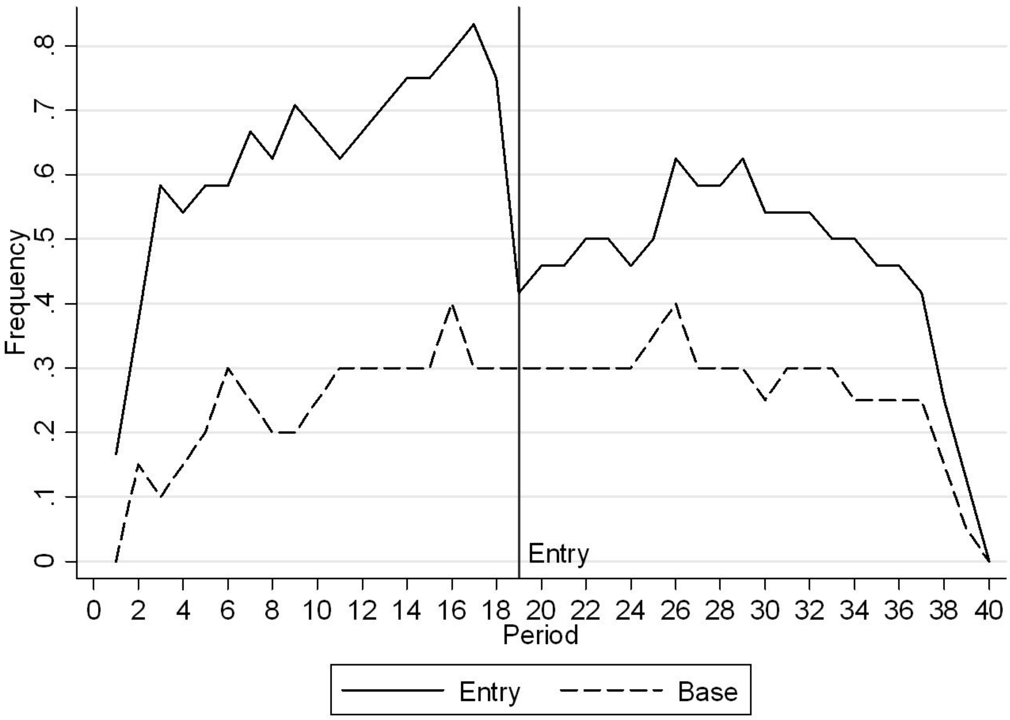

Figure 5.5: Coordination on a Common Price in Entrant Treatment and Baseline Treatment.

larger than two per group in each treatment for each round. The entrant treatment displays a much higher degree of coordination. In line with our conjecture and the findings of Weber (2006), the results suggest an inherent coordination problem can be overcome provided that groups start off small. We calculate the average frequency of coordination at a price larger than two per group over the entire 40 periods. The differences in coordination frequencies are significant according to the MWU test (p=0.02).

The frequency of coordinating groups steadily increases in the pre-entry periods peaking at over 80 percent just before entry which could be due to learning and experience. At the entry period, it drops considerably to about 40 percent of coordinating groups. As mentioned earlier, this is mainly due to entrants who initiated undercutting in the period they join their group. The pattern after entry is similar to that before entry to the extent that the fraction of coordinating groups increases over time even though the high level of pre-entry coordination is not reached again. After period 36 a clear end-effect emerges. In the Baseline Treatment, the percentage of coordinating groups is much lower, revolving around 30 percent in most of the periods. The strongest form of collusion emerges when a group manages to coordinate at the Pareto-efficient price bid of 100. At this market price, firms share the entire surplus of the market, either receiving half of the profit (before entry) or a third of the profits (after entry). Figure 5.6 shows the frequency of coordination at the perfectly collusive level for

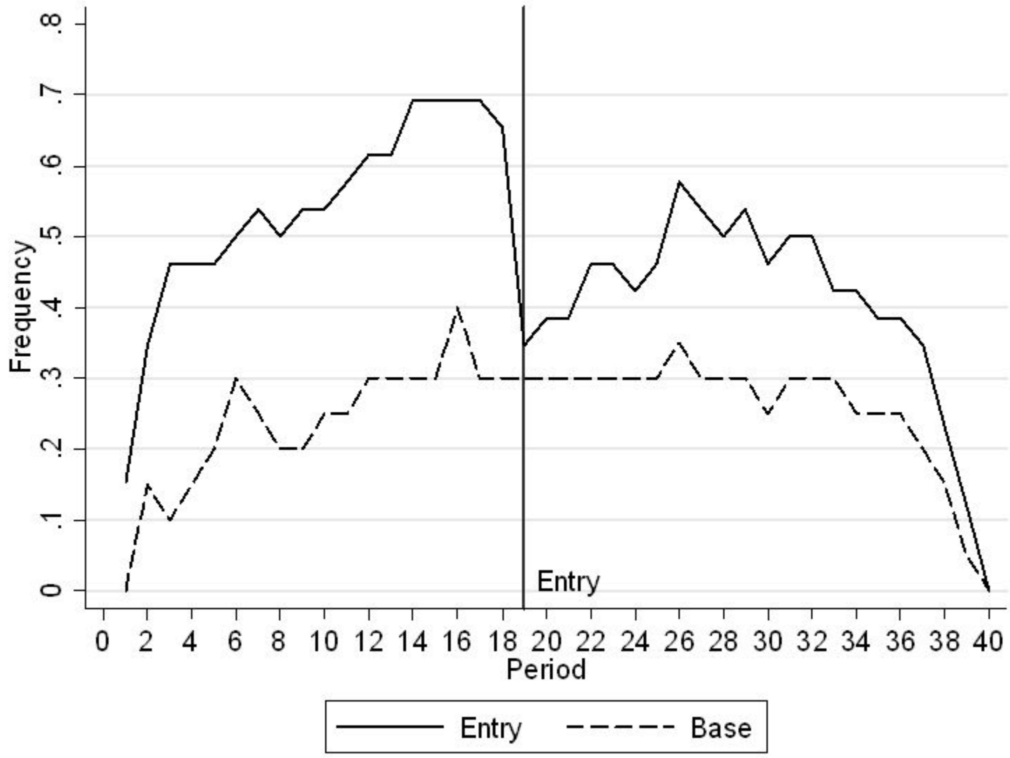

Figure 5.6: Coordination on the Perfectly Collusive Outcome in Entrant Treatment and Baseline Treatment.

both treatments. The evolution of perfectly collusive groups is similar to that in Figure 5.5 with significantly more collusion in the Entrant Treatment both when comparing subession two of the Entrant Treatment with subsession one of the Baseline Treatment, but also when comparing the second subession of both treatments. The higher degree of coordination in the Entrant Treatment in the second subsession compared to the Baseline Treatment also provides evidence for the existence of a coordination effect as a major cause for the number effect. Calculating the average frequencies of collusion at the perfectly collusive outcome per group over the entire 40 periods yields a significant difference between treatments according to the MWU test (p=0.07). Note that the market in our experiment can also be interpreted as a shrinking market as incumbents know that there will be future entry. In line with Abbink and Brandts (2009), we find that subjects facing shrinking profits have an incentive to coordinate early knowing that profits post-entry will be substantially reduced.

Observation 2 *Groups in the Entrant Treatment coordinate significantly more than groups in the Baseline Treatment. This also holds for Pareto efficient coordination. This provides further evidence of the coordination effect in tacit collusion.*

5.4 Individual Results

5.4.1 Behavior of Entrants

The dominant insight from the literature surveyed in the introduction is that entrants in cartelized markets may destabilize collusion. In our setup, the entering party knows the market history and this is common knowledge. We conjecture that this helps groups to sustain collusion. To test this conjecture and to get a deeper insight into the determinants of the entrants' behavior, this section explores in how far entrants respond to the performance of their group prior to entry.

To analyze what determines entrants' behavior after entry, we categorize the markets pre- and post-entry. We define a market as collusive in subsession one or in subsession two (periods $1-18$ and periods $19-40$, respectively) if during at least 9 consecutive periods before (after) entry groups were able to coordinate on a collusive price of 99 or 100. Note that this time interval exactly correspond to 50 percent of the periods in the first subsession. Otherwise the market is defined as non-collusive. Using this rather strict definition, over 60 percent of the markets in the entry treatment still classify as collusive prior to entry.[12]

We characterize several possible reactions of entrants in the first period after entry occurs (period 19) which we condition on the type of market they join. The reference point of the reaction of the entrant is the minimum of the price bids of the other players (which is the market price). We distinguish three possible reactions of entrants: firstly, they can match the minimum price bid of the previous period. Secondly, they can undercut that price by setting a price bid below the minimum. Thirdly, entrants can signal their willingness to collude by setting a price in period 19 which is higher than the minimum price. Using this classification, we can generate Table 5.2. In this table, the reaction of the entrant is relative to the market price of period 18. The characterization of the markets into collusive or non-collusive is based on the entire subsession one.

	Pre-Entry Market Behavior		
Reaction of Entrant	Collusive	Non-collusive	All
Match	11 (69 percent)	2 (20 percent)	13 (50 percent)
Undercut	5 (31 percent)	5 (50 percent)	10 (38 percent)
Signal	-	3 (30 percent)	3 (12 percent)
	16 (100 percent)	10 (100 percent)	26 (100 percent)

Table 5.2: Reaction of Entrant in t=19 to Group Behavior in subsession 1.

In the collusive markets, a clear majority of the entrants follow the behavior of their group. Almost 70 percent of them match the market price and collude as well. A representative market in which an entrant always matched is depicted in Figure 5.7. The figure nicely

[12]Although this definition is strict as one could also define a market at lower market prices as collusive, we chose this classification to be conservative. A less restrictive classification only strengthens our findings but does not qualitatively alter the results.

illustrates how both incumbents perfectly collude from the very start and how the entrant emulates this behavior after entry.

In five markets entrants undercut. Signalling by entrants was not observed in collusive markets. This is due to the fact that almost all (14 out of 16) of the collusive markets priced at the perfectly collusive level in period 18 so that signalling was ruled out by definition.

The reactions of entrants in the non-collusive markets are distributed more evenly. Matching the market price was much less prevalent than in collusive markets (20 percent). This is not surprising, given that the market price typically is less attractive in these markets. Entrants therefore try to steer away from it either by undercutting in order to gain the whole market share or by trying to signal their willingness to coordinate at a higher price. This latter reaction occurred in 3 markets. Figure 5.8 exemplifies a market with a signalling agent. Prior to entry, there are episodes both of competition and of collusion. In period 19, one incumbent decreases his price bid and in the following period the other incumbent follows suit. The entrant, on the other hand, consistently bids the fully collusive price thereby eventually restoring collusion.

A majority of 50 percent (5 markets) of the entrants however undercut in the first period after entry. Entrants might strongly undercut the minimum price bid in period 18 as they expect the level of cooperation to decrease even though they would generally prefer to collude. If these expectations would be an issue, one should observe undercutting in the first and/or second period after entry followed by periods of signalling. We therefore examine the sequence of reactions of entrants in the four periods following entry.

When studying the responses of entrants in the four periods following entry, the expectations of lower market prices by entrants indeed seem to be a relevant factor in both collusive and non-collusive markets. In the collusive markets in almost 20 percent of the cases the entrant first undercuts in the first and/or second period and subsequently signals by raising the price bid. In non-collusive markets, this phenomenon is much stronger: in 50 percent of the groups (5 markets) entrants first undercut and then signal. An example of such a group is also depicted in Figure 5.9. The entrant first undercuts at a price of 75 but then signals his willingness to collude from period 21 onwards by setting the fully collusive price of 100 during the 5 following periods.

To summarize, the prevalent response of entrants who join collusive markets is to match the collusive price thereby stabilizing and sustaining collusion post-entry. There is much more variation in the behavior of entrants who join non-collusive markets. Moreover, a large majority of these entrants undercut in at least two periods within the four periods following entry. On the other hand, signalling is observed in a majority of these markets as well.

Observation 3 *The large majority of entrants that enter a collusive market also colludes, thereby sustaining the pre-existing cartel. In non-collusive markets, the majority of entrants undercut at some point thereby making it harder to establish collusion. Overall, entrants' responses reinforce the behavioral patterns of the markets pre-entry: entrants in cartelized markets mainly collude, whereas entrants in non-cartelized markets mainly engage in pricing*

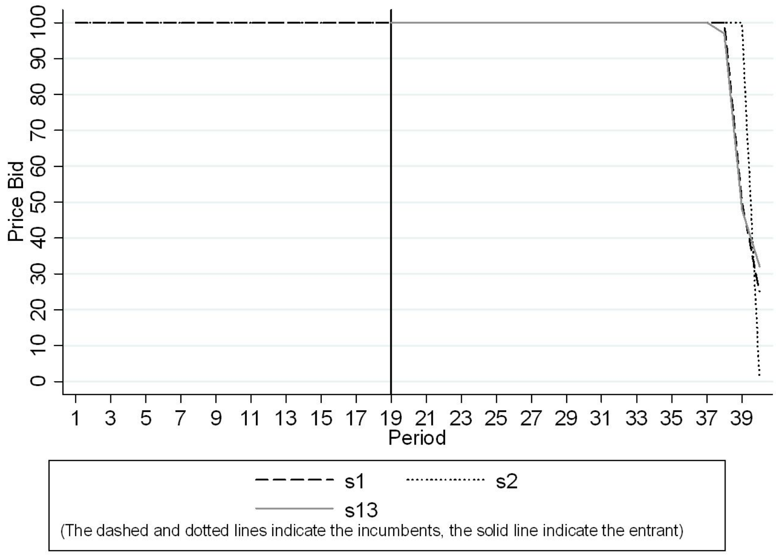

Figure 5.7: Price Bids in Group 1 of Session 1, Example of "Always Collude" in a collusive Market.

behavior which is not conducive to collusion.

5.4.2 Behavior of Incumbents

This section presents the reaction of incumbents to entry analogous to Section 5.4.1 above. Table 5.3 shows that incumbents in both collusive as well as non-collusive markets match the price much more often than entrants. Analogous to the analysis of entrants, the reaction of incumbents in period 19 takes the price bid of the other incumbent in period 18 as a benchmark. Over 90 percent of the incumbents match in collusive markets while only 35 percent match in the non-collusive markets. An illustration of such a market is given in Figure 5.7. In collusive markets, undercutting by incumbents is hardly observed. These observations are in line with empirical studies on reactions of incumbents to entry without a specific focus on collusive markets. Robinson (1988) and Yip (1982) find almost no reaction to entry by incumbents in the short-term. Cubbin and Domberger (1988) find only a reaction by incumbents in roughly a third of the cases. Moreover, Levenstein and Suslow (2004) find that in many industries cartels accommodated entrants. Entry was accommodated in cases such as the bromine cartel, the diamonds cartel, the potash cartel and the sugar cartel. In non-collusive markets, however, undercutting is more prevalent as 40 percent of incumbents undercut post-entry.

The reactions of incumbents in the first four periods after entry are more dispersed. Again, in the collusive markets the majority of incumbents always matches. In the non-collusive markets, many of the incumbents undercut a group of which is shown in Figure 5.8 where both incumbents s9 as wel as incumbents s10 undercut.

Observation 4 *In the first period after entry, the majority of incumbents match the price*

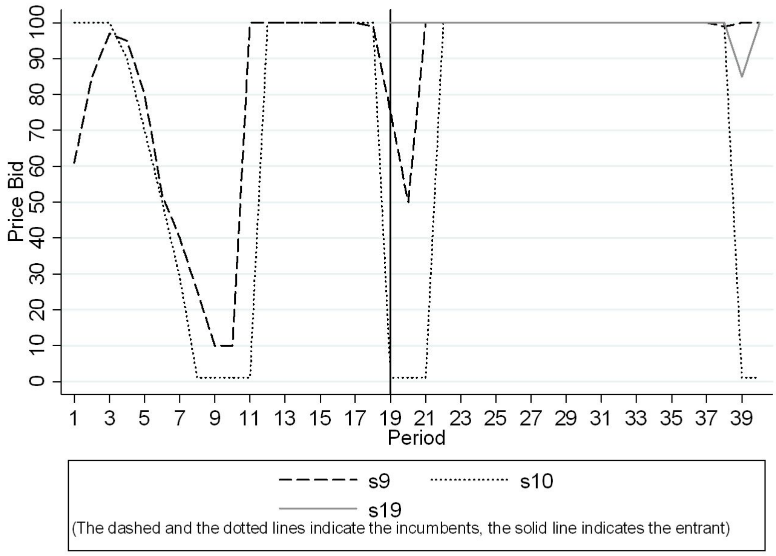

Figure 5.8: Price Bids in Group 5 of Session 2, Example of "Always Signal" in a non-collusive Market.

	Pre-Entry Market Behavior		
Reaction of Incumbent	Collusive	Non-collusive	All
Match	29 (91 percent)	7 (35 percent)	36 (69 percent)
Undercut	3 (9 percent)	8 (40 percent)	11 (21 percent)
Signal	-	5 (25 percent)	5 (10 percent)
	32 (100 percent)	20 (100 percent)	52 (100 percent)

Table 5.3: Reaction of Incumbent in t=19 to Entry.

bid of the other incumbents, especially in markets that were defined as collusive prior to entry. In the longer run, incumbents from collusive markets mainly match whereas incumbents from non-collusive markets mainly either undercut or signal.

5.4.3 Initiators of Undercutting and Punishment by Group Members

In this section we take a closer look at markets where undercutting takes place in the period after entry. We are particularly interested whether there is a pattern concerning who initiates undercutting and whether this depends on the type of market, that is whether the market is collusive or non-collusive.

In markets defined as collusive in the first subsession, undercutting by either of the three players occurs in six markets of 16 markets. In four of these markets this was initiated by the entrant only. In one market, undercutting was initiated by the incumbents and in another market it was initiated by incumbents and entrant simultaneously.

In non-collusive markets, the picture is more mixed. Undercutting occurred in eight out of ten markets. In two out of ten markets, it is initiated simultaneously by entrants and

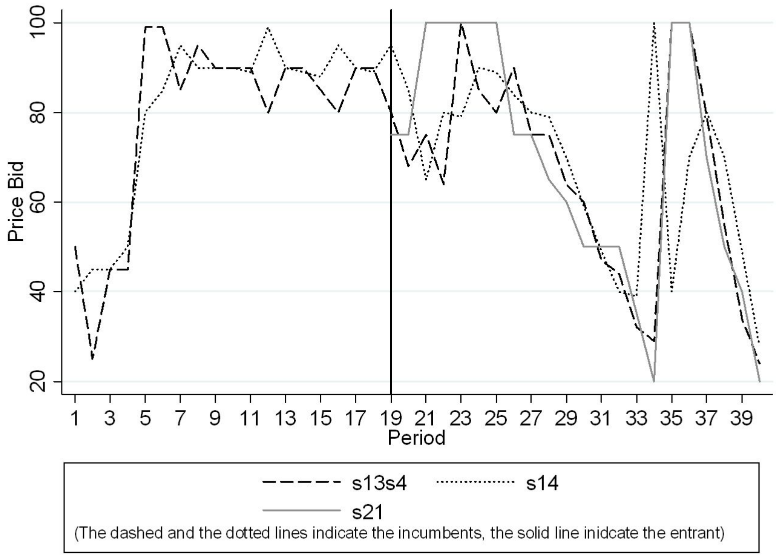

Figure 5.9: Price Bids in Group 7 of Session 4, Example of "Undercut, then Signal" in a non-collusive Market.

incumbent(s), an example of which is shown in Figure 5.9. In three markets, it is the entrant who starts. In the remaining three markets, at least one incumbent starts to undercut. This happens in Group 5 of Session 2 shown in Figure 5.8 in which both incumbents undercut strongly.

As it is the participants in non-collusive groups who pull down the average market prices after entry as shown in Figure 5.3, it is interesting to analyze whether there is some pattern concerning competing between entrants and incumbents in these groups. In three groups, a total of five incumbents undercut strongly. Their average bid reduction compared to the market price in period 18 is 47 percent. Concerning the entrants, we can single out three of them who undercut strongly. Their average bid reduction however is only 18 percent. The fall in market prices after entry therefore mainly stems from competing incumbents in non-collusive groups.

As undercutting was often initiated by entrants, one would expect that incumbents in the corresponding markets, especially in the collusive ones, react by retaliating in the form of punishment. We define punishment as setting the competitive price (a price bid of one) in the period after undercutting occurs in the line of Green and Porter (1984). In collusive markets severe undercutting however only happens in a single market, in which one of the incumbents punishes an undercutting entrant in one period and then reverts to the fully collusive price bid in the following period. Punishing occurs more often in markets defined as non-collusive pre-entry. In two of three of those markets, an entrant initiates undercutting and one of the incumbents punishes in one period and reverts to full collusion in the following period. In the third market, an incumbent initiates undercutting (in period 18) and the other incumbent subsequently punishes for three consecutive periods before reverting to full collusion. This is illustrated in Group 5 of Session 2 shown in Figure 5.8. Overall, punishment is a rarely observed. This is in line with findings of the sugar cartel, discussed in Chapter 4, which existed around the 1930 in the US. Genovese and Mullin (2001) find that even though cheating occurred throughout the lifetime of the cartel, it was hardly ever met by retaliatory measures. Contrary to that, cheating was either ignored or matched. This is consistent with the behavior we observe in our experiment.

Observation 5 *Undercutting is often initiated by entrants, especially in collusive markets. In non-collusive markets, undercutting or competing by either entrants or incumbents is equally likely but it is mainly the incumbents who undercut strongly thereby causing the strong reduction in average market prices in the period after entry. Moreover, punishment occurs more often in non-collusive markets than collusive markets.*

5.5 Concluding Remarks

This research explores the effects of entry on firms' price decision and firms' incentive to coordinate their pricing strategies in concentrated markets. We show that groups that start off as duopolies and are extended to triopolies collude more compared to baseline groups that interact in groups of three from the very start of the experiment. We attribute this difference in treatments to collusion being easier to establish in smaller groups in which coordination on a common price is less difficult. Entrants who have observed the group's choices emulate their behavior upon entry. By transferring the implicit set of self-enforcing rules from the smaller to the larger group, collusion can be sustained after entry has occurred.

The results also suggest the existence of a coordination effect in collusion. This effect refers to the increased difficulty of coordination as more players need to agree on a common scheme of sharing the profits and is related to a higher level of strategic uncertainty with more players in a market. An alternative interpretation of our findings is therefore that the coordination problem can be alleviated if groups starts off in a small configuration first before they are enlarged. Our findings thereby shed some light on cartel behavior in oligopolistic industries: if firms start to interact in concentrated markets, they find it easier to coordinate their actions and to reach a collusive agreement. An entrant who knows the industry, can benefit from this and join the cartel, thereby perpetuating collusion. With our existing treatments it is not entirely possible to explain whether higher post-entry collusive levels stem from the fact that the entrant knows the industry he enters into or whether it stems from the fact that the incumbents knowing that the entrant watches signal their willingness to collude by setting higher prices pre-entry. Additional treatments need to be run in order to investigate this further.

Moreover, we identify some patterns concerning individual group behavior. The results suggest that entrants seem to imitate the mode of behavior of their group members upon entry: the majority of entrants joining collusive market collude as well thereby sustaining collusion. The majority of entrants in non-collusive markets reinforce competition by undercutting the price bid of incumbents. This gives further evidence for the self-enforcing rules argument discussed above: by watching their markets, entrant firms learn the business code of the incumbent industry and adopt the same behavior after entry. These findings also show that history matters and that there exists a path dependency for each market in our experiment. Markets that start off as collusive stay collusive after entry while markets where collusion does not establish stay more or less competitive after entry.

In addition, undercutting is often initiated by entrants, an effect which is particularly strong in collusive markets. One explanation is that entrants anticipate that the cartel price drops due to their entering. The fact that many entrants first undercut and then signal after they observe the incumbents to keep on pricing at the perfectly collusive price gives some support for this conjecture. Another possible reason for undercutting by entrants in collusive markets is that they try to recoup deviation profits as they expect collusion to break down. Finally, punishment after undercutting by other players occurs in these markets, but is rare. This is consistent with the empirical findings on the 19th century sugar cartel in the US by Genovese and Mullin (2001), where cheating was either ignored or matched.

The results presented in this chapter contribute to the existing literature on number effects such as Fouraker and Siegel (1963) as we show that the number effect is caused by a coordination problem inherent in larger groups which can be partially resolved by starting as a smaller group.

Moreover, the study presented here adds to the findings of Weber (2006), as we show that the coordination problem can also be resolved in an oligopoly game in which the Pareto-efficient outcome of the stage game does not coincide with the Nash equilibrium. Moreover, in our setting subjects gain by deviating from the Pareto-efficient outcome of the stage game, an effect which is not present in the minimum effort coordination game studied in Weber (2006).

The results may also have some relevance with regards to policy matters. In coordinated effects analysis in merger control, our findings suggest that an analysis that purely focuses on the number of players, their market shares or HHI values may not suffice. It appears that it is important to also consider how a certain markets structure has formed over time. Tacit collusion might be sustainable in larger markets provided that they grow slowly enough. If a firm enters a mature, cartelized industry and knows the market, it could well be that this entrant simply joins the cartel, internalizing the collusive agreement so that tacit collusion can be sustained. Secondly, it suggests that entry as such does not necessarily have to be a destabilizing factor for cartels as is often claimed.

Further research could be done along the following dimensions. Firstly, it is interesting to study larger groups to see whether the coordination problem could still be overcome if groups contain more than three players. There could then be several points of entry. One could set up an experiment starting with two players gradually adding entrants until a group reaches its maximum size towards the end of the session. Another line of research could test the behavior of uninformed entrants, as this could help to explain the importance of entrant's information in bringing about collusion. It would also be interesting to explore the reverse treatment of reducing an existing triopoly to a duopoly to test whether the observed effects are symmetric.[13] This might have some implications for competition policy as the reduction of the number of firms can also be interpreted as a merger. Less coordination in the reduced groups may suggest that there is a lower risk of coordinated effects due to a merger. We will explore some of these dimensions in future studies.

[13]This has been done for Cournot games in Huck et al. (2007).

Chapter 6

Cartel Law: Rationale, Enforcement and Trends

6.1 Introduction

While Chapter 4 and 5 focus on analyzing the determinants of collusion, the following two chapters explore the antitrust framework that has been implemented to curb collusion. In this chapter, we introduce the US and EU cartel law and cartel law enforcement practices. We will provide an overview which will serve as a basis for the analysis of a specific cartel detection measure which is analyzed in Chapter 7. After discussing the rationale for government intervention in cartels, the current chapter discusses the main laws used in the EU and US jurisdictions to prosecute cartels. We then examine a specific program aimed at making firms self-report their involvement in a cartel. Finally, we discuss recent developments in enforcement on both sides of the Atlantic.

Collusive practices such as price fixing, market sharing or bid rigging are illegal, both under EU and US antitrust law. The rationale for government intervention against these business practices stems from the fact that competition is artificially restricted and that prices typically remain higher than if such agreements were not in place. These manifestations of market power are inefficient as they do not lead to an optimal allocation of resources in an economy and result in a loss of welfare that is also known as allocative inefficiency.

To illustrate this, let us assume that the cartel is able to set the monopoly price. Figure 6.1 shows this graphically. The cartel acts as if it were a single entity and mimics the monopoly outcome. The monopoly quantity is given by Q_M with corresponding monopoly price given by p_M. At the perfectly competitive outcome, prices would be equal to marginal cost, given by p_N, and the corresponding equilibrium quantity would be given by Q_N. The inefficiency arises because the monopoly solution restricts the quantity supplied by $\Delta Q = Q_N - Q_M$. Due to the inflated price of the monopolized good, purchases get allocated to other industries. This substitution away from the monopolized product to an alternative product creates a misallocation of resources and from a social point of view too little of the monopolized product is produced.

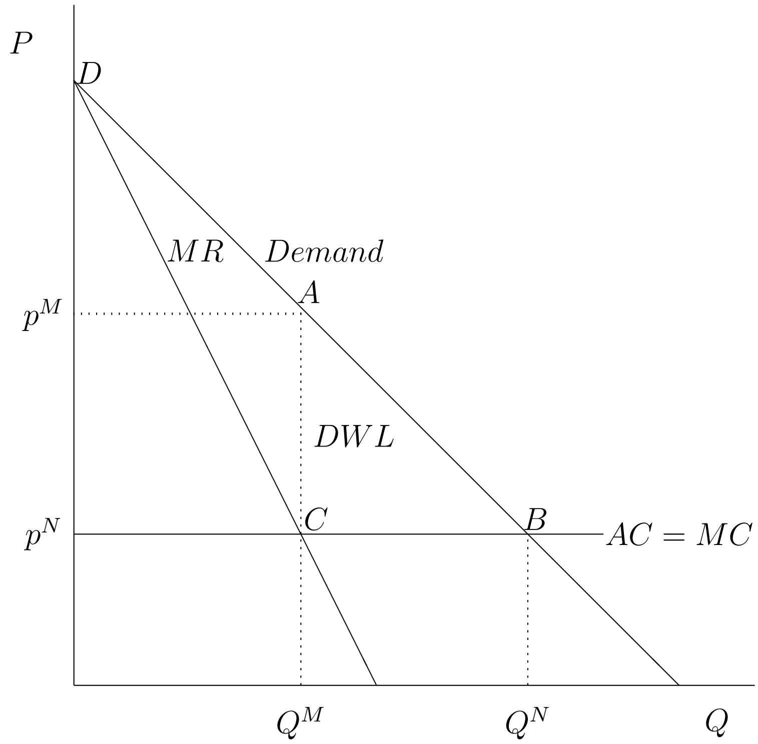

Figure 6.1: Monopoly Market with linear Demand.

Moreover, a shift from the competitive outcome to the monopoly outcome leads to a reallocation of resources away from consumers. Under competition, consumer surplus is given by the triangle DBp_N. In a monopoly, this area shrinks to DAp_M. In part, the consumer surplus is reallocated to producers, given by the area p_mACp_N. The remaining area, the triangle ABC, is a net loss however, as it is not distributed to anyone. The overall welfare loss is therefore given by the triangle ABC.

In addition to allocative inefficiency, inefficiencies may also arise because cartel members might not produce the goods and services at an efficient level, which is known as X-inefficiency.[1] Moreover, as competition in the industry is severely restricted, this may hamper product and service innovations which would otherwise take place. This loss in dynamic efficiencies might be severe, especially if the industry is characterized by frequent product innovations. Some scholars, however, argued that cartels lead to higher dynamic efficiencies as the benefits of successful innovation can be reaped for longer periods when competition is less fierce.[2] In order to curb cartel formation, governments have created legislation and institutions targeted at fighting cartels.

[1]See also Leibenstein (1966).

[2]See for instance Schumpeter (1912).

6.2 Antitrust Laws against Collusive Practices in the US and the EU

Nowadays, both the US and the EU have a comprehensive system of laws, regulations and institutions that are aimed at curbing anti-competitive agreements. In the US, antitrust enforcement has a long-standing tradition starting with the implementation of the Sherman Act in the late nineteenth century. In the EU, competition laws are comparatively young as they were only enacted with the Treaty of Rome in 1957.[3] This section briefly introduces the main laws governing agreements between firms in both jurisdictions. We then go on to discuss different tools to detect cartels which are used by competition authorities.

6.2.1 US Cartel Law

In the US, cartels are dealt with under Section I of the Sherman Act which was enacted in 1890 as a result of important transformations in the US economy.[4] Starting from the second half of the nineteenth century, the US manufacturing industry underwent tremendous change. This change was brought about by an extension of the railway system and the telegraph lines spreading throughout US territory. Other important innovations included technological advances in areas such as chemicals and advances in capital markets. All these factors helped to create a single market.

In the late nineteenth century, the US economy was hit by several economic crises which were triggered through low and fluctuating prices.[5] These were also brought about by the very same factors that led to the creation of a single market. Firms did not have to compete only locally but nationally which increased competition within industries.[6] Moreover, economies of scale and scope decreased costs and prices. In order to recoup the large investments made by many firms, they operated at full capacity to cover the sunk costs and decreased prices which led to frequent price wars.[7]

The surge of cut-throat competition made firms rethink their strategies and in an attempt to soften competition, they created cartels that entailed price and market sharing agreements. What is more, the US economy at that time witnessed a merger wave which led to the rise of large corporations.[8] The Sherman Act was a reaction to the growing number of large business corporations and cartels that came to the detriment of small businesses and final consumers who suffered from the higher prices. Section I of the Sherman Act prohibits contracts, combinations and conspiracies which restrain trade and introduces fines and prison sentences for violators. It reads:[9]

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[3]Note however that at the national level, authorities such as the German antitrust agency already had laws regulating cartels.

[4]See Viscusi et al. (2005).

[5]See Motta (2004).

[6]See Motta (2004).

[7]See Viscusi et al. (2005).

[8]See Viscusi et al. (2005).

[9]US Department of Justice (2009).

Section 1

> Every contract, combination in the form of trust or otherwise, or conspiracy, in restraint of trade or commerce among the several States, or with foreign nations, is declared to be illegal. Every person who shall make any contract or engage in any combination or conspiracy hereby declared to be illegal shall be deemed guilty of a felony, and, on conviction thereof, shall be punished by fine not exceeding $10,000,000$ if a corporation, or, if any other person, $350,000$, or by imprisonment not exceeding three years, or by both said punishments, in the discretion of the court.

The Sherman Act covers collusive agreements between firms and monopolization attempts but mergers are outside the realm of this piece of legislation. After the introduction of the Sherman Act, the US witnessed a merger wave. Indeed, this was also a strategy of firms to move into an area that was not restricted by antitrust law enforcement. The Clayton Act which was implemented in 1914, was a means to cover mergers that restrict competition. It also covers price discrimination practices and opened up the possibility for private parties to claim treble damages, that is for victims of cartels, for instance, to claim money transfers from offenders.

6.2.2 EU Cartel Law

As discussed in Chapter 2, the Treaty of Rome (1957) also formally introduced the cornerstone of European competition law. In a way, the origins of Articles 81 and 82, which deal with agreements between firms and abuses of a dominant position, respectively, can already be traced back to the Treaty of Paris enacted in 1951 that formed the European Coal and Steel Community (ECSC). The rationale for dealing with competition issues at such an early point of common European endeavors had two main sources: firstly, there was a general interest in curbing German power by guaranteeing that other European countries had access to essential resources such as coal and steel. Secondly, there was a rising belief in the notion of free competition as an instrument for an effective functioning of markets.[10] As the European Union was still in its infancy, competition law was not only a means to enhance competition as such but served the general goal of overall welfare and economic progress. Today, the primary purpose of competition law in Europe is to promote economic efficiency and market integration.

The foundations of European competition law can be found in Articles 65 and 66 of the Treaty of Paris which prohibit horizontal agreements in restraint of competition and abuses of a dominant position. As mentioned above, these principles can today be found in Articles 81 and 82. In particular, Article 81 covers four main types of economic agreements: horizontal conduct, vertical restraints, licensing and joint ventures. Article 81 reads:[11]

[10] See also Motta (2004).
[11] European Commission (2002a).

> 1. The following shall be prohibited as incompatible with the common market: all agreements between undertakings, decisions by associations of undertakings and concerted practices which may affect trade between Member States and which have as their object or effect the prevention, restriction or distortion of competition within the common market, and in particular those which:(a) directly or indirectly fix purchase or selling prices or any other trading conditions; (b) limit or control production, markets, technical development, or investment; (c) share markets or sources of supply; (d) apply dissimilar conditions to equivalent transactions with other trading parties, thereby placing them at a competitive disadvantage; (e) make the conclusion of contracts subject to acceptance by the other parties of supplementary obligations which, by their nature or according to commercial usage, have no connection with the subject of such contracts.
> 2. Any agreements or decisions prohibited pursuant to this article shall be automatically void.

The laws described in Sections 6.2.1 and 6.2.2 present the main building blocks of anti-cartel enforcement in the US and the EU. They were amended by a large number of regulations and guidelines that were introduced and modified over the years on both sides of the Atlantic. In order to detect cartels, competition agencies rely on different sources of information. Information often comes from whistleblowers, that is from employees that work for one of the cartel members. Moreover, competitors to or customers of the cartel frequently come forward and report to the cartel authorities. A more indirect way to detect a cartelized market are so-called screening test in which agencies monitor markets for suspicious firm behavior according to a predefined set of economic criteria. A channel of information that became increasingly popular since the 1990s is self-reporting by cartel members. We discuss this in detail in the next section.

6.3 Corporate Leniency Programs

Corporate leniency programs offer firms that engage in illegal agreements such as market sharing a more lenient treatment provided that they collaborate with the antitrust authority. They offer reductions in fines to those cartel members that self-report and cooperate with antitrust agencies, e.g. in delivering information about the cartel(s) in question. This implies that firms are not criminally charged for the illegal activity. This in turn reduces fines for the corporation and fines or prison sentences (under US legislation) for individuals. As these schemes often only apply for the first corporation to come forward, leniency programs create a ‘race to the courthouse’ as each firm fears that the other will apply first for leniency. Since its introduction, leniency programs have changed the landscape of traditional antitrust enforcement tremendously. Some scholars claim that this scheme is allegedly “the most effective generator of large cases”.[12] In the following, we will give a review of the leniency

[12] Spratling (1999).

programs introduced in the US and the EU, respectively and discuss their development.

6.3.1 US Corporate Leniency Programs

The first leniency program was introduced in the US in 1978. Under this scheme, cartel members were *eligible* to receive full amnesty so long as they were the *first* to self-report before the start of a formal investigation. A complete pass from criminal prosecution was not guaranteed, however, and the Department of Justice (DoJ) still had a great deal of discretion under what circumstances full amnesty was granted. Due to these shortcomings, this first scheme never became very successful in attracting self-reporting firms and the antitrust agency only collected one case per year on average. As the shortcomings of the first program became apparent, a revised scheme was developed dramatically expanding the scope of amnesty granted.[13] The current program has the following features.

Automatic leniency will be granted if the following conditions are met:[14]

1. There is no prior investigation underway and the firm is the first to come forward
2. The firm commits to promptly terminate the participation in the illegal activity
3. The firm completely collaborates with the DoJ from the point of coming forward, reports all illegal activities and provides full and continuous cooperation
4. The firm did not coerce other parties to participate in the illegal activity nor was it the ringleader or originator
5. If a firm receives full amnesty, all employees of this firm coming forward to cooperate also receive full amnesty.

Discretionary leniency will be granted if the following conditions are met:

1. Amnesty may also be granted if an investigation is already underway given that:
   - at the time the corporation comes in, the US Department of Justice does not yet have evidence against the company that is likely to result in a sustainable conviction
   - the same conditions concerning the prompt termination and full cooperation need to be fulfilled.
   - immunity will only apply should the US Department of Justice conclude that granting immunity would not be unfair to others.

[13] See U.S. Department of Justice (1993).

[14] See also Motta (2004, p.193).

Regarding the last point, the US Department of Justice considers how early the corporation reports and whether the cooperation coerced another firm to participate in the illegal activity or was the cartel leader, or the originator.

These changes were important in two respects. Firstly, the program provided certainty and transparency. It was now clear that amnesty was automatic when the firm was the first one to come forward and when no investigation had been initiated so far. Secondly, leniency was now also possible if an investigation had already started.

6.3.2 EU Leniency Programs

In the EU, the first leniency program was introduced in 1996.[15] Under the current program, the European leniency program grants fine reductions, if the following conditions are met:[16]

1. The firm has to be the first one to report information such that (a) under the Commission's view will enable it to carry out a targeted inspection in connection with the cartel, and if, at the time of the application for immunity, the Commission did not yet have sufficient evidence to adopt a decision to carry out an inspection and had not yet carried out such an inspection. (b) if immunity under (a) has not been granted to any firm involved, the Commission will grant immunity to the undertaking that is the first to submit information and evidence which will enable the Commission to find an infringement, provided that the Commission did not yet have, at the time of the submission, enough evidence to make such a finding.

2. The firm commits to terminate the participation in the illegal activity, except for what would, in the Commission's view, be reasonably necessary to preserve the integrity of the inspections.

3. The firm must cooperate fully and continuously with the Commission from the time it submits its application throughout the Commission's administrative procedure

4. The firm was not coercing other firms into the illegal activity

An important difference between the US and the EU leniency programs is that, unlike in the US, a granting of leniency does not lead to immunity from prosecution. Typically, the Commission will still adopt a decision finding an infringement but the decision will contain a section that the firm cooperated with the Commission during the procedure in order to explain the non-imposition of fines. Moreover, as the Commission does not have the right to impose penalties on individuals involved in the illegal activity, immunity obviously is not relevant.

The current EU leniency program has removed a great number of shortcomings inherent in the earlier version. The 1996 leniency notice left a lot of discretion to the Commission

[15]See European Commission (1996).
[16]See Wils (2007).

regarding whether or not leniency was granted and to what extent. This was also due to subjective wording. It was not clear for instance, what the term "instigator" exactly implied. Moreover, leniency could only be granted if the firm coming forward was the first to provide "decisive evidence of the cartel's existence." These terms were not explained properly and no advice was provided on how to interpret them. Furthermore, it was not clear to what extent immunity was granted. Full or significant leniency was guaranteed only in cases where the Commission had not already started an investigation or if it did not have substantial evidence to open a formal procedure. An applicant not knowing whether this was the case was therefore reluctant to approach the Commission. Moreover, firms only received information about the exact magnitude of the fine at the moment of the final decision, which often implied years of uncertainty. Lastly, an applicant was required to stop the illegal activity at the point it came to the Commission. This was problematic as it raised suspicion among remaining cartel members which in turn had an incentive to start destroying evidence of their activity.

Early in 2002, the Commission implemented a revision of the leniency program that alleviates many of the above-mentioned drawbacks.[17] One major change compared to the earlier note was the broadening of leniency to applicants coming forward after the formal start of an investigation. Moreover, the note was rephrased to reduce earlier semantic ambiguities. The term "instigator" was replaced by a clearer "to coerce other undertakings to participate in an infringement". What is more, applicants received a written confirmation of leniency once the requirements were met. In addition, the amount of information a firm needed to provide in order to qualify for leniency was reduced considerably. However, the Commission still required the applicant to stop the illegal activity at the point of submission of the evidence.

In December 2006, an additional revision was implemented which now constitutes the current EU leniency notice.[18] This new note provided advice by identifying more clearly what type of information the firm has to submit to be eligible for leniency. Moreover, it is possible to phrase the application in "hypothetical terms" initially. It introduced a threshold information level to immunity which requires that the information must be such that the Commission is able to carry out a "targeted" inspection. Moreover, it clarified that the firm in its initial application does not need to provide all necessary information at once but can do so in continuous cooperation with the Commission. Another important addition was the introduction of a marker system that assures the firm its place in the queue and that guarantees that the firm is granted leniency even under limited information. Finally, the 2006 notice got rid of the requirement that an applicant immediately has to cease its involvement in the illegal activity and replaces it by the requirement that a firm must end it involvement "immediately following its application except what would [..], be reasonably necessary to preserve the integrity of the inspections."

[17] See European Commission (2002b).

[18] See European Commission (2006).

6.4 Trends and Developments in US and EU Antitrust Enforcement

In the US as well as in the EU, the early laws, regulations and guidelines changed considerably over the decades following their enactment. Overall, antitrust enforcement has become more efficient and expeditious and the agencies were given more power in fighting cartels. What is more, by taking into account insights from economic theory, the laws and regulations became more fine-tuned. In this section we identify and discuss the main developments and trends that took place during the last thirty years in both jurisdictions.

In the US, there was a shift towards criminal enforcement starting in the mid-1970s.[19] The Antitrust Procedures and Penalties Act enacted in 1974, made violations of the Sherman Act a felony. Moreover, the Antitrust Procedures and Penalties Act increased the maximum corporate fine from $50,000$ US Dollars to 1 million Dollars.[20] There was a shift away from criminal cases involving corporations to criminal cases involving individuals.[21] Especially in recent years, the percentage of defendants sentenced to jail surged. In 2007, almost ninety percent of the defendants charged were sentenced to jail, an increase of 135 percent over the 1990s.[22] In 1990, the Sherman Act maximum corporate fine was increased from 1 million Dollars to 10 million US Dollars. In summer 2004, the maximum penalties for the Sherman Act were raised once more to up to 100 million Dollars for corporations and 1 million US Dollars for individuals.[23]

Together with a regime shift towards stricter prosecution and higher fines, the budget of the antitrust authority increased steadily. This is also depicted in Figure 7.1 in Chapter 7. Moreover, the DoJ concentrated more on hard-core cartels that were active internationally. This resulted in the detection and conviction of big, globally operating cartels such as the Vitamins cartel. Another major instrument in the recent success in detecting and convicting international cartels was the introduction of the leniency program discussed earlier.

The EU witnessed major institutional changes, especially since the 1990s. One of them was the establishment of the Court of First Instance in 1989, that was implemented as an appellate court for cases involving Articles 81 and 82.[24] The court was created to put greater checks and balances on the Commission's enlarged powers and responsibilities. DG COMP expanded over time and a specialized anti-cartel unit was established in 1998 within its borders concentrating on cartel detection and conviction.[25] In 2005 a specialized Cartel Directorate was introduced which grouped together about 60 cartel specialists into one single Directorate.[26] This decision was probably influenced by an earlier introduction of a leniency

[19] See Kovacic (2003).
[20] Gallo et al. (2000).
[21] Gallo et al. (2000).
[22] See Hammond (2008).
[23] See Hammond (2005).
[24] See Carree et al. (2008).
[25] See Schinkel (2007).
[26] See Guersent (2006).

program in 1996, which became more effective after its revisions in 2002 and 2006 and led to a record number of firms applying for leniency. As in the US, EU antitrust enforcement increased fines considerably in new fining guidelines that are effective since Autumn 2006. Finally, the creation of a chief economist team in autumn 2003 bolstered the in-house expertise in fighting cartels.[27]

Today, cartel prosecution in the US has reached record heights. As mentioned above, revision of the US penalty guidelines dramatically increased the magnitude of fines imposed on convicted firms. This is depicted in Figure 6.2. Between 2000 and 2007, criminal fines more than quadrupled, amounting to 630 US Dollars. Within the same time interval, the percentage of defendants sentenced to jail increased from almost 40 percent to almost 90 percent. Moreover, in the year 2007 a record number of jail days was imposed.[28] One of the major cartels detected in recent years was Hofman-La-Roche, which received a fine of 500 million US Dollars in 1999. Another major case was Korean Airlines which was sentenced to 300 million US Dollars worth of fines.[29]

Active detection alone however was not the single reason for the increase in detection and fines. One major factor in the surge of cartel prosecution was the introduction of the leniency program. The broadening of the scope of the leniency program and the increase in clarity proved to be effective. Since the revision of the program applications have increased by more than tenfold.

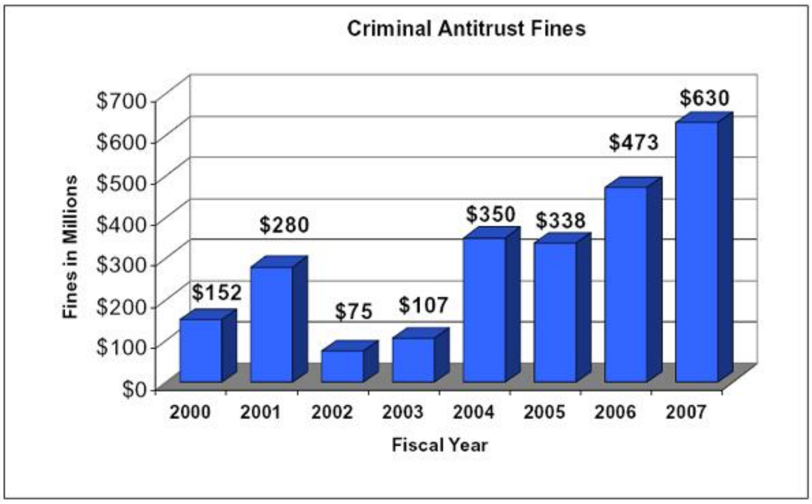

Figure 6.2: Criminal Fines imposed by the US DoJ. *Source: www.doj.gov.*

Figure 6.3 shows the trend in the number of prosecutions in the European Commission since 1962 up until 2006. The number of cases increased tremendously since the late 1990s. Moreover, the average length of case investigation has decreased considerably from 3.5 years before the 1990s to roughly two years since 1990.[30] Furthermore, there was a surge in fines

[27]See Carree et al. (2008).
[28]See Hammond (2008).
[29]See Hammond (2008).
[30]For a thorough discussion on the effectiveness of EU antitrust competition, see Schinkel (2007) and Carree et al. (2008).

starting around the year 2000. This is depicted in Figure 6.4. Another important change has been the implementation of the leniency program. Due to this new measure, EU cartel policy has been very successful in prosecuting cartels in recent years. In November 2008, for instance, four car glass manufacturers located in the UK, France, Belgium and Japan received fines totalling 1.3 billion Euros for setting up a market sharing agreement.[31] In the same year, a cartel of wax producers was fined 676 billion Euros for fixing market shares as well as prices in the industry.[32] In 2007, the highest fine for a cartel agreement was imposed to the escalators and elevators industry totalling 992 million Euros.[33]

Since the revised EU leniency note in 2002, a large number of leniency cases were processed. By spring 2007, the leniency notice generated a total of thirty-one cases. The total amount of fines collected for these cases were in excess of 6 billion Euros.[34] In almost seventy-five percent of the cases in which the investigation started after the implementation of the notice, some sort of leniency was granted to the parties involved. Since 2006, this share has been at one hundred percent.

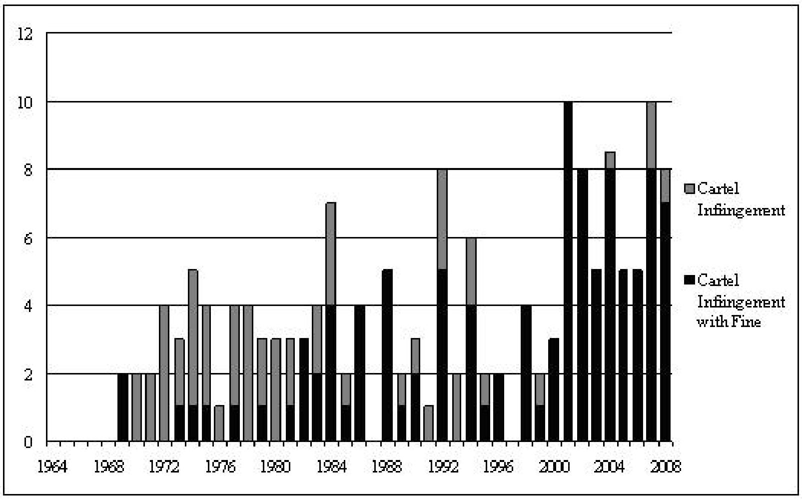

Figure 6.3: EC cartel Decisions (grey bars) and Cartel Decisions with a Fine (black bars) per year 1964 – 2008. *Source: Carree et al. (2008).*

6.5 Concluding Remarks

This chapter explained the rationale for government intervention in a market where firms collude. It discussed the main cartel legislation in the EU and the US. Specific emphasis was given to leniency programs which are today the main tool for cartel detection in competition authorities. In Section 6.4 the rising impact of cartel laws both in the US and in the EU since the last decades was discussed. As described in Section 6.2, antitrust laws where establised

[31]See IP/08/1685
[32]See Case COMP/39.181
[33]See Case COMP/E-1/38.823.
[34]See Stephan, (2009).

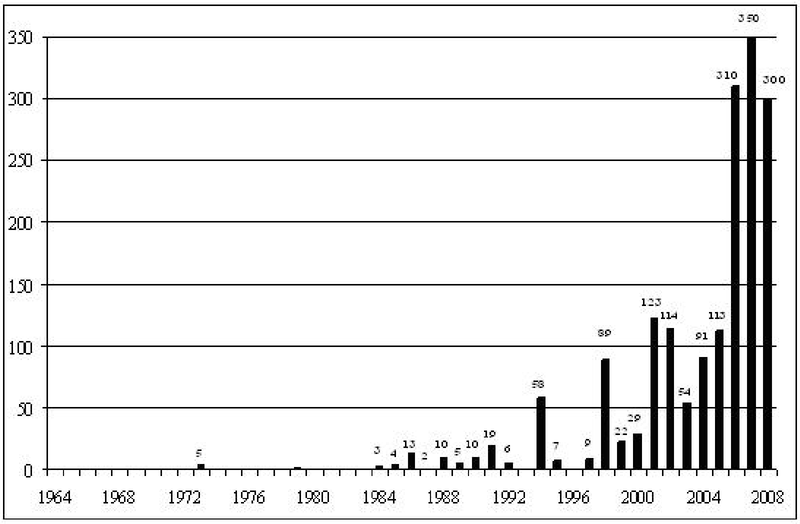

Figure 6.4: Average Total Fine per Antitrust Infringement 1964 – 2008 *Source: Carree et al. (2008).*

out of historical necessity: in the US, this happen due to the formation of trusts and an economic crisis; in the EU, they were introduced with the Treaty of Rome. Since then, they were amended by a large number of regulations and guidelines. One important addition to the set of detection tools has been the leniency program.

Due to their purported instrumental role in detecting high-profile cases, leniency programs are often seen as a poster child for breaking up secret cartels. The current Deputy Assistant Attorney General in the U.S. Department of Justice Scott Hammond, compared the program to other means of detecting cartels in 2000:

> "Over the last five years, the United States Corporate Leniency Program (Amnesty Program) has been responsible for detecting and cracking more international cartels than all of our search warrants, secret audio or videotapes, and FBI interrogations combined. It is, unquestionably, the single greatest investigative tool available to anti-cartel enforcers." (Hammond, 2000)

A similar view is held in Europe. In 2001, Mario Monti, then Competition Commissioner of the European Commission said that:

> "The leniency Notice has played an instrumental role in uncovering and punishing secret cartels." (European Commission, 2001)

The citations show that leniency programs are seen as the main instrument in breaking up secret cartels. Looking at the mere numbers of cartels that were detected by these self-reporting schemes or were leniency played a major role in convicting the firms, one might be tempted to concord with the view from policy makers. However, it is difficult to judge the success of these schemes by mere observation of market data. One major issue here is that we cannot make any inference from the pool of detected cartel to the total population of existing cartels due to informational problems. The actual effectiveness of leniency programs has been extensively explored in the academic literature. The following chapter will review some recent theoretical, empirical and experimental literature on this topic. It will show that the findings of the literature lead to a more differentiated picture of the success of leniency programs. Furthermore, we present novel analysis on the effectiveness of leniency in the context of recent cartel policy developments using a theoretical model in the second part of the following chapter.

Chapter 7

Leniency Programs: 'The Cleaning-out-the-Closet-Effect'

7.1 Introduction

In the discussion of the effectiveness of leniency programs described in Chapter 6, it is important to note that only limited inferences can be drawn from either the number of leniency applications or their characteristics.[1] After all, we only observe discovered cartels, but we don't know much about the underlying population of cartels. The class of cartels that were caught, in other words, might suffer from a sample selection bias. On this observation, Harrington and Chang (2008) model the stochastic endogenous formation of a heterogenous population of cartels, which is suitable for evaluating the effects of antitrust policy on cartel formation rates. They show that the duration of detected cartels can serve as a proxy for the effectiveness of changes in competition policy in the following way: longer durations of cartels that were detected after a policy amendment indicate a reduced cartel formation rate of the underlying pool of cartels. In general, the ultimate impact of leniency programs on cartel formation and the discovery of cartels remains an open question.

To study the question what type of cartels the leniency programs are likely to have attracted, it is important to put the yield of the leniency programs in the historical context of enforcement. Miller (2009) studies US cartel enforcement before and after the introduction of the 1993 corporate leniency program, which he treats as an exogenous shock. His time-series of indictments and information reports filed for violations of Section 1 of the Sherman Act between 1985 and 2005 reveals a spike in cartel cases directly following the introduction of the program, after which the number falls and stays below initial levels. Miller (2009) directly estimates a structural model of such "cartel discoveries" and interprets these robust findings as consistent with enhanced detection resulting from the introduction of the leniency program, followed by increased deterrence after cartels factored the destabilizing effects of leniency in when forming.

[1]This chapter is based on joint work with Maarten Pieter Schinkel and Jan Tuinstra. We thank Jeroen Kingma for excellent research assistance.

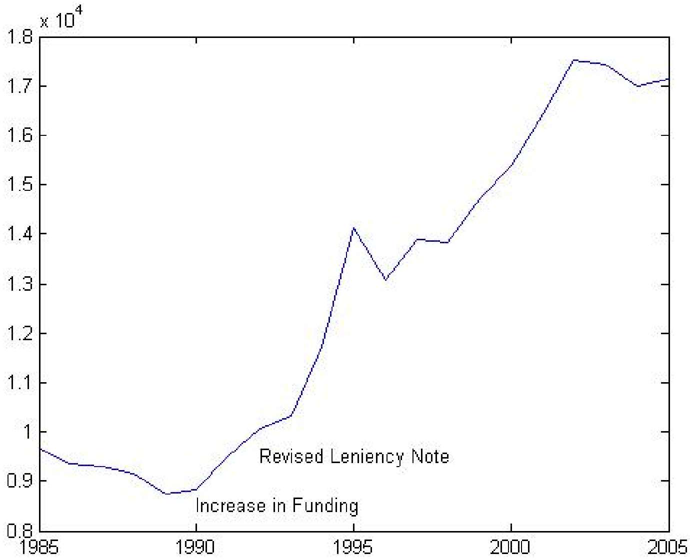

Figure 7.1: Real Funding of US Department of Justice Antitrust Division in 1985 Million US Dollars

At both sides of the Atlantic the introduction of the revised leniency programs in the early 1990's was accompanied by significantly stepped-up cartel enforcement as discussed in Section 6.4 of the previous chapter. This development appears to have slightly preceded the introduction of leniency options. In the early 1990's, funding of the DoJ's Antitrust Division was sharply increased as illustrated in Figure 7.1. Between 1990 and 1995 its budget increased by roughly 60%.[2] The division made several high-profile cartel arrests and successfully prosecuted international companies for their international cartel involvement.[3] It further received greater powers to punish cartels.[4] The European Commission followed in the mid 1990's and strengthened the enforcement of the Article 81(1) prohibition of concerted practices with the object or effect to prevent, restrict or distort competition in the common market. The Directorate General Competition was enlarged with a specialized anti-cartel unit and given greater powers to investigate and punish cartels. As a result, the number of EC cartel infringement decisions, as well as the average fine per cartel decision surged.

When leniency is unexpectedly introduced into a pool of cartels that just previously saw a discrete increase in overall enforcement efforts, an alternative interpretation of the two stylized facts reported in Miller (2009) appears. First, the initial steep increase in cartel cases directly following the introduction of the leniency program may be the less profitable, or already collapsed cartels that had been destabilized by the stepped-up cartel enforcement just before the 1993 corporate leniency program was introduced. This implies that the surge in leniency applications may also have stemmed from old cartels.

[2] See "Appropriation Figures for the Antitrust Division" at: http://www.usdoj.gov/atr/public/10804a.htm.

[3] For instance the *Aluminum Phosphide* cartel (1993) and the *Lysine* cartel (1996).

[4] In 1990, US congress considerably increased the fines for companies and the penalties for individuals. Furthermore, in 1993 the focus shifted on international antitrust violations and gave the FBI more powers to collect evidence. See Connor (2003).

Second, the finding that the number of applications some years into the program decreased below initial levels is not necessarily a proof of deterrence. Instead, cartels may still be active but forced further underground and more difficult to catch. It appears that the large number of leniency applications—a substantial part of which may be less profitable cartels—has tied up the authorities' resources available for active detection.

Starting from the observation that leniency made a large number of firms approach the antitrust authorities, this chapter analyzes which type of cartels these schemes typically attract. One contribution of the study presented in this chapter is that we take recent historical trends in antitrust enforcement into account when studying the effectiveness of leniency programs. First, there is an unexpected increase in enforcement activity, which increases the perceived probability of detection and successful prosecution.

This destabilizes some cartels, while others remain stable. Second, more rigorous enforcement is followed by the introduction of a leniency program. We categorize the share of the leniency applications into cartels that had already collapsed before the introduction of the program. We find that this fraction can be substantial. The results indicate that the number of leniency applications collected cannot simply be equated with the number of cartels detected as a result of the implementation of a self-reporting scheme. The number of applications may thus be a crude measure of the success of leniency programs and does possibly overestimate their direct effectiveness.

The remainder of this chapter is organized as follows. Section 7.2 discusses recent theoretical as well as empirical literature on the effects of leniency programs. In Section 7.3, we develop a stylized model of the recent history of US and European cartel enforcement. We then study a benchmark model of cartel enforcement without a leniency program. In Section 7.5, we analyze the effects of an unexpected increase in cartel enforcement efforts on cartel stability. In the following, the effects of an introduction of a leniency program is studied. Section 7.7 characterizes the 'cleaning-out-the-closet' effect, as the leniency program attracts a substantial number of claims from cartels that had already ceased to exist.

7.2 Literature Review

A growing theoretical literature on leniency programs has shown that leniency programs can be effective in destabilizing cartels. The possibility to defect on the cartel and simultaneously apply for leniency adds to the inherent problems of internal distrust amongst the cartel members, making collusion less attractive. Research along these lines includes Motta and Polo (2003), Spagnolo (2004), Motchenkova (2005) and Chen and Rey (2007). A common feature of these models is that they model leniency in a stationary environment in which the stage game consists of a Prisoner's Dilemma. Detection and conviction rates are independent of cartel behavior and profits from collusion and deviation are fixed.

Spagnolo (2004) finds that a leniency program can implement the first best solution and result in complete and cost-less deterrence. This is the case if there is a budget balancing constraint so that the collected fines imposed on the firms equal the reward given to the leniency applicant. Crucial in this respect is that leniency is only offered to the first firm coming forward and that reporting firms can also be offered rewards. In his model leniency is restricted to firms that provide the competition authority with information before the start of an inquiry. Spagnolo's finds that an effective leniency program (which implies that a defecting firm can increase its payoff further by also reporting) has two main effects. The direct effect is that a firm that defects and reports pays only a reduced fine. An indirect effect arises because a defecting firm that reports assures that the cartel is convicted and that any further collusion will result in higher fines for repeated offenders. This reduces the cost the firms are able to pay in order to punish first time defection as the overall value of the further collusion is reduced. Moreover, Spagnolo (2004) also shows that leniency can be exploited by firms which use the possibility to report as a threat to discipline fellow cartel members. Cartels that might otherwise be unstable, might become stable in a regime with a leniency program as firms employ these strategies.

A model focusing on the desistance effects of leniency is Motta and Polo (2003). Desistance with respect to cartels refers to the phenomenon that a cartel that has been convicted does not restart its activity for a certain period. Different from Spagnolo (2004), their research explicitly allows for fine reductions even to firms coming forward after the opening of a formal cartel investigation. They explore the optimal allocation of a given budget of the competition authority, which can be divided between detection and conviction of cartels. Moreover, the probability of conviction can stochastically change over time taking either the value one or zero. One major result of Motta and Polo (2003) is that a leniency program can never implement the first best solution. The first best solution can only be implemented through active detection in the form of higher conviction and detection probabilities and higher fines. Furthermore, the optimal leniency program should also grant fine reductions to firms that come forward if an investigation is already underway. Even though they find that this mechanism has a negative effect in that it reduces the deterrence effect due to lower expected fines, this effect is outweighed by an increase in deterrence due to more effective prosecution.

Different from Motta and Polo (2003), Chen and Rey (2007) take the detection and prosecution probability as given and explore the optimal fine reductions both pre- and post-investigation within that framework. In their model, the antitrust authority uses random investigations as their active detection method. Moreover, industries are heterogeneous as they have different collusive payoffs. They show that it is optimal to offer higher fine reductions when investigations are infrequent and not very effective. Moreover, leniency should be granted once the investigation is already underway especially if active detection is not very effective, and, contrary to earlier findings, leniency should also be given to repeated offenders.

While the models just discussed focus on corporate leniency program, Aubert, Rey, Kovacic (2006) focus on the effect of extending leniency to individuals. As in Spagnolo (2004), they also allow for rewards, both to firms and to individuals. An important feature of their model is that the introduction of the individual leniency program creates an agency problem between the firm one the one hand, and the employees on the other hand, which leads to the following effects. Firstly, since the firm now has to bribe each employee involved in the cartel in order to prevent reporting, individual leniency programs reduce the per period collusive profits thereby making collusion less stable. Moreover, allowing for individual leniency creates a complementarity in the sense that individual and corporate leniency programs taken together can induce reporting in cases where only one instrument would have been insufficient to do so. An adverse effect of individual leniency programs is that it might reduce the amount of benign cooperation within a firm since cooperation could be mistakenly been interpreted as a form of collusion and subsequently be reported. Given that the probability of making a mistake is not too high though, these schemes can indeed result in truthful reporting. However, as any employee that is fired can become a potential whistleblower, the introduction of a individual leniency programs can lead to a turnover of staff which is inefficiently low.

Motchenkova (2005) uses a model of optimal control to study the effects of leniency. In a continuous time pre-emption game, she analyzes the optimal stopping time of two firms involved in a cartel given that the antitrust authority introduces a leniency program. In her setting, there is a leading firm that applies first for leniency and gets full immunity from fines. The following firm however cannot react instantaneously to the action of the first applicant. She shows that in order to reduce cartel stability, the leniency program should be strict and the procedure to claim leniency should be confidential. The underlying mechanism of this finding is that due to the fact that the rival firm cannot react instantaneously to another firm claiming leniency, the expected future losses if the cartel is revealed are higher. The effect of leniency programs on the duration of cartels is ambigous. In cases where leniency programs are moderate and fines are proportional to the harm of the cartel, one can distinguish two different scenarios. With a high rate of law enforcement, the existence of a leniency program increases the firms' incentive to stop the cartel activity and report. Hence the duration of cartels is reduced. If fines and the rates of law enforcement are low, however, the introduction of leniency may make collusion more attractive for firms. She also shows, however, that if the antitrust authority is weak in the sense that fines as well as detection probability are low, the introduction of a leniency program may induce more collusion.

The first experimental paper to investigate the effects of leniency programs is Apesteguia et al. (2007) that is using a one-shot homogenous goods Bertrand triopoly model. They run four different treatments: in Standard, there is cartel prosecution without leniency, in Leniency, reporting firms receive a immunity or reduction of fines depending in how many firms report simultaneously, in Bonus self-reporting firms receive a reward which consists of redistributions from the fines collected from the other firms, and in Ideal, firms play the simple Bertrand game without the existence of prosecution and leniency. The results show that the leniency program reduces the average market prices in comparison to Standard.

Furthermore, the cartel formation rate reduces from 67% in Standard to 50% in Leniency. The possibility of rewards however has an adverse effect as the cartel formation rate in this treatment is hightest and average prices are higher than under leniency only. Even though this paper uses a simple and elegant approach to investigate leniency programs, it seems important to allow for learning given the complexity of the different treatments which is not possible in their one shot-framework.

Hinloopen and Soetevent (2006) overcome many of the shortcomings in Apesteguia et al. (2007) by using a repeated, homogeneous Bertrand game to study the effect of leniency programs. Furthermore, subjects are allowed to communicate and can choose whether to collude or not. They are matched in the beginning in groups of three and play the game for twenty rounds without rematching. Their experiment allows for communication at the stage before prices are chosen. In their treatment with leniency, subjects have the option to self-report after prices have been determined and have become commonly known. The experimental results show that leniency has a significant deterrence effect as cartel formation rates drop in comparison to the treatment where leniency is not an option. Furthermore, it reduces cartel duration of cartels that remain stable in the regime with leniency. Moreover, the agents undercut prices more strongly than without these programs. A desistance effect, however, does not occur in their experiment since a same fraction of firms restarts colluding after having been convicted in the treatments with and without leniency programs.

The above research models the interplay between colluding firms and a competition authority in which the latter uses both active detection and a leniency program in a stationary framework with exogenously given detection rates and fixed collusive profits. In Chen and Harrington (2007), the probability of detection and prosecution however varies over time. The probability of prosecution after detection is continuous and stochastically fluctuating. Using this setup, they find that if the self-reporting schemes are sufficiently lenient in that the fines are reduced substantially, cartels become less stable. However, if the leniency program grants smaller fine reductions, the overall effects on cartel stability are ambiguous. In this scenario, it might be optimal to only grant partial leniency. Another important finding of Chen and Harrington (2007) is that it might be optimal to set restrictions on granting leniency for firms and that given that the antitrust authority already has found enough evidence itself, leniency should not be given.

The above literature mainly finds that leniency has an overall positive effects on cartels. Recent research which is closer to the results we present in this chapter particularly emphasizes possible adverse effects of leniency programs. Leniency programs may stabilize some types of collusive arrangements, or encourage new cartels to form. In addition, they may be exploited by conspirators to make cheating less profitable thereby enhancing cartel stability. To these belong Magos (2008), Chang and Harrington (2008), Bigoni, Fridolfson and Spagnolo (2008) and Stephan (2008), which we discuss in the following paragraphs.

Magos (2008) develops a two-firm model in which there is uncertainty concerning the nature of the economy. The study focuses on the effects of leniency programs on *ex ante* deterrence in the framework of failing firms. The timing of the game is as follows: firms first decide whether they collude or not. In case they do, the game proceeds to the next stage, where firms make a decision whether they deviate or collude. After that, nature makes a draw that determines the probability that the economy is in a bad state. In the bad state, any cartel agreement collapses from period two onwards. In the good state, profits would be such that collusion is sustainable. Only after observing the state of nature, firms decide whether to apply for leniency and the competition authority detects the cartel with a certain probability. Starting from period two uncertainty disappears completely. In case of certainty, firms would internalize the existence of a leniency program and either collude and not report or not collude at all in equilibrium. In either case, one would not observe any leniency application. If there is uncertainty, however, Magos (2008) shows that firms have an incentive to report if the economy is in a bad state so leniency programs collect a lot of failing cartels. At the same time however leniency increases deterrence as firms face a prisoner's dilemma and triggers a race to the courthouse effect that dominates the reduction in fines. In other words, anticipating that the other firm would report under uncertainty once the cartel has been formed, each firm is reluctant to engage in the collusive agreement to start with.

Chang and Harrington (2008) extend the model of Harrington and Chang (2008). In the latter study, cartels form and collapse according to a Markov process. When given the opportunity, cartels are set up. They can also collapse, either through detection by a antitrust authority or due to an adverse economic shock. Harrington and Chang (2008) extend this model by introducing a leniency program and by imposing an implicit resource constraint, in the sense that the higher the caseload is, the lower the conviction probability on the non-leniency cases becomes. The likelihood that a cartel is convicted therefore depends inversely on the caseload of the antitrust authority by means of an implicit resource constraint. Moreover, the cartel authority has some flexibility concerning the choice of policy instruments and can either catch cartels through active detection or through leniency program. They show that if the competition authority has flexibility in terms of enforcement, less focus will be given on non-leniency cases. They also show that leniency programs can both lower or increase the frequency of cartel formation depending on the mix of parameters. Moreover, weak cartels with low collusive profits get destabilized by the introduction of leniency, whereas stable cartels have a longer duration and continue to be formed. The net effect is a lower cartel *formation rate* but a longer *duration* of cartels that still form.

Bigoni, Fridolfson and Spagnolo (2008) study the effects of leniency in an experimental setting. They extend the model of Hinloopen and Soetevent (2006). Their study differs in a couple of dimensions from Hinloopen and Soetevent (2006). First, they allow for rewards. Second, firms can report and set prices before this information becomes common knowledge. Third, they use a differentiated Bertrand model. Their study shows that fines in a regime without leniency have a deterrence effect but may also lead to higher prices. Furthermore, the effects of leniency programs are ambigous as they not only lead to lower rates of cartel formation but also to higher average prices in the industries were a cartel survives the introduction of the leniency program. Moreover, almost complete deterrence is achieved in the leniency treatment that allows for rewards. Excluding the ringleader from rewards however partially neutralizes this deterrence effect and pushes up average prices. Lastly, other than Hinloopen and Soetevent (2006), they identify a significant desistance effect of leniency programs.

Stephan (2008) studies the European leniency cases since the introduction of the program in 1996 until April 2007, to test the purported success of the scheme. He shows that the 1996 leniency note collected mainly cases that were either already investigated in the US or simultaneously investigated both in the US and the EU. Only eight of the twenty-three cases (roughly thirty percent) were cases only involving an EU investigation. It is not unreasonable to assume that it was mainly the US that was instrumental in uncovering the other cases. Firstly, US law treats collusion as a criminal offense so individuals can expect to be held personally responsible. Managers involved in the cartel fear to lose financially as well as in terms of personal freedom as prison sentences are possible under US law. This provides a strong incentive for individuals of those firms to self-report. Moreover, under the US system firms are guaranteed some degree of anonymity which is not provided in the EU. Lastly, the US leniency notice assures an additional swift and clean procedure for firms through their plea bargaining system. It also appears that a number of European Commission investigations on international cartels involving leniency had started after information on investigations into the same cartel by the US authorities had already been in the American popular press. The Sorbates cartel, for example, was already under investigation of the DoJ well before Chisso came forward to the European Commission in exchange for leniency. Moreover, a number of cartels had already broken down at the point a firm decided to approach the Commission. To these belong the Belgian Brewers cartel, the Carbonless Paper cartel and all eleven cases of in the chemical industry that had been collected by April 2007. In the Belgian Brewers and the Carbonless Paper cases, the leniency applicant self-reported half a year and one year after the collapse of the cartel, respectively. Lastly, a vast majority of the cases collected in the EU were confined to a single industry, namely the chemicals sector.

Overall, these studies show that leniency programs may have considerable adverse effects. Our study is similar to the works of Motta and Polo (2003), Spagnolo (2004) and Magos (2008) as we take a repeated oligopoly model as a conceptual framework to study the effect of leniency programs. Different from their work, however, we embed recent antitrust developments in the form of two policy shocks into this framework. Moreover, we illustrate the findings using numerical examples. Other than Chang and Harrington (2008) we do not present an overall model of the effects on leniency programs on deterrence or on desistance as in Motta and Polo (2003). Rather, the analysis focuses on the identification of one central phenomenon, which is the leniency applications of collapsed cartels in this setting, an effect which can be considerable depending on the parameter mix. In the following section, we present the basic framework of the model.

7.3 A Stylized Model of Cartel Enforcement

Consider an economy with N separate markets $i = 1, \ldots, N$. Each market consists of $n_i \geq 2$ identical firms. That is, firms within a market are symmetric and produce with the same technology. Moreover, firms apply a common discount factor δ in each market. No firm is active in more than one industry, and we do not allow firms to exit or enter in or across markets. We refer to a representative firm in market i as firm i.

Conditions for collusion vary across markets, so that it is more attractive to form a cartel for firms that operate in some markets than it is for firms active in others. These variations relate to differences in the number of competing firms, volumes and (monopoly) price-cost margins, that is, in the elasticity of industry demand.

When colluding, all firms use the same set of strategies to form and sustain a cartel, within and across industries. The interaction between the firms within a market is modeled as a discrete, infinitely repeated game. In each period, each firm decides to either compete, collude, or, when the market colluded in the previous period, defect from the cartel. Under these conditions, within each industry each firm faces the same trade-offs in deciding whether or not to join a cartel. Should a cartel form in a certain market, it will therefore include all the firms in that market.

Firms play grim trigger strategies, so unilaterally undercutting the collusive price level is immediately followed by reversion to competition for ever after as discussed in Chapter 4. This implies that at any point in time, each market is in one of three possible states: either all firms compete, or all firms collude, or the industry is in the single transition period after a unilateral price defection, from collusion to competition. The per period payoffs associated with competing (superscript 'n' for Nash), colluding (superscript 'coll', for colluding) and unilaterally defecting the cartel by undercutting the cartel price (superscript 'd' for defecting) are denoted by π_i^n, π_i^{coll} and π_i^d, respectively, where $\pi_i^d > \pi_i^{coll} > \pi_i^n$.

7.3.1 Stages in Competition Law Enforcement

The timing of the game is as follows. First, the antitrust authority sets its budget, which determines the detection probability β. In addition to that, the authority penalizes a discovered cartel with a fixed fine of F and allows for leniency by reducing the fine by r for reporting cartels. After having observed the enforcement regime, firms decide whether to compete, collude or defect.

The agency starts off with a given budget and no leniency program (Phase I). It then unexpectedly increases its cartel enforcement efforts (Phase II) which translates into a higher detection probability. Shortly after, this is followed by the unannounced introduction of a leniency program (Phase III).

For the purpose of our analysis, we assume that the perceived probability of detection and conviction is the same across industries, but varies under different enforcement regimes. We distinguish three levels. The basic probability of detection when all firms in an industry collude is $\beta \in [0, 1]$, which is a increasing function of the budget that the antitrust authority allocates to discovery activities.

If at least one firm defects from the cartel agreement and undercuts the agreed cartel price, the perceived probability of detection of all cartel members increases for a period to $\beta^d = \lambda_d \beta$. This may reflect turmoil in an industry, for instance, in the form of sudden decreases in prices from long-term levels, which attracts the attention of the antitrust authority. Price wars can trigger targeted inspections and thus increase the risk of exposure for all firms in the industry for a given period of time. Note that β and λ_d should be such that $\beta\lambda_d \leq 1$.

If a cartel collapses in a period but is not detected in that period it still faces a positive risk of being detected in the following period. We assume that a cartel that dissolved in period t faces a perceived probability of detection in period $t + 1$ of $\beta^o = \lambda_o \beta$ where $0 \leq \lambda_o \leq 1$, where 'o' stands for 'old cartel'. After period $t + 1$, the probability of detection collapses to zero. Hence, the detection probabilities are given by $0 \leq \beta^o \leq \beta \leq \beta^d \leq 1$ and these probabilities are perceived commonly by all firms. This setup captures that it is often more difficult to successfully prosecute members of an old cartel that is no longer in operation and of which direct and indirect evidence has gradually faded or been erased.[5]

A successfully prosecuted cartel is fined an amount F, which for simplicity we assume is independent of the volume of affected commerce, the duration and the harmfulness of the infringement. Under their leniency programs, competition agencies can award reductions of the imposed fines, depending on the order in which and the extent to which firms cooperate in the investigation. We assume that a cartel always creates sufficient hard evidence with each individual firm involved to successfully apply for leniency. Let r be the percentage by which the original fine is reduced if leniency is granted—that is, $r = 1$ if a company receives full amnesty.

7.4 Cartel Enforcement without Leniency

In this section, we study the stability of cartels under a constant enforcement regime (β, F). If an industry competes, the expected discounted profits of each firm i are given by

$$V_i^n = \frac{\pi_i^n}{1 - \delta}. \tag{7.1}$$

If firms instead conspire to raise prices, the expected discounted profits of collusion for each firm i would be

$$V_i^{coll} = \pi_i^{coll} - \beta F + \beta\delta V_i^n + (1 - \beta)\delta V_i^{coll}, \tag{7.2}$$

in which $\pi_i^{coll} - \beta F$ is the expected per-period profit of collusion and $\beta\delta V_i^n + (1 - \beta)\delta V_i^{coll}$ are the expected future profits from collusion depending on whether the firm gets detected

[5]The assumption that older cartels are harder to prosecute is made in different forms in the literature. Motta and Polo (2003) and Spagnolo (2004) also assume full information decay after one period. Harrington (2004) and Schinkel et. al. (2008) assume a continuously decreasing probability of success in litigating for private damages.

in the current period, so that it reverts to competition thereafter, or not. Rearranging (7.2) gives

$$V_i^{coll} = \frac{\pi_i^{coll} + \beta(\delta V_i^n - F)}{(1-(1-\beta)\delta)}. \tag{7.3}$$

Clearly, it only pays to form a cartel if the expected payoffs from collusion are greater than the expected payoffs from competition, that is, if $V_i^{coll} > V_i^n$, which reduces to

$$\pi_i^{coll} - \pi_i^n > \beta F. \tag{7.4}$$

Hence, cartels are profitable, if the per-period illicit gains over the competitive profits are higher than the expected fine.

Once in a cartel, each firm has the option to defect. The expected discounted payoff from defection for each firm i is

$$V_i^d = \pi_i^d - \lambda_d \beta F + \delta V_i^n - \delta(1-\lambda_d\beta)\lambda_o\beta F. \tag{7.5}$$

In equation (7.5), the term $\pi_i^d - \lambda_d\beta F$ gives the expected period profit of deviating from a collusive agreement. As a cartel can only be convicted one period after its breakdown, the expected continuation payoffs from deviating are given by $\delta V_i^n - \delta(1-\lambda_d\beta)\lambda_o\beta F$. The first part, δV_i^n, gives the continuation profits after a firm has deviated and the cartel has broken down. The second part of the expression, $-\delta(1-\lambda_d\beta)\lambda_o\beta$, gives the expected fine for a firm which is not caught in the period it defects but in the period afterwards when the cartel has already collapsed. Note that, as we assumed earlier, once a firm deviates this triggers infinite reversion to the Nash outcome.

Note that it is the price war that follows unilateral undercutting that attracts the attention of the antitrust authority to the industry and raises the probability of detection. If firms would instead quietly leave the cartel and prices remained unaffected, the probability of detection would stay at β for one period, after which it would drop to β^o and then to zero by the discounting of the evidence. It can therefore be optimal for each cartel member to withdraw from the conspiracy yet refrain from undercutting the cartel price. This effect may sustain the cartel price level as a result of unilateral actions, without the need to coordinate.[6]

In order to specify under what conditions defection without undercutting the cartel price is optimal, we need to look at the payoffs of such a strategy. That is, the expected payoff of withdrawing from the cartel without undercutting it is given by

$$V_i^s = \pi_i^n + \delta V_i^n - \beta F - \delta(1-\beta)\lambda_o\beta F,$$

or a single period of normal expected cartel level profits, $\pi_i^n - \beta F$, followed, with probability $(1-\beta)$, by a low probability of discovery, resulting in expected fine $\lambda_o\beta F$ and the discounted

[6]This effect was pointed out in the context of private antitrust damages claims in Harrington (2004).

stream of competitive profits thereafter. The payoff V_i^s is strictly smaller than V_i^d if

$$\pi_i^d - \pi_i^n > (\lambda_d - 1)(1 - \beta\delta\lambda_o)\beta F \tag{7.6}$$

We assume in the following that equation (7.6) is always satisfied. A firm will therefore always prefer to defect when its stops its participation in the collusive agreement. The above findings lead to the following proposition.

Proposition 3. *In the absence of leniency programs, cartels are unstable in markets in which*

$$\pi_i^d \geq C_1 \equiv \frac{1}{1-\kappa}[\pi_i^{coll} - \kappa\pi_i^n - \beta F] + [\lambda_d + \delta\lambda_o(1 - \lambda_d\beta)]\beta F, \tag{7.7}$$

where $\kappa \equiv (1-\beta)\delta$

Proof. Each cartel member will find it profitable to defect from a collusive agreement whenever $V^d > V^{coll}$, or substituting, whenever

$$\pi_i^d + \delta V_i^n - \beta[\lambda_d + \delta\lambda_o(1 - \lambda_d\beta)]F > \frac{\pi_i^{coll} + \beta(\delta V_i^n - F)}{(1-(1-\beta)\delta)}.$$

Rearranging and simplifying this constraint gives condition (7.7). □

Intuitively, Proposition 3 tells us that cartels can be stable under market conditions in which the per-period gains from collusion are high enough and the expected fines are sufficiently low. Likewise, deviation from a collusive agreement is encouraged by a decreasing risk of being successfully prosecuted for past cartel involvement, and discouraged when the risk of detection when a cartel member deviates is higher. To illustrate Proposition 3, we present a numerical example in Figure 7.2.[7] The different markets in the economy are characterized by different combinations of instantaneous cartel- and defection profits. Note that only the area above the 45-degree line is relevant, as naturally $\pi_i^d > \pi_i^{coll}$.[8]

To analyze the implications of Proposition 3, it is insightful to analyze some comparative statics. We first separately examine a change in $\lambda_0, \lambda_d, \delta$ and F on the incentive constraint in equation (7.7). In Proposition 4, we look at the overall effect of an increase in detection on cartel sustainability.

Proposition 4. *An increase in the detection probability of a terminated cartel* λ_o *and an increase in the detection probability of an active cartel* λ_d *will make collusion easier to enforce. An increase in fines* F *will stabilize collusion if:*

$$\lambda_d < \frac{1 - \delta\lambda_o(1-\kappa)}{(1-\delta\lambda_o)(1-\kappa)}. \tag{7.8}$$

[7] The parameter values for the graph are given by $\beta = 0.1$, $\delta = 0.95$, $\pi^n = 0$, $\lambda_2 = 2$, $\lambda_0 = 0.5$, $F = 1$.

[8] Note in addition that all firms must have found it profitable to collude in the first place, so that $V_i^{coll} > V_i^n$, or $\pi_i^{coll} - \pi_i^n > \beta F$. This implies that $\pi_i^{coll} > 0.1$.

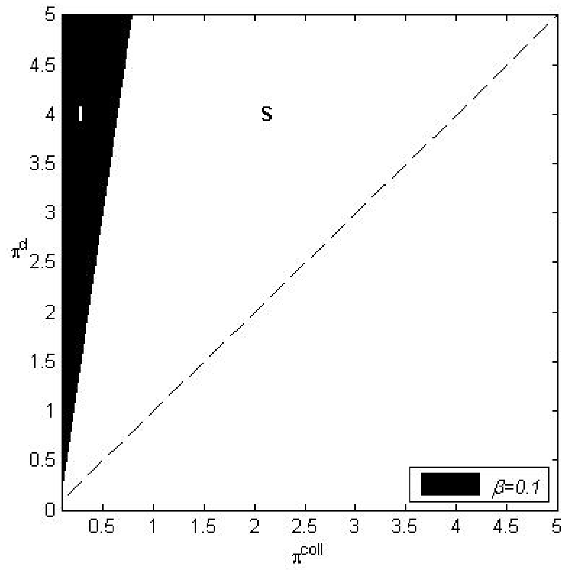

Figure 7.2: Cartel (In-)Stability in Regime with low Detection Probability.

Furthermore, if firms get more patient (if δ goes up), this will make collusion easier to enforce.

Proof. First, the partial derivatives of equation (7.7) with respect to λ_o and with respect to λ_d are given by

$$\frac{\partial C_1}{\partial \lambda_o} = \delta(1 - \lambda_d\beta)\beta F \geq 0,$$

and

$$\frac{\partial C_1}{\partial \lambda_d} = (1 - \delta\lambda_o\beta)\beta F > 0.$$

The effect of an increase in fines on the ICC in equation (7.7) is ambiguous however:

$$\frac{\partial C_1}{\partial F} = -\left(\frac{1}{1-\kappa} - \lambda_d - \delta\lambda_o(1 - \lambda_d\beta)\right)\beta, \tag{7.9}$$

which could be positive or negative. It is easy to show that an increase in F will slacken the incentive compatibility constraint if equation (7.8) holds. The effect of of $\frac{\partial C_1}{\partial \delta}$ can be reformulated as:

$$\pi_i^{coll} - \pi_i^n \geq \left(1 - \frac{\lambda_o(1-\kappa)^2(1-\lambda_d\beta)}{(1-\beta)}\right)\beta F. \tag{7.10}$$

which always holds due to (7.4). □

Proposition 4 implies that, both an increase in the perceived detection probability of a terminated cartel λ_o and an increase in the perceived detection probability of a deviating firm make collusion more stable as it slackens the incentive constraint of the cartel. In other words, as the detection rates increase, breaking out of a collusive agreement becomes less attractive. In this sense, a stepped up enforcement policy has the paradoxical effect of stabilizing a cartel.[9] The effect of an increase in fines is ambiguous. As $\lambda_o \to 1$, for instance, an increase in fines will stabilize collusion. As $\beta \to 1$, however, an increase in fines will destabilize collusion. The next section analyzes the effects of an overall increase in the detection probability on cartel stability.

7.5 Stepped up Cartel Enforcement

Now consider Phase II in our representative regime, in which the competition authority (unexpectedly) makes cartel enforcement a higher priority, increases its enforcement budgets thereby increasing the probability of detection but still does not have a leniency program. This shock affects the payoff from both colluding and defecting in equations (7.3) and (7.5) respectively. The payoff from colluding always decreases, as

$$\frac{\partial V_i^{coll}}{\partial \beta} = -\frac{\delta(\pi_i^{coll} - \pi_i^n) + (1-\delta)F}{[1-\delta(1-\beta)]^2} < 0. \tag{7.11}$$

The effect of an increase in β on the defection payoffs is less clear-cut. Only for sufficiently high values of δ and λ_o will an increase in the detection probability lead to an increase in the defection payoffs. Typically, however, an increase in the detection rate will make it less appealing to defect. To see this, note that

$$\frac{\partial V_i^d}{\partial \beta} = (\delta\lambda_o(2\lambda_d\beta - 1) - \lambda_d)F, \tag{7.12}$$

so that an increase in β has ambiguous effects on the defection payoffs. The overall effect of an increase in detection efforts on the incentive to deviate as analyzed in Proposition 3 is therefore also ambiguous. This of course will depend on the relative changes in the payoffs of defection and collusion. Should V_i^{coll} (V_i^d) be more sensitive to changes in the perceived detection probability β than V_i^d (V_i^{coll}), an increase in β might indeed destabilize (stabilize) collusion. The following proposition analyzes formally under which conditions an increase in the detection rate β makes it harder to sustain a collusive agreement. Intuitively, an increase in β decreases the collusive payoffs. Moreover, it increases the probability of getting caught after defection, as $\lambda_o\beta$ and $\lambda_d\beta$ increase.

Proposition 5. *An increase of the detection probability β makes it harder for an industry to sustain a collusive agreement (or equivalently slackens the ICC given in equation (7.7), whenever $F \geq F^*$ where*

$$F^* = -\frac{\delta(\pi_i^{coll} - \pi_i^n)}{1-\delta+[1-\delta(1-\beta)]^2[\delta\lambda_o(2\lambda_d\beta - 1) - \lambda_d]} \tag{7.13}$$

.

[9] See also Mc Cutcheon (1997) and Harrington (2004) for an analysis of adverse effects of antitrust laws on cartel stability.

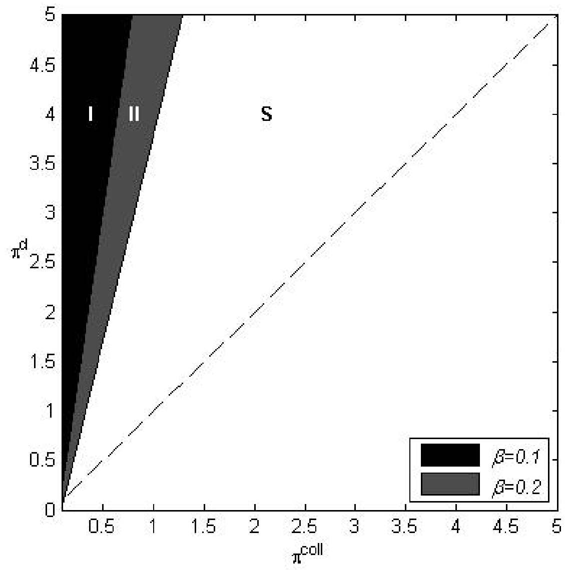

Figure 7.3: Cartel (In-)Stability in a Regime with a high Detection Probability.

Proof. The ICC in equation (7.7) will become stricter indicating that it becomes harder to sustain a cartel, if $\frac{\partial V_i^d}{\partial \beta} > \frac{\partial V_i^{coll}}{\partial \beta}$ or whenever

$$(\delta\lambda_o(2\lambda_d\beta - 1) - \lambda_d)F > -\frac{\delta(\pi_i^{coll} - \pi_i^n) + (1-\delta)F}{[1-\delta(1-\beta)]^2}$$

. Rearranging and simplifying gives Proposition 5. □

Let us now look at the implications of Proposition 5. Given that F^* is negative, Proposition 5 will always hold and an increase in the detection rate will have the desired effect of destabilizing collusion. The numerator of equation (5) is positive by definition. A sufficient condition for the denominator to be positive is:

$$\lambda_d \geq \frac{\delta\lambda_o}{2\delta\lambda_o\beta - 1}. \tag{7.14}$$

In order to rule out the cases where an increase in β leads to more collusion, we will assume from now on that (7.14) holds.[10] In Figure 7.3, we apply the same parameter values as in Figure 7.2 and increase the detection probability.[11] An increase of β widens the area of unstable cartels from I to II.

7.6 Introduction of a Leniency Program

This section examines the effect of an introduction of corporate leniency programs on firms incentives to cheat on a collusive agreement. Such programs allow fine reductions if firms

[10]See also Harrington (2004), Section 5, for an analysis of perverse effects of antitrust policy.

[11]The parameter values are given by $\beta = 0.2$ and as before $\delta = 0.95, \pi^n = 0, \lambda_2 = 2, \lambda_0 = 0.5, F = 1$.

cooperate with the antitrust agency and provide the agency with enough evidence to convict the cartel. We assume that the firm has to be the first to come forward in order to be eligible for amnesty. In case two or more firms claim leniency simultaneously, we assume that the leniency discount is assigned randomly to only one of the applicants. Obviously, if a cartel member decides to defect and leniency is available, that firm will apply for the program. Therefore, the expected profit of defecting and claiming leniency V^{dr} is given by:

$$V_i^{dr} = \pi_i^d - (1-r)\,F + \delta V_i^{coll} - C. \tag{7.15}$$

where $(1-r)\,F$ is the expected amount of the original fine that still has to be paid under leniency and C is a given cost of preparing a leniency application, which can include legal fees. Note that the expected payoff of reporting a cartel given by (7.15) is increasing in the fine discount granted (lower $(1-r)$) and is increasing in the deviation payoffs π^d. As expected, the higher the cost of leniency applications, the lower a firm's incentive to apply for the program. We can now derive conditions under which introducing a leniency program a short period of time after increasing enforcement efforts adds to the destabilization of cartels.

Proposition 6. *At a detection rate β, a leniency program will destabilize cartels that were not already destabilizes though the increased in the detection probability in Phase II if*

$$(1-r)\,F + C < \pi_i^d - \frac{1}{1-\kappa}(\pi_i^{coll} - \kappa\pi_i^n) + \frac{\beta}{1-\kappa}F \leq (\lambda_d + \delta\lambda_o(1-\lambda_d\beta))\,\beta F. \tag{7.16}$$

Proof. Given that we fix the detection rate, a firm would have an incentive to apply for leniency whenever $V_i^{dr} > \max(V_i^{coll}, V_i^d)$. Since we would like to find the conditions under which a leniency program destabilizes cartels that were stable under the benchmark enforcement regime, it needs to hold that $V_i^{coll} > V_i^d$. This implies that equation (7.7) of Proposition 3 has to be violated, which gives us the RHS of inequality (7.16) in Proposition 6. The other relevant incentive compatibility constraint that must hold in order to destabilize additional cartels through the introduction of leniency is $V^{dr} > V^c$ or substituting $\pi_i^d - (1-r)\,F + \frac{\delta}{1-\delta}\pi_i^a - C > \frac{\pi_i^{coll} + \beta(\delta V_i^n - F)}{(1-(1-\beta)\delta)}$. Rearranging this latter expression gives the LHS of inequality (7.16). □

Equation (7.16) shows that high fine reductions (high r), low costs of preparing a leniency application (low C) and a high probability of detecting an already collapsed cartel (high λ_o) will make it more attractive for a firm to come forward. The effects of the introduction of a leniency program on the stability of cartels is illustrated in Figure 7.4.[12] As a reaction to the implementation of a self-reporting mechanism, more cartels are being destabilized as shown by a further outward shift of the diagonal to the lower-left (indicated by area III). In

[12]We used the same parameter values as in Figure 7.4, so that $\beta = 0.2$, $\delta = 0.95$, $\pi^n = 0$,$\lambda_2 = 2$, $\lambda_0 = 0.5$, $F = 1$. In addition, we have specified $C = 0, r = 1$.

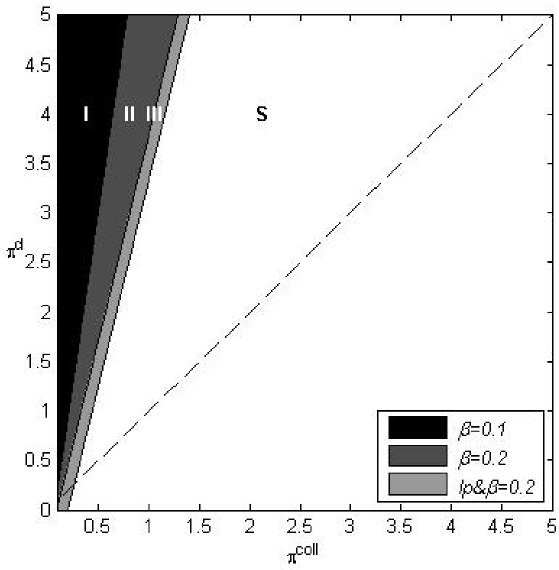

Figure 7.4: Cartel (In-)Stability in a Regime with Leniency Program and a high Detection Probability.

other words, area III depicts all additional cartels that are destabilized by the introduction of leniency. Note that in this example more cartels are being destabilized through the increase in the perceived risk of getting caught than through the subsequent introduction of leniency.

7.7 'Cleaning-out-the-Closet'

As the leniency program is implemented immediately following the stepped up enforcement in Phase II, leniency applicants can be of two types: firstly, they can stem from the pool of cartels that remained stable in Phase II and collapsed only after the introduction of leniency. Secondly, they can stem from the pool of cartels that collapsed in the previous period due to the increased in enforcement effort in Phase II. This is due to the fact that collapsed cartels can be detected up to one period after their demise. Due to this residual risk of detection, members of collapsed cartels have an incentive to apply for leniency for their participation in a cartel that already had ceased to be active. We refer to this strategy as 'cleaning-out-the-closet'. In the following we study the possible ramifications of such a strategy.

Let us explore the payoff of applying for leniency of a cartel member involved in a collapsed cartel. The payoff of reporting a terminated cartel is given by

$$V_i^r = V_i^n - (1-r)\,F - C. \tag{7.17}$$

As the cartel is already terminated, cartels receive a payoff of V_i^n. The remaining fine that has to be paid is given by $(1-r)F$ which equals zero under full amnesty. The payoffs of reporting increase in the amnesty granted and decrease in the costs of filing for leniency. On the other hand, the payoff of not claiming leniency for an old cartel is denoted by V_i^{nr} and is given by

$$V_i^{nr} = V_i^n - \lambda_o \beta F. \tag{7.18}$$

An firm which decides not to come forward still faces the residual risk of being detected as a collapsed cartel. The expected costs of this strategy are given by $\lambda_o \beta F$.

The following proposition shows under which conditions a firm has an incentive to file for leniency for a terminated cartel.

Proposition 7. *A firm will claim leniency for a cartel which already broke up in the past whenever*

$$\lambda_o \beta F \geq (1 - r) F + C. \tag{7.19}$$

Proof. A firm has an incentive to report an already collapsed cartel whenever $V_i^r > V_i^{nr}$ or substituting whenever

$$V_i^n - (1 - r) F - C \geq V_i^n - \lambda_o \beta F.$$

Rewriting yields equation (7.19). □

It is interesting to see under which conditions, the 'cleaning-out-the-closet' effect described in Proposition 7 might arise. Looking at equation (7.19), in cases where the cost of filing a leniency application are close or equal to zero, a firm will always want to report an already terminated cartel whenever the expected fine of not reporting is greater than the expected fine of reporting a collapsed cartel. Should C be positive, the critical fine necessary to make reporting of a collapsed cartel attractive increases in the cost of filing a leniency application and decreases in the risk of getting caught for an old cartel as equation (7.19) can be reformulated as $F > \frac{C}{\lambda_o \beta - (1-r)}$. As expected, the critical fine F also decreases in the reduction in the fine granted. Summarizing, in cases where $C > 0$, an enforcement regime with high reductions in fines, a high detection rate and low administrative costs to claim leniency gives firms that were involved in a recently collapsed cartel an incentive to file for leniency. The 'cleaning out the closet'-effect is illustrated in Figure 7.4. As the figure is drawn for the case of full amnesty in case the leniency program exists ($r = 1$) and as there is a positive risk of getting detected for a terminated cartel ($\lambda_o \beta \neq 0$), all cartels that collapsed due to the increase in the perceived risk of detection in Phase II will have an incentive to claim leniency. In other words, a leniency program under these circumstances would not only collect leniency claims of still operating cartels (region III in Figure 7.4) but also those of cartels that were destabilized in the period before due to the increase in detection effort (region II in Figure 7.4). For the example in Figure 7.4, of all the leniency claims that are collected (areas II plus III) only 29% would be claims of active cartels.[13]

[13]We assume here that markets are uniformly distributed over the triangle with the endpoints $(0, 0), (0, 5), (5, 5)$.

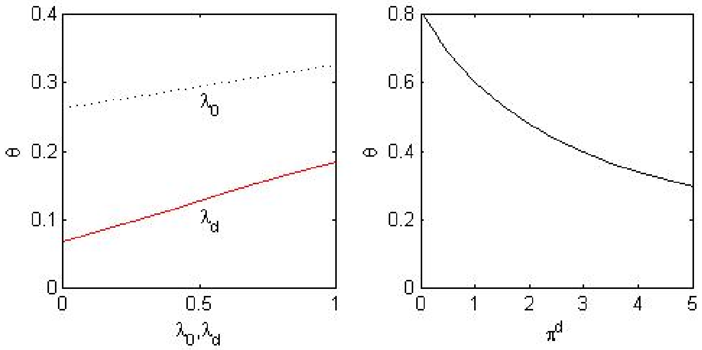

Figure 7.5: Comparative Statics of θ.

It is insightful to look at how the number of active cartels claiming leniency over the total number of leniency applications changes as the parameters of the model change. Assuming $C = 0$ and $r = 1$, any former cartel member whose cartel has collapsed in the previous period, has an incentive to claim leniency for a collapsed cartel. In this scenario, let $\theta = \frac{number\ of\ active\ cartels\ claiming\ leniency}{total\ number\ of\ leniency\ applications}$. The parameter θ can therefore be interpreted as a measure of effectiveness in detecting active and still harmful cartels. In Figure 7.4, that is, θ is equal to the area III (active cartels) divided by the sum of areas II (terminated cartels) and III (active cartels).

The higher θ, the higher the percentage of active cartels over the total leniency applications and the more effective a leniency program is in busting harmful cartels. The graphs in Figure 7.5 show the comparative statics between the effectiveness of leniency programs θ and the detection probability of collapsed cartels, deviating firms and deviation profits as given by λ_o,λ_d and π_i^d, respectively.

Remember that an increase in λ_o and λ_d will make deviation less profitable. As only the curves separating areas I and II and areas II and III are depending on λ_o and λ_d, an increase in either λ_o or λ_d, will shift these curves inwards. Areas I and II therefore decrease. The payoff from collusion given by (7.3) however is independent of λ_o. As a result, area III increases. This in turn increases the share of active cartels applying for leniency given by θ.

Intuitively, as the risk of getting caught for an old cartel increases, there is less incentive to defect in Phase II when the detection is stepped up, which stabilizes cartels *ceteris paribus.* This means that in the regime without a leniency program, less cartels are destabilized (area I as well as area II decrease). Once a leniency program is introduced, relatively more active cartels are destabilized and therefore θ goes up.

Summarizing, a higher risk of getting caught for a terminated cartel λ_o and a higher risk for getting caught when deviating λ_d decreases the share of terminated cartel that are collected by a leniency program. The right graph of Figure 7.5 shows the relationship between θ and π_i^d. It shows that the share of collapsed cartels is increasing in the payoff from defecting. Looking at Figure 7.4, as π^d increases we see that area II increases relatively faster than area III which pulls down the value of θ and thereby increases the share of collapsed cartels leniency programs collect.

7.8 Concluding Remarks

Leniency programs have changed the channels by which antitrust authorities unearth cartels. While cartels before the leniency-era were mainly caught through active detection mechanisms, competition agencies around the world now heavily rely on leniency programs to discover cartels. This is mainly because leniency programs have resulted in staggering numbers of applications and in turn prosecutions of cartels. As empirical evidence suggests however, it is not clear what types of cartels have an incentive to self-report. Some of these applicants are firms having participated in collapsed cartels.

The study presented in this chapter analytically explored the issue of the quality of leniency applications received. The results indicate that the number of applications that a self-reporting program attracts does not necessarily reflect the effectiveness of leniency schemes. We begin from the empirical observation that after the leniency program was introduced unexpectedly, a large number of firms came forward to claim leniency at an antitrust agency. Looking at recent developments in antitrust jurisdictions on both sides of the Atlantic, we examined what kind of cartels are likely to apply for leniency. We showed in a stylized model with an infinite time horizon and two unexpected policy changes that the share of terminated cartels of the total number of applications received can be substantial.

The intuition for this result is the following: an increase in the budget of the cartel enforcement agency increases the perceived detection probability, thereby destabilizing a number of cartels. The leniency program which is introduced shortly after not only destabilizes additional cartels, but also attracts those cartels that were terminated through the earlier increase in detection probability. We constructed a measure defined as the ratio of active cartels applying for leniency over the total number of leniency applications received. Using this indicator, we showed that the share of terminated cartels claiming leniency can be substantial.

The problem of collecting collapsed cartels can be especially severe if the competition authority is budget constrained. Resources must then be allocated either to active detection or to handling leniency cases and this may lower the detection rate. In our framework it is possible to implicitly allow for a budget constraint for the competition authority. The competition authority then has to allocate resources between active detection that affects the detection probability β on the one hand, and the leniency program on the other hand. Let us assume that the competition has a fixed budget and that due to the introduction of leniency, the detection rate goes down to its previous level prior to stepped up enforcement. This happens because the competition authority allocates resources away from active detection towards handling leniency cases. One can then show using the example of this chapter that the leniency program does not destabilize any additional cartels.

This implies that in this regime, no still active cartel would break down and apply for leniency The introduction of a leniency program would thus not have any effect on the stability of cartels that survived the stepped up enforcement in regime II. The only cartels that would have an incentive to come forward would be the cartels that were destabilized through the previous increase in enforcement as discussed in Section 7.5. In this scenario, it would be the ‘cleaning-out-the-closet’ effect that would dominate. In other words, the effectiveness θ of a leniency program will be equal to zero and all the applications will entirely stem from cartels that collapsed in Phase II.

Concluding, as the number of leniency applications is a noisy signal of the number of cartels that are broken up due to the introduction of such programs, policy makers should be careful in equating the amount of applications with the effectiveness of these policies. As we have shown, depending on the timing of events and the budget constraint of the agency, leniency programs can indeed attract a large number of collapsed cartels while at the same time not break up many active cartels. Policy makers should be careful to find the right mix and weighing of the tools to fight cartels. Leniency programs are instrumental in detecting cartels, but the programs should not come at the expense of active detection.

Chapter 8

Summary and Conclusion

This thesis explores issues in merger theory and the theory of collusion using game-theoretical as well as experimental methods. Moreover, it discusses topics in market concentration from a variety of angles. Chapter 2 and 3 make an assessment when an increase in market concentration can become problematic in the sense that it is likely to hurt consumer welfare. Chapter 4 and 5 analyze when an increase in concentration can change firms' awareness of their interdependency thereby making them more willing to cooperate and collude. Furthermore, it explores how collusion can be bred despite the incidence of entry. Chapter 6 and 7 introduce competition law and enforcement aimed to curb collusion among firms. Chapter 7 analyzes some adverse effects self-reporting schemes aimed at detecting collusion may have.

Conceptually, one can divide this thesis into three parts. Part I (Chapter 2 and 3) focus on merger theory and merger policy. Part II (Chapter 4 and 5) concentrate on on the determinants of cartel formation and cartel stability in the face of entry. Part III (Chapter 6 and 7) center on cartel law and cartel law enforcement. Chapters 2, 4 and 6 function function as introductory chapters into Chapter 3, 5 and 7, respectively. They give a literature review on each of the respective topics. Chapters 3, 5 and 7 present new insights into merger policy, cartel stability and the interaction of cartel laws and firms' incentives, respectively using both theoretical as well as experimental methods. The following sections present each chapter in more detail.

Chapter 2 gives an introduction into the basic models of merger theory. It shows that absent efficiency gains a merger in Cournot market typically is unprofitable for the merging firms unless the products are sufficiently differentiated. The outsider firms benefit from the merger, as they generally are able to increase their market share post-merger. In Bertrand markets, however, both insiders as well as outsiders profit from the merger as both of them are able to raise prices. We also describe different methods to measure efficiency gains in that chapter. The first method, merger simulation can be powerful but is very data-intensive and is therefore difficult to use in actual antitrust cases where deadlines to assess a market are tight. As an alternative to measure merger-efficiencies, we introduce the so-called Werden-Froeb index (WFI) in Chapter 3. This index quantifies the weighted average cost savings of the products produced by the merged entity that are required to restore the equilibrium pre-merger. Different to simulation models, the index is exact a uniquely determined. It also requires less information to be calculated as one only needs information on the products produced by the merged entity. The WFI offers a way to introduce the merger-efficiency defense more easily. It could be used as a screening devise in Phase I of a merger investigation or in Phase II, should the merger raise substantial competitive concerns. It would be interesting to do empirical work on the WFI using data of actual cases that went into Phase II, but were eventually consumed. Using these data it is possible to construct the implicit WFI values used in merger control across different jurisdictions. Another project is to calculate the remedies that would be necessary to lower the WFI values so as to satisfy their threshold level. This also requires analyses into the changes of ownership and control of the parties involved.

Chapter 4 and 5 explore *if and how* changes in market concentration can change the behavior of firms both from a theoretical perspective and an experimental perspective. Chapter 4 analyses how a change in the number of firms in a market changes the incentive to collude. In general, a larger market (measured by a higher number of firms) makes it more difficult for firms to engage in a collusive agreement which is expressed in a higher critical discount rate needed to sustain collusion. There are differences however that depend on the mode of competition in the market at hand. For a given number of firms, price setting markets require a higher critical discount rate for collusion to be viable than quantity-setting markets. In other words, *ceteris paribus* quantity-setting markets à la Cournot tend to be less competitive than price-setting markets à la Bertrand markets. Next to factors such as the number of firms, Chapter 4 explores other structural determinants that play a role for collusion to be stable. To those belong the demand conditions, symmetry of the industry and the extent of entry. Empirical studies have pointed out that entry is indeed one of the most crucial factor to break existing collusion. Moreover, both theoretical and empirical literature have pointed to the importance of behavioral factors such as transparency or coordination to make collusion sustainable.

In Chapter 5, we come back to one of the determinants of collusion pointed out in Chapter 4. Specifically, we study the effects of sequential entry on the sustainability of collusion using a laboratory experiment. We find that it is possible to sustain collusion in the face of entry where entrants know the history of the group they are joining into. Moreover, the results suggest that collusion is easier to start in smaller groups and that once collusion is established it can be transferred into the group enlarged by entry. A second research question relates to two effects that can be attributed to the so-called number effect. There exists a structural effect that refers to an increase in firms' incentives to deviate from a collusive agreement with more firms in a market. Second, coordination becomes more difficult with more players. With the experimental design we seek to isolate the coordination effect. The results show that in markets based on price competition collusion it is indeed easier to sustain if players start to interact in smaller markets. The average market price is significantly higher after entry in these markets compared to the markets that were large from the beginning. Furthermore, the frequency of coordination on the Pareto-efficient level are higher in the markets with entry as well. The individual analysis points out that entrants seem to emulate the behavior of the group they enter into.

It would be interesting to extend the study along the following dimensions. Firstly, one could study larger groups to see whether the coordination problem can still be overcome if groups contain more than three players. The experimental design would be such that there are several points of entry. Groups would start with two players and entrants will be added gradually until a group reaches its maximum size towards the end of the session. Another line of research could focus on testing the behavior of uninformed entrants, as this could help to explain the importance of entrant's information in bringing about collusion. It would also be interesting to explore the reverse treatment of reducing an existing triopoly to a duopoly to test whether the observed effects are symmetric. This might have some implications for competition policy, as the reduction of the number of firms can also be interpreted as a merger. Less coordination in the reduced groups may suggest that there is a lower risk of coordinated effects due to a merger. Another possible extension would be an experiment in which subjects play a Cournot game instead and to test if entry in this setting has similar effects than in the Bertrand game.

After discussing factors determining the extent of collusion in concentrated markets, Chapter 6 and Chapter 7 explore antitrust laws and antitrust enforcement aimed at curbing collusion between firms. Chapter 6 gives a general overview of the main laws in the EU and the US that tackle cartels. It discusses in detail a more recent policy tool aimed at facilitating prosecution of cartels that rewards self-reporting of firms that are involved in cartels. Furthermore, the chapter shows recent developments in antitrust enforcement on both sides of the Atlantic. In both the US and the EU, enforcement has become more strict in recent decades with higher fines for cartelizing firms and greater incentives for corporate leniency applicants. What is more, the cartel units have been enlarged and reorganized and the budget for the agencies have been stocked up, which is likely to lead to more efficient enforcement. The introduction of the leniency program has been judged one of the crucial recent policy tools to fight cartels.

Chapter 7 critically assesses effectiveness of the leniency programs. In a theoretical model of an infinitely repeated, stationary oligopoly game with two unexpected policy changes, the impact of leniency programs on cartel stability is analyzed. First, there is an increase in the budget of the antitrust division, which leads to an increase in the perceived detection probability. This destabilizes a number of cartels. Second, a leniency program is introduced shortly after, in which also collapsed cartels are prone to prosecution by the antitrust authority. We show that in this stylized setting a leniency program attracts two types of cartels: 1. active cartels that were not profitable enough to survive leniency programs, 2. cartels that already collapsed in the previous period. Depending on the parameter values of the model, we show that leniency programs might collect a significant number of already collapsed cartels. As a share of the leniency applications are of cartels that already had stopped operating at the time they are being reported, the number of applications cannot be equated with the number of cartels that are broken up as a result of the implementation of a self-reporting scheme. This indicator may thus be an imperfect measure of the success of leniency programs and might overestimate the direct effectiveness of self-reporting schemes.

One can extend this line of research along some dimensions. Traditionally, cartel formation and detection literature has focused on homogeneous industries. It would be interesting to extend this literature by studying the cartel formation process assuming firm heterogeneity where heterogeneity could be modeled as differences in capacities or production costs. In a second step, it would be interesting to analyze the effects antitrust policy and especially leniency programs in such markets. In the traditional literature assuming homogeneity, detection literature typically shows that a stricter antitrust enforcement destabilizes cartels. With heterogeneous firms the effects of antitrust enforcement on cartel formation and stability are less obvious however.

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Appendix

Appendix A:

A Routine for Calculating WFIs using Matlab

To illustrate the ease of use of the WFI in merger control, consider the following simple routine, written in MATLAB for mergers typically encountered by competition authorities.[1] It calculates the WFI for a full merger between any number of firms, which may pre-merger produce several commodities, in a market that competes in prices.

The required inputs for the software are the matrix of elasticities of commodities involved in the merger (Em), the column vector of *status quo* prices (pv), and the column vector of *status quo* quantities (qv), as measured on the market. The user can then specify the row vector *prior*, which has the same dimension as pv and qv. For this vector, enter 0 for all products that remain outside of the merger, and a positive number for all products that are involved in the merger, such that: (i) products produced by the same firm pre-merger get the same number; and (ii) products produced by different firms pre-merger get different numbers. For example, *prior* = [1 1 0 2 2 0 1] represents a merger between two firms, in which pre-merger products 1, 2 and 7 are produced by one of the merging firms, products 4 and 5 by the other merging firm, and products 3 and 6 by non-merging firms.

The routine returns the full matrix of price effects, recovered from the elasticity-matrix, pre- and post-merger matrices of price-effects, $\mathbf{Q}_0$ and $\mathbf{Q}_1$, the vector of marginal production costs, $\mathbf{c}^{(n_l)}$, the vector of absolute CMCRs, $\triangle\mathbf{c}_B$, and, of course, the value of the WFI_B.

```
function [Q,Q1,Q0,c,dc,wfib]=wfibmultiple(Em,pv,qv,prior);

Q=(diag(qv)*Em*inv(diag(pv)))'; % recovering price-effects from elasticities
n=max(size(Em)); % determining the number of firms

Q0=zeros(n,n); % determining the pre-merger matrix of price-effects
for i=1:n
  for j=1:n
```

[1] See http://wfi.acle.nl for a user-friendly online version.

```
    if i==j
        Q0(i,j)=Q(i,j);
        elseif prior(i)==prior(j)
            Q0(i,j)=Q(i,j);
        end
  end
end

L=logical(prior); % deleting nonmerging firms
Q0=Q0(L,L); % deleting nonmerging firms, pre-merger
Q1=Q(L,L); % deleting nonmerging firms, post-merger

pvr=pv(L); % consider relevant prices
qvr=qv(L); % consider relevant quantities

c=pvr+inv(Q0)*qvr; % pre-merger marginal costs
dc=(inv(Q0)-inv(Q1))*qvr; % absolute CMCRs
wfib=(dc'*qvr)/(c'*qvr); % WFI

Q % writing output:
Q0
Q1
c
dc
wfib
```

Appendix B:

Instructions for Participants in Experiment

Instructions Baseline

General

Welcome to this experiment on decision-making! Please read these instructions carefully. The experiment lasts 20 rounds. You can earn money in this experiment. The amount of money that you are able to earn depends on the decision you make as well as the decisions taken by the other persons in your group. You will receive an initial payment of 5 Euros. In addition, you can earn points with the decisions you make during the experiment. Your earnings in points each round will be summed up at the end of the experiment. You receive 1.50 Euros per 100 points you earned. At the end of the experiment the amount that you earned will be paid out to you in cash.

Neither you nor any other subject will be asked to reveal her/his identity during or after this experiment. Please keep your decisions private and note that communication with any other subject is not permitted during the experiment. If you have any questions, please raise your hand and an experimenter will come to your booth.

Roles of Subjects and Groups

You are randomly matched with two other persons at the beginning of the experiment. All subjects remain in the same group during the entire experiment. You will not be told which two other subjects you are matched with.

Sequence of Events and Tasks

In each round, each participant in your group is asked to choose a whole number between 1 and 100. The three numbers are compared and the group member who chose the lowest number gets points equal to the number she/he chose. The other group members will receive no points. In case of a tie of two group members, each of them gets half of the points they chose. In case of a tie of three group members, each of them gets a third of the points they chose.

For instance if the first group member chooses the number of 45, the second group member chooses the number 93 and the third group member chooses the number 51, the first group member receives 45 points and the second group member and the third group member receive 0 points. If the first and the second group member chooses the number of 22, and the third group member chooses the number 79, the first group member and the second group member receive 11 points and the third group member receive 0 points. If all three group members choose a price of 54, each of them gets 18 points.

Information for Subjects during the Experiment

When they submit their choice, from round 2 onwards, the participants will see the results of the previous round of their group. They will see their own choices, the number of the other participants in her/his group, her/his own points in that round and her/his total accumulated points up to that round.

Participants will also have a history table from round 2 onwards which shows the results of all preceding rounds of their group. It displays her/his own past numbers chosen, the numbers chosen by the other participants in her/his group, her/his past points gained and her/his past accumulated points up to that round.

GOOD LUCK WITH THE EXPERIMENT!

Instructions for Incumbents in Entrant Treatment

General

Welcome to this experiment on decision-making! The experiment lasts 40 rounds. You can earn money in this experiment. The amount of money that you are able to earn depends on the decision you make as well as the decisions taken by the other persons in your group. You will receive an initial payment of 5 Euros. In addition, you can earn points with the decisions you make during the experiment. Your earnings in points each round will be summed up at the end of the experiment. You receive 1.50 Euro per 100 points you earned. At the end of the experiment the amount that you earned will be paid out to you in cash.

Neither you nor any other subject will be asked to reveal her/his identity during or after this experiment. Please keep your decisions private and note that communication with any other subject is not permitted during the experiment. If you have any questions, please raise your hand and an experimenter will come to your booth.

Roles of Subjects and Groups

You are randomly matched with two other persons at the beginning of the experiment. This group consists of two subjects, called Starters, who participate in the group from the start of the experiment. The other subject, called Entrant, joins the group in a randomly chosen round between round 15 and round 25 and will participate in this group until the end of the experiment. In this experiment you are a Starter. All subjects remain in the same groups in this experiment. You will not be told which two other subjects you are matched with.

Sequence of Events and Tasks

Before Entrant enters

Decisions of Starters

In each round, the two Starters are asked to choose a whole number between 1 and 100. The two numbers chosen are then compared and the Starter who chose the lowest number makes earnings in points equal to the number she/he chose. The other Starter will get no points. If both Starters choose the same number the points are split equally between them.

For instance, if one Starter chooses the number 44 and the other Starter chooses the number 89, the first Starter gets 44 points and the second Starter gets nothing. If both Starters choose the number 16, for instance, both will get 8 points.

The Entrant will observe the round results of her/his group in each round before she/he enters. In each round, she/he will see the numbers chosen by the two Starters.

After Entrant enters

Immediately before the round in which the Entrant enters, both the Starters and the Entrant are informed about the fact that entry takes place by a message on their computer screen. The following round then starts and the group members again have to choose a number in each round except that there are now three active group members, the two Starters and the Entrant, that have to choose a price. As before, in each round, until the end of the experiment, each group member chooses a number. The three numbers are compared and the group member who chose the lowest number gets points equal to the number she/he chose. The other group members will receive no points. In case of a tie of two group members, each of them gets half of the points they chose. In case of a tie of three group members, each of them gets a third of the points they chose.

For instance if the first Starter chooses a price of 45, the second Starter chooses a price of 93 and the Entrant chooses a price of 51, the first Starter receives 45 points and the second Starter and the Entrant receive 0 points. If all three group members choose a price of 36, each of them gets 12 points.

Information for Subjects during the Experiment

Starters

Before Entry

When they submit their choice, from round 2 onwards, the Starters will see the results of the previous round of their group. They will see their own choices, the number of the other Starter, her/his own points in that round and her/his total accumulated points up to that round. Starters will also have a history table from round 2 onwards which shows the results of all preceding rounds of their group. It displays her/his own past numbers chosen, the numbers chosen by the other Starter, her/his past points gained and her/his past accumulated points up to that round.

After Entry

After entry Starters will have the same screens when they make their entry. They will see the results of the last round as well as a history table showing all results so far. Starters also see the choices made of the entrant in their group after entry. This is shown in the last round results and the history table.

Entrants

Before Entrant enters

Before joining their group, Entrants will see the numbers chosen by each Starters of their group in each round on their computer screens.

After Entrant enters

After the Entrants entered their group, the Entrants will have the same screens as the Starters. They will see their own choices, the choices of the 2 Starters in their group and their own earnings.

GOOD LUCK WITH THE EXPERIMENT!

Instructions for Entrants in Entrant Treatment

General

Welcome to this experiment on decision-making! The experiment lasts 40 rounds. You can earn money in this experiment. The amount of money that you are able to earn depends on the decision you make as well as the decisions taken by the other persons in your group. You will receive an initial payment of 5 Euros. In addition, you can earn points with the decisions you make during the experiment. Your earnings in points each round will be summed up at the end of the experiment. You receive 1.50 Euro per 100 points you earned. At the end of the experiment the amount that you earned will be paid out to you in cash.

Neither you nor any other subject will be asked to reveal her/his identity during or after this experiment. Please keep your decisions private and note that communication with any other subject is not permitted throughout the course of the experiment. If you have any questions, please raise your hand and an experimenter will come to your booth.

Roles of Subjects and Groups

You are randomly matched with two other subjects in the beginning of the experiment. This group consists of two subjects, called Starters, who participate in the group from the start of the experiment. The other subject, called Entrant, joins the group in a randomly chosen round between round 15 and round 25 and will participate in this group until the end of the experiment. Immediately before the start of the experiment, you receive a message on the screen informing you whether you are a Starter or an Entrant. All subjects remain in the same groups in this experiment. You will not be told which two other subjects you are matched with.

Sequence of Events and Tasks

Before Entrant enters

Decisions of Starters

In each round, the two Starters are asked to choose a whole umber between 1 and 100. The two numbers chosen are then compared and the Starter who chose the lowest number makes earnings in points equal to the number she/he chose. The other Starter will get no points. If both Starters choose the same number the points are split equally between them.

For instance, if one Starter chooses the number 44 and the other Starter chooses the number 89, the first Starter gets 44 points and the second Starter gets nothing. If both Starters choose the number 16, for instance, both will get 8 points.

Decisions of Entrants

The Entrant will observe the round results of her/his in each round before she/he enters. In each round, she/he will see the numbers chosen by the two Starters.

Before joining her/his group, an Entrant has to submit an estimate of the minimum number chosen by her/his group in each round. Her/his earnings in each round depend on the difference between this estimate and the realized minimum number in her group. If the entrants estimate is within 20 percent of the actual minimum number then she/he will receive the average earnings of his group in this round. If not he/she will earn nothing in this round.

For example, if one Starter chooses 78, the other Starter chooses 89, the minimum number is 78. If the estimate equals 34, the Entrant will receive no points in that round. If one Starter chooses 30, the other Starter chooses 69, the minimum equals 30. If the estimate equals 33, the difference is 3 and falls within the 20 percent estimation error and her/his earnings are (30+0)/2=15.

Sequence of Events and Tasks

After Entrant enters

Immediately before the round in which the Entrant enters, both the Starters and the Entrant are informed about the fact that entry takes place by a message on their computer screen. The following round then starts and the group members again have to choose a number in each round except that there are now three active group members, the two Starters and the Entrant, that have to choose a price. As before, in each round, until the end of the experiment, each group member chooses a number. The three numbers are compared and the group member who chose the lowest number gets points equal to the number she/he chose. The other group members will receive no points. In case of a tie of two group members, each of them gets half of the points they chose. In case of a tie of three group members, each of them gets a third of the points they chose.

For instance if the first Starter chooses a price of 45, the second Starter chooses a price of 93 and the Entrant chooses a price of 51, the first Starter receives 45 points and the second Starter and the Entrant receive 0 points. If all three group members choose a price of 36, each of them gets 12 points.

Information for Subjects during the Experiment

Starters

When they submit their choice, from round 2, onwards the Starters will see the results from that round of their group. They will see the number they chose in that round, the number of the other active group member(s), her/his own points in that round and her/his total accumulated points up to that round.

Starters will also have a history table from round 2 onwards which shows the results of the last rounds. It displays her/his own past numbers chosen and the numbers chosen by the other group member(s), her/his past points gained and her/his past accumulated points up to that round. (Note that the numbers displayed in this example are randomly generated by the computer. They provide no guidance as to how you should choose your numbers).

Entrants

Before Entrant enters

Entrants will watch the choices of the Starters in each round their computer screens before they join the group on.

After Entrant enters

After the Entrants entered their group, the Entrants will have the same screens as Starters.

GOOD LUCK WITH THE EXPERIMENT!

Appendix C: Proofs to Chapter 2

Proof of Proposition 1

Comparison of Post-Merger Quantities of Insiders and Outsiders with Pre-Merger Quantities

In the following, we show that the industry output post-merger is smaller than the industry output pre-merger. That is:

$$\begin{aligned} 3q^* - (2q^I + q^o) &> 0 \\ 3\left(\frac{a-c}{2b(1+\theta)}\right) - \left(\frac{(\theta-2)}{b\,(\theta(\theta-2)-2)}\,(a-c) + \frac{(a-c)}{b\,(\theta(2-\theta)+2)}\right) &> 0 \\ \Leftrightarrow b\theta(2-\theta)(a-c) &> 0 \end{aligned}$$

which holds for $\theta \in [0,1)$.

Comparison of the Prices of Insiders, Outsiders Post-Merger and the Pre-Merger Price

Next, we show that the post-merger prices both for the insiders and for the outsiders increase post-merger. First, we show that the price of the insiders increase post-merger or:

$$p^I - p^* = \frac{1}{2}\frac{a\,(\theta+1)\,(\theta-2) + c\,(\theta(\theta-3)-2)}{\theta(\theta-2)-2} - \frac{a+c(1+2\theta)}{2(1+\theta)} > 0$$

$$\Leftrightarrow \frac{1}{2}\theta(a-c)\frac{1+\theta(1-\theta)}{(1+\theta)(2+\theta(2-\theta)}$$

which holds for $\theta \in [0,1)$.

Now we show that the price of the outsider also increases as a result of the merger:

$$p^0 - p^* = \frac{a+c(1+\theta(2-\theta))}{\theta(2-\theta)+2} - \frac{a+c(1+2\theta)}{2(1+\theta)} > 0$$

$$\Leftrightarrow \frac{1}{2}\frac{\theta^2(a-c)}{(1+\theta)\,(2+\theta(2-\theta))} > 0$$

which holds for $\theta \in [0,1)$.

We now check whether the price increase for the insiders is greater than that of the outsiders:

$$p^I - p^0 = \frac{1}{2}\theta(1-\theta)\frac{a-c}{2+\theta(2-\theta)} > 0$$

which holds for $\theta \in [0,1)$.

Comparison of Post-Merger Profits of Insiders, Outsiders and Pre-Merger Profits:

We now show that the profits of the outsider increase post-merger or:

$$\pi^o - \pi^* > 0$$

substituting (2.12)and (2.7) into (8) yields

$$\frac{(a-c)^2}{b\left(\theta(\theta-2)-2\right)^2} - \frac{1}{4b}\left(\frac{a-c}{1+\theta}\right)^2 > 0$$

which can be simplified to:

$$b\theta^2(4+\theta(4-\theta))(a-c)^2 > 0$$

which is always satisfied for $\theta \in [0, 1)$.

Next, we show that there is a critical value of θ, denoted as θ^* above which a merger of two firms in a triopoly market is unprofitable. A merger in this market is profitable whenever the post-merger profits of the insiders are larger than the pre-merger profits or:

$$\pi^I \geq \pi^* = \frac{1}{4}\frac{(\theta+1)(\theta-2)^2(a-c)^2}{b\left(2+\theta(2-\theta)\right)^2} - \frac{1}{4b}\left(\frac{(a-c)}{1+\theta}\right)^2 > 0$$

which can be simplified to

$$-\theta^3 + 2\theta^2 + \theta - 1 < 0$$

This is satisfied only if:

$$\theta < \theta^* \approx 0.554\,96$$

For any $\theta \in [0, 1)$ for which $\theta < \theta^*$, a merger between two firms in this model will be profitable. For any $\theta > \theta^*$, the merger between two firms is unprofitable.

Proof of Proposition 2

Comparison of the Prices of Insiders, Outsiders Post-Merger and the Pre-Merger Price

In the following, we will show that

$$p^I > p^o > p^*$$

First, we show that the differences of insiders' prices post-merger and outsider prices post-merger is strictly larger than zero, that is:

$$p^I - p^o > 0$$

substituting (2.15) and (2.17) into (8) yields

$$\frac{(2+\theta(1-3\theta))a+(2+\theta(3+\theta))c}{2(2+\theta(2-\theta))} - \frac{a(1+\theta)(1-\theta)+c(1+2\theta)}{2+\theta(2-\theta)} > 0$$

which can be simplified to:

$$\theta\,(1-\theta)\,(a-c) > 0$$

as $\theta \in [0, 1)$ the inequality in (8) always holds.

Next, we show that

$$p^o - p^* > 0$$

$$\begin{aligned} \frac{a(1+\theta)(1-\theta)+c(1+2\theta)}{2+\theta(2-\theta)} - \frac{(1-\theta)a+(1+\theta)c}{2} &> 0 \\ \theta^2\,(1-\theta)\,(a-c) &> 0 \end{aligned} \tag{8.1}$$

inequality (8.1) is always strictly bigger than zero as $\theta \in [0, 1)$

Comparison of Post-Merger Quantities of Insiders and Outsiders with Pre-Merger Quantities

We now show that

$$3q^* > q^o + 2q^I$$

or

$$3q^* - q^o + 2q^I > 0$$

Substituting and simplifying gives

$$\frac{1}{2b}\,(a-c)\,\frac{2+\theta(1-3\theta}{(1+2\theta)(2+\theta(2-\theta)} > 0$$

which is positive for all $\theta \in [0, 1)$.

Comparison of Post-Merger Profits of Insiders, Outsiders and Pre-Merger Profits:

In the following, we show that

$$\pi^o > \pi^I > \pi^*$$

First, we show that the insiders' profits are strictly larger than the outsider's profit post-merger

$$\pi^o - \pi^I > 0$$

which is

$$\begin{aligned}
\frac{1}{b}\frac{(a-c)^2}{1+2\theta}\frac{(1-\theta)(1+\theta)^3}{(2+\theta(2-\theta))^2} - \frac{1}{4}\frac{(2+3\theta)^2(1-\theta)}{b(2+\theta(2-\theta))^2(2\theta+1)}(a-c)^2 &> 0 \\
\Leftrightarrow \frac{1}{4b}\frac{\theta^2(a-c)^2}{1+2\theta}\frac{3+\theta(1-4\theta)}{(2+\theta(2-\theta))^2} &> 0 \qquad (8.2)
\end{aligned}$$

where inequality (8.2) is positive for $\theta \in [0,1)$

Next, we show that

$$\pi^I - \pi^* > 0$$

Substituting yields

$$\begin{aligned}
\frac{1}{4b}\frac{(2+3\theta)^2(1-\theta)}{(2+\theta(2-\theta))^2(2\theta+1)}(a-c)^2 - \frac{1}{4b}\frac{(1-\theta)(1+\theta)}{(1+2\theta)}(a-c)^2 &> 0 \\
\Leftrightarrow \frac{1}{4b}\frac{\theta^2(1-\theta)(1+\theta(1+\theta)(4-\theta))}{(1+2\theta)(2+\theta(2-\theta))^2}(a-c)^2 &> 0
\end{aligned}$$

which is positive for $\theta \in [0,1)$. Due to transitivity it holds that $\pi^I > \pi^o > \pi^*$.

Samenvatting-Summary in Dutch

Inleiding in het Onderwerp

Adam Smith's beroemde bespreking van de 'onzichtbare hand' bevat de boodschap dat een systeem van sterk concurrerende ondernemingen, met nauwelijks of geen interventie door de overheid, leiden kan tot een situatie die voor de maatschappij als geheel de hoogste baten oplevert. In werkelijkheid is er echter niet altijd sprake van volkomen concurrentie. Vaak zijn er weinig bedrijven op een bepaalde markt actief, hetgeen tot inefficiënt hoge prijzen kan leiden. Ook op markten met toetredingsbarrières zijn evenwichtsprijzen mogelijk inefficiënt hoog. In het bijzonder kan mededingingsbeperkend gedrag het concurrentieproces schaden.

Om concurrentie op een imperfect functionerende markt te bevorderen of te herstellen bestaan er nationale en internationale mededingingsautoriteiten en mededingingswetten die op een markt kunnen interveniëren. Zij beschermen consumenten tegen misbruik van marktmacht in de vorm van bijvoorbeeld te hoge prijzen, minder productdifferentiatie, of kartels die de markt tussen bedrijven opdelen en concurrentie beperken. Overheidsinterventie door mededingingsautoriteiten kan op verschillende manieren gebeuren. Mededingingsautoriteiten kunnen bijvoorbeeld een geplande fusie verbieden als ze verwachten dat daardoor de gefuseerde bedrijven hun dominante positie kunnen misbruiken. Een lichtere vorm van interventie is het toelaten van een fusie onder bepaalde voorwaarden. Dit kan betekenen dat één of meerdere van de gefuseerde bedrijven een onderdeel van hun activiteit aan derde partijen moeten verkopen voordat ze kunnen fuseren. Mededingingsautoriteiten zijn ook wettelijk verantwoordelijk voor het opsporen en stoppen van kartels. Op opgespoorde kartels wordt een boete opgeleverd die afhankelijk is van factoren als de omzet van de bedrijven en de zwaarte van de overtreding.

De doelstelling van dit proefschrift is een bijdrage te leveren aan de literatuur op het gebied van industriële organisatie dat zich bezighoudt met de mededingingswet. De belangrijkste vraag die wordt geanalyseerd is hoe de handhaving van de mededingingswet en de vormgeving van het mededingingsbeleid geoptimaliseerd kunnen worden. Dit wordt gedaan binnen het kader van speltheoretische en experimentele methodes. De drie meest belangrijke bijdragen van dit proefschrift zijn als volgt. Ten eerste wordt een nieuwe index gepresenteerd om efficiëntiewinsten, die bij een fusie kunnen ontstaan, te kwantificeren. Deze index heeft het voordeel dat hij eenvoudig te berekenen en te interpreteren is en weinig data eisen stelt.

Wij stellen voor deze index complementair met andere methodes bij de fusiecontrole te gebruiken. Analyse van fusieefficiënties in de mededingingspraktijk kan door deze index bevorderd worden.

Ten tweede levert deze dissertatie inzichten in de effecten van markttoetreding op gekartelliseerde markten. Wij laten zien dat, anders dan in bestaand onderzoek beschreven, marktoetreding een bestaand kartel niet per se opbreekt. De experimentele uitkomsten tonen aan dat toetreders, die de markt waarop ze toetreden kennen, deel van het kartel kunnen worden. Marktoetreding hoeft dus niet automatisch een kartel op te breken. Een alternatieve interpretatie van de uitkomsten is dat kartels op markten die klein beginnen en door marktoetreding groeien inderdaad makkelijker stand kunnen houden dan markten die vanaf het begin een bepaalde grootte hebben. Dit levert ook nieuwe inzichten op voor de analyse van gecoördineerde effecten in de fusiecontrole en voor de bestrijding van kartels.

Ten deerde levert deze dissertatie inzichten op over welk type kartels door clementieprogramma's bekend wordt. Wij tonen in het kader van een theoretisch model dat vooral oude kartels opgespoord worden. Het aantal door clementieverzoeken opgespoorde kartels is dus niet gelijk aan het aantal dat door clementieprogramma's opgebroken wordt. Deze uitkomst werpt een ander licht op het vermeende succes van clementieprogramma's. Dit proefschrift is ingedeeld in twee centrale thema's. Het eerste thema is fusies en fusiecontrole door mededingingsautoriteiten. Het tweede thema is karteltheorie en kartelbeleid. In de volgende secties wordt een beknopt overzicht van deze twee centrale thema's gepresenteerd.

Fusies en Fusiecontrole

Een fusie is een combinatie van twee of meerdere onafhankelijke bedrijven tot een eenheid. Een fusie kan op meerdere manieren tot stand komen. Er is sprake van een horizontale fusie als bedrijven fuseren die direct met elkaar in concurrentie staan en op hetzelfde niveau in de productieketen zitten. Dit is bijvoorbeeld het geval tussen twee bedrijven die allebei zuivel produceren of tussen twee autoproducenten. Er is sprake van een verticale fusie als bedrijven fuseren welke niet met elkaar concurreren en die op verschillende niveaus van het productieproces actief zijn. Voorbeelden van deze soort fusies zijn fusies tussen een autoproducent en de leverancier. Door een fusie neemt de marktconcentratie ceteris paribus toe. Dat verhoogt de invloed van de gefuseerde bedrijven op de prijsvorming. In het algemeen heeft dat tot gevolg dat prijzen op deze markt tot nadeel voor de consumenten omhoog gaan. Een fusie kan ook tot hogere efficiëntie leiden omdat de gefuseerde bedrijven transacties beter kunnen organiseren. Stel dat er twee autoproducenten zijn A en B. A heeft een nieuwe en betere productiemethode voor auto's ontwikkeld, maar mist een international distributienetwerk. Autoproducent B heeft een goed ontwikkeld en gevestigd distributienetwerk. Als A en B fuseren, zou het combineren van deze twee assets tot een efficiëntie winst leiden. Dat leidt tot besparingen in de variabele kosten die kunnen worden doorgegeven aan de consument in de vorm van lagere prijzen.

Een mededingingsautoriteit toetst fusies vanaf een bepaalde grootte. In de analyse kijkt ze naar factoren die tot verhoging van prijzen kan leiden, zoals een toename van de marktconcentratie, het aantal bedrijven op de markt, etc. Maar ze kijkt ook of er efficiëntievoordelen kunnen ontstaan door de fusie, die tot lagere prijzen kunnen leiden. Deze factoren worden tegen elkaar afgewogen in het besluit een fusie te stoppen of door te laten gaan.

Kartel en Kartelbeleid

Kartels zijn afspraken tussen bedrijven waarin ze hun keuzes over bijvoorbeeld productie van hoeveelheden of prijzen onder elkaar coördineren. Een kartel is een vorm van misbruik van marktmacht en heeft vaak een verhoging van prijzen als directe gevolg. Op lange termijn kan het ook tot minder productinnovatie en productvariatie leiden. Een mededingingsautoriteit probeert kartels op te sporen. Dit kan op een actieve en passieve manier gebeuren. Ten eerste kan een mededingingsautoriteit proberen markten te screenen. Hierbij worden bijvoorbeeld prijs- of hoeveelheidgegevens van een bepaalde markt over een langere periode verzameld en onderzocht. Het probleem van deze methode is dat het moeilijk is uit de regelmatigheden in de prijsvorming conclusies te trekken over het bestaan van een kartel. Een alternatieve methode is een clementieprogramma waardoor bedrijven de kans krijgen hun deelname in een kartel te melden in ruil van een verlaging van de boete. Belangrijk is hier dat alleen het eerste bedrijf dat het kartel meldt immuniteit kan verwachten. Daardoor heeft elk kartellid de prikkel de eerste te zijn en wordt de stabiliteit van kartelafspraken door deze wedloop verzwakt.

Overzicht van de Hoofdstukken

Het voorgaande is een beknopt overzicht van de twee centrale thema's uit mijn proefschrift. De thema's worden dieper uitgewerkt in de hoofdstukken zelf. Hoofdstuk 1 geeft een algemene inleiding in industriële organisatie en de toepassing voor mededingingsbeleid. Hoofdstukken 2 tot en met 3 gaan in op de vraag onder welke voorwaarden een fusie consumentwelvaart vermindert. Hoofdstukken 4 tot en met 7 presenteren kartelonderzoek. Hoofdstukken 4-5 analyseren kartelformatie en de effecten van markttoetreding in een gekartelliseerde markt. Hoofdstukken 6-7 analyseren de interactie van kartelstabiliteit en kartelbeleid. Conceptueel zijn de hoofdstukken 2,4 and 6 inleidingen in hoofdstukken 3, 5 en 7, en geven een overzicht over de literatuur. Hoofdstukken 3, 5 en 7 presenteren nieuw onderzoek in fusie- en karteltheorieën en beleid.

Hoofdstuk 2 geeft een inleiding en een overzicht van de fundamentele fusietheorieën en fusiecontrole. Het eerste deel van dit hoofdstuk gaat in op een aantal basismodellen van speltheorie en bespreekt statische modellen met complete informatie. Twee toepassingen, het Cournot model en het Bertrand model, die competitie in hoeveelheden en prijzen analyseren, worden gepresenteerd. Met hulp van deze modellen wordt ook een fusie geanalyseerd. De nadruk van het tweede gedeelte van dit hoofdstuk ligt op fusiecontrole en nieuwe ontwikkelingen daarin. Er volgt een inleiding in de zogenaamde 'efficiency defense' in fusiecontrole waardoor het mogelijk wordt met kostenbesparingen die door een fusie mogelijk worden in de analyse en toetsing van een fusie rekening te houden. Hoofdstuk 2 geeft daarna een kort overzicht over de technieken die het mogelijk maken kostenbesparingen te kwantificeren.

Hoofdstuk 3 presenteert een nieuwe methode om fusieefficiënties te meten. Het hoofdstuk maakt gebruik van statische oligopoliemodellen om de kostenbesparingen te kwantificeren die nodig zijn om het consumenten surplus in een markt constant te houden. De kostenbesparingen van elk product worden door middel van een index, de zogenaamde Werden-Froeb-index (WFI) geaggregeerd. Deze index meet de gewogen gemiddelde verlaging in marginale kosten die nodig is om de prijzen en hoeveelheden constant te houden ten opzichte van de situatie van voor de eventuele fusie. In vergelijking met andere methodes om fusieefficiënties te meten heeft deze index relatief weinig data nodig. Bovendien is het makkelijk te gebruiken en te interpreteren. Wij stellen dus voor dat de WFI in combinatie met andere maten zoals het HHI wordt gebruikt.

Hoofdstuk 4 geeft een overzicht over oneindig vaak herhaalde spelen waarmee in de literatuur gebruikelijk kartels worden geanalyseerd. Het hoofdstuk analyseert ook hoe de prikkels om samen te werken veranderen als het aantal bedrijven op een markt verandert. Wij doen dit in het kader van het Bertrand model en het Cournot model. De resultaten tonen dat zoals bij prijs- en hoeveelhedencompetitie een groter aantal bedrijven kartelvorming bemoeilijkt. Daarna geeft Hoofdstuk 4 een literatuuroverzicht over de determinanten van collusie vanuit het perspectief van theoretisch onderzoek, alsmede vanuit het perspectief van empirisch onderzoek. Uit de bestaande literatuur lijken factoren zoals het aantal bedrijven, markttoetreding en markttransparantie tot de belangrijkste determinanten van kartelstabiliteit te behoren.

Hoofdstuk 5 onderzoekt de effecten van markttoetreding op gekartelliseerde markten. De nadruk ligt hierbij op het vraagstuk onder welke voorwaarden collusie kan standhouden als er markttoetreding is. Bestaand empirisch en theoretisch onderzoek benadrukt meestal dat markttoetreding collusie verzwakt. Hier zijn twee verschillende redenen voor. Ten eerste verhoogt een groter aantal bedrijven in een kartel de prikkels van elk individueel bedrijf van de kartelafspraak af te wijken door middel van een lagere prijszetting. Dit noemt men ook wel het structurele effect. Ten tweede wordt het voor meer kartelleden moeilijker met elkaar af te spreken en een gezamenlijk akkoord ten opzichte van bijvoorbeeld prijzen of hoeveelheden te bereiken. Deze tweede factor wordt ook wel het coördinatie-effect genoemd. In dit onderzoek proberen wij deze twee effecten van elkaar te onderscheiden en te kwantificeren. Wij doen dit in het kader van een laboratorisch laboratorium experiment. De resultaten tonen dat kartels in een Bertrand markt die klein beginnen en door marktoetreding groeien inderdaad makkelijker stand kunnen houden dan markten die vanaf het begin een bepaalde grootte hebben. In de eerstgenoemde markten zijn de gemiddelde marktprijzen en de frequentie van collusie significant hoger. Een alternatieve interpretatie van de uitkomsten is dat toetreders, die de markt waarop ze toetreden kennen, deel van het kartel kunnen worden. Marktoetreding hoeft dus niet automatisch een kartel opbreken.

Hoofdstuk 6 geeft een inleiding in instrumenten in het mededingingsbeleid om kartels in een markt te bestrijden. Het hoofdstuk geeft een verklaring waarom de overheid moet ingrijpen om kartels te bestrijden en welke methodes bestaan om kartels op te sporen. Ten eerste is het mogelijk om actief te proberen kartels op te sporen door een screening methode, waarbij bepaalde markten gecontroleerd worden. Ten tweede is er het zogenoemd clementieprogramma. Hierin komen bedrijven in aanmerking voor een vrijstelling of verlaging van de boete indien zij informatie verstrekken aan de mededingingsautoriteiten over kartels waarbij zij betrokken zijn. Omdat slechts de eerste bedrijven die clementie aanvragen volledige immuniteit of een significant grotere verlaging van de boete dan latere melders kunnen krijgen, ontstaat er een wedloop voor boetevrijstelling die tot gevolg heeft dat kartels een grotere kans hebben om uit elkaar te vallen. Hoofdstuk 5 geeft een overzicht over de ontwikkelingen in de VS en de EU ten opzicht van hun clementieprogramma's en bestudeert de voor-en nadelen van clementieprogramma's.

Hoofdstuk 7 stelt de vraag welk type kartels in het bijzonder door clementieprogramma's bekend wordt. Eerder onderzoek op dit terrein benadrukte vooral de voordelen van clementieprogramma's bij het bestrijden van kartels. Ons onderzoek analyseert het functioneren van deze programma's in een historisch kader. Wij bestuderen de gevolgen van clementieprogramma's in een oneindig vaak herhaald spel met twee onverwachte exogene veranderingen in het mededingingsbeleid: de eerste verandering is een verhoging van de kans dat een kartel opgespoord wordt. De tweede is de introductie van een clementieprogramma. Wij tonen aan dat in dit kader een clementieprogramma vooral oude kartels opgespoord worden die niet meer op de markt actief zijn. Het aantal door clementieverzoeken opgespoorde kartels is dus niet gelijk aan het aantal kartels die door clementieprogramma's opgebroken wordt.

Hoofdstuk 8 sluit af met de belangrijkste conclusies uit dit onderzoek.

The Amsterdam Center for Law & Economics (ACLE) is a joint initiative of the economics and law faculties of the Universiteit van Amsterdam. The objective of the ACLE is to promote high-quality research in the fields at the interface of law and economics.