Three Essays on Firm Strategies Influenced by Antitrust Authorities

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"The old story in antitrust cases is that
the government wins the battle and loses the war.
The question is: What do you get in relief?"

Harry First (Charles L. Denison Professor of Law, NYU)

Contents

List of Figures

List of Tables

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Chapter 1

Introduction

This thesis contains three essays which are all from the broader field of the theories on competition, collusion and antitrust enforcement. The chapters can be read independently, although there is a certain connection between the articles. The essays in *Chapter 2* and *3* provide models where firms try to sustain horizontal collusive agreements under the review of an antitrust authority. *Chapter 4* extends the topic to vertical integration, where firms interact in a vertical merger game under the review of an antitrust authority. The thesis is organized as follows:

The essay in *Chapter 2*: THE IMPACT OF ANTITRUST POLICY ON COLLUSION WITH IMPERFECT MONITORING deals with information spillovers between the antitrust authority and collusive firms in an environment of imperfect information. The model investigates how the sustainability of collusive agreements in uncertain environments is affected by an antitrust authority that shares information with firms and by an authority that keeps the information secret. The model investigates the impact of antitrust enforcement by the means of fines in combination with these different information policies. Using a model along the lines of GREEN and PORTER (1984), it is shown that fines increase the sustainability of collusion in industries with relatively low probability of demand shocks. Moreover, even in situations where collusion is sustainable without antitrust enforcement, introducing a fine reduces welfare. In addition, information spillovers from the antitrust authority to the colluding firms reinforce the effect of fines on collusion and enable even industries facing a high probability of demand shocks to collude. The analysis partly involves leniency programs. These programs were introduced by antitrust authorities to reduce the fines against colluding firms that report information about their cartel partners to the antitrust authority and helped thereby to punish other cartel members. Making use of results from the analysis of the information spillovers, the effect of leniency programs is investigated. It is shown that leniency programs have ambiguous consequences on the sustainability of collusion. On the one hand, the program has a weak positive effect in industries with low probability of demand shocks, since it reduces the fine that is needed by the firms to sustain collusion. Since leniency reduces the costs for getting information about rivals price setting, leniency programs have an adverse effect however. This is due to the fact that firms with a high probability of demand shocks need this information to sustain collusion.[1]

The subsequent essay in *Chapter 3* focuses on THE DETERRENCE EFFECT OF EXCLUDING RINGLEADERS FROM LENIENCY PROGRAMS. In particular, the model investigates if ringleaders of cartels should be eligible for a fine reduction when cooperating with the antitrust authority or whether they should be excluded from such programs. Both approaches can be found in antitrust laws. For instance, the leniency program established in the US law in 1978, stipulates that it is not possible for ringleaders to obtain a fine reduction through leniency. However, due to the changes in the EU leniency regulations in 2002 and 2006, ringleaders have the possibility to participate in such

[1]This essay was partly written during a research stay at the Midi-Pyrénées School of Economics (M.P.S.E.) in Toulouse. I am grateful to the financial support of the German Academic Exchange Service (DAAD) during this project. Furthermore, I wish to thank Achim Wambach, who is a co-author of this article, for many fruitful discussions. Versions of the model have been presented on the *RGS Doctoral Conference in Economics* at the University of Dortmund, the 3rd *annual Competition & Regulation Meeting - Strategic Firm-Authority Interaction in Antitrust, Merger Control and Regulation* at the University of Amsterdam, the *Augustin Cournot Doctoral Days 2007* at the Université Louis Pasteur in Strasbourg, the 1st *Conference of the Research Network on Innovation and Competition Policy: Modern Approaches in Competition Policy* at the Centre for European Economic Research (ZEW) in Mannheim, the *2007 Annual Meeting of the German Economic Association* at the University of Munich, the 1st *Doctoral Meeting of Montpellier* at the University of Montpellier 1, the 4th *IUE International Student Conference: Cooperation, Coordination and Conflict* at the Izmir University of Economics, the *XIII. Spring Meeting of Young Economists* at the University of Lille 2, and on the 6th *Annual International Industrial Organization Conference* at the Marymount University.

a program in Europe. The model in this essay looks at the implications of excluding ringleaders from leniency programs for the sustainability of collusion. On the one hand, it is shown that excluding ringleaders decreases the sustainability of collusion by forgoing the information of an additional potential whistleblower means for the antitrust authority. On the other hand, a ringleader will request from the other cartel members a compensation for not being able to apply for leniency. Such a compensation, however, results in an asymmetry between the ringleader and the ordinary cartel members which destabilizes collusion. Compared to the legal environment where ringleaders are eligible for leniency, excluding the ringleader reduces the cartel activity if the effect of asymmetry outweighs the two collusion-enhancing effects of ringleader discrimination: first, the effect of a decreasing probability that the antitrust authority is able to convict the cartel and secondly the effect of a reduced number of firms competing in the “race to report”. It is shown that if the probability that an antitrust authority investigates an industry is low, excluding ringleaders from leniency programs increases the sustainability of collusion. If the probability of review is high, an exclusion may decrease the sustainability.[2]

The model in *Chapter 4* is about Vertical integration and (horizontal) side-payments. It analyzes the emerging of an asymmetrically vertical integrated market structures when side-payments among firms are feasible. For instance, side-payments have been observed during the vertical merger process of E.ON and Ruhrgas – two major players on the first two tiers of the German natural gas market – in 2003, where E.ON payed around 90 million Euros to its competitors to stop a lawsuit against the merger. The model investigates how side-payments can be crucial to explain the development of a market structure where a vertically integrated firm co-exists with separated competitors in a successive duopoly. By assuming backward integration, it is

[2] I would like to thank my co-author of this essay, Alexander Rasch, for many and very fruitful discussions on this topic. Furthermore, I wish to thank the participants of the *Research Seminar in Applied Microeconomics* at the University of Cologne, especially Oliver Gürtler, Axel Ockenfels, and Dirk Sliwka for helpful remarks on a very early version of this model. The model has been presented on the 35^{th} *Conference of the European Association for Research in Industrial Economics* at the Toulouse School of Economics and it is accepted for presentation on the *2009 Annual Conference of the Royal Economic Society* at the University of Surrey and on the 7^{th} *Annual International Industrial Organization Conference* at the Northeastern University.

shown that a downstream firm can prevent counter-mergers of its rivals by transferring side-payments to them. However, an integrated downstream unit will never transfer side-payments to a separated upstream firm, since this would decrease its profits. Furthermore it is argued that antitrust authorities may allow for such side-payments, since they may increase the overall welfare compared to a market structure where all firms are separated. However, if firms would be willing to integrate without side-payments anyway, allowing for side-payments detains a market structure of full integration. A market where all firms are integrated results, however, in a higher welfare compared to a partially integrated market. Hence, a ban on side-payments would then result in an increase in welfare.[3]

Finally, in the concluding remarks in *Chapter 5* the results of the presented essays are summarized.

[3]I would like to thank Andreas Engel, Alexander Rasch, and Achim Wambach for very fruitful discussions, especially on the timing of the game.

Chapter 2

The impact of antitrust policy on collusion with imperfect monitoring

2.1 Introduction

Starting with Becker (1968) there has been a large debate in the literature on the impacts and the optimal adjustments of antitrust rules. In recent years the economic effect of the interaction of antitrust authorities and firms is still one major topic of the economic discussion on antitrust enforcement. One reason for this is the introduction of leniency programs in 1978 in the United States and later in 1996 in the European Union.[4] Leniency programs were implemented to increase the conviction rate of cartels by decreasing the information asymmetries between the antitrust authority and the firms. They seem to have indeed the desired effect. E.g. Brenner (2005) and Arlman (2005) report that the number of decisions on cartels in the European Union has increased substantially after the introduction of leniency in 1996 from 15 cases in the period from 1990 to 1995, to 38 cases from 1996 to 2003.[5] Since sharing of information

[4] These programs were introduced to give colluding firms incentives – by reducing the fines against these firms – to report information about the cartel to the antitrust authority and thus helping to punish other cartel members. For a detailed overview see Spagnolo (2007).

[5] However, it is not clear whether this increase is due to the effectiveness of the leniency program in encouraging whistle blowing or due to an increase in cartel activity. This problem will be discussed in *Section 2.5*.

seem to be a crucial component for the success of antitrust enforcements, developing a model with regard to antitrust authorities and firm interaction requires necessarily to model informational problems and spillovers of information. This essay takes account of those considerations.

While the literature on leniency programs has only focused on the information spillovers from firms to the antitrust authority so far, this work deals with an environment where the opposite information flow direction – from the antitrust authority to the firms – becomes relevant.[6] These information spillovers are the focus of the first part of this essay. In the second part the results from the first part are used to investigate the effectiveness of leniency programs in uncertain environments.

In the model an antitrust authority is assumed to decide on the size of the fine for collusive behavior, whether information during the antitrust procedure will be disclosed or not and whether leniency is granted or not. Firms attempt to collude in a market with uncertain demand, but observe only their individual demand. Using a model along the lines of Green and Porter (1984), it is shown that the effect of leniency programs is ambiguous, since the program has a weakly positive effect in industries with low probability of demand shocks and an adverse effect if the probability of demand shocks is high. Leniency unambiguously increases the number of prosecuted cartel cases, however.

Similar to previous literature it is found that fines can increase the sustainability of collusion, but only in industries with a relatively low probability of demand shocks. Information spillovers from the antitrust authority to the colluding firms reinforce the effect of fines on collusion and enable industries to collude even when they face a high probability of demand shocks. In all cases, fines unambiguously reduce welfare, even

[6] The regulations for the access to information during prosecution is given by the *Commission Notice on Immunity from fines and reduction of fines in cartel cases* (OJ C 298/11, 8.12.2006, paragraphs 31–35) in conjunction with the *Commission Notice on the rules for access to the Commission file in cases pursuant to Articles 81 and 82 of the EC Treaty, Articles 53, 54 and 57 of the EEA Agreement and Council Regulation (EC) No 139/2004* (OJ C 325/7, 22.12.2005, paragraph 7). Paragraph 7 says: "[...] access [to the files] is granted, upon request, to the persons, undertakings or associations of undertakings, as the case may be, to which the Commission addresses its objections [...]". Consequently all cartel members may have access to the information the rival's have revealed (e.g. effective demand or price setting).

in situations where collusion would have been sustainable without fines.

The intuition for these results is as follows: That fines can be used as a threat to sustain collusion in an uncertain environment has already been shown by Cyrenne (1999). Interestingly, this works only if the probability of demand shocks is relatively low. For a high probability of demand shocks, the introduction of a fine does not make collusion more stable, because the fine would have to be paid too often and collusion would never be profitable. In the standard Green Porter model temporary price wars in equilibrium are required to support collusion. By substituting the fine for these price wars, consumers are worse off, as the number of periods where collusion takes place increases. Thus, welfare will be reduced. Informational disclosure by the antitrust authority allows the firm to learn about the behavior of their competitors. As this information is costly (the fine has to be paid), the model works along the lines of the literature on costly private monitoring (see e.g. Compte (1998), Kandori and Matsushima (2003), Ben-Porath and Kahneman (2003), and Martin (2006)). If discounting is not too strong, the ability to monitor the competitors allows firms to collude, even in industries with a high probability of demand shocks. Finally, leniency in this model has the effect of reducing the expected fine. While for a low probability of demand shocks, a larger fine is useful in sustaining collusion, for a high probability of demand shocks it is the lower fine (which implies cheaper costly monitoring) which encourages collusion. Thus, leniency works in both directions. That antitrust policy can have the perverse effect of making collusion more stable is also shown by Cyrenne (1999), Spagnolo (2000), Harrington (2004a), Harrington (2004b), and Chen and Harrington (2007) also.

The model developed here contributes to the literature where information disclosure by the government influences market behavior. There exist several other examples where governmental institutions helped industries to sustain collusive pricing. Alexander (1994) shows that the National Industry Recovery Act (NIRA) between 1933 and 1935, which was introduced in the USA to stop price deflation and bankruptcies during the Depression, increased the concentration level of industries. Levenstein

(1995) analyzes the price-enhancing effect of publishing firm specific transaction prices by the government in the American salt industry in the late nineteenth century. Similar effects are found by ALBEAK, MOLLGARD, and OVERGAARD (1997) who analyze the price path of the Danish concrete industry and find an increase of prices during a period of price publishing by the Danish antitrust authority.

The chapter is organized as follows. In *Section 2.2* the specifications of the model and – as a benchmark – the standard model without an antitrust authority are presented. In *Section 2.3* the impact of fines on the possibility of firms to sustain collusive agreements is analyzed. In *Section 2.4* the model it extended by an information disclosure policy and in *Section 2.5* by a leniency programs. *Section 2.6* concludes.

2.2 The Model

The analysis of infinitely repeated games under imperfect monitoring follows the model discussed by TIROLE (1988), based on GREEN and PORTER (1984).[7] Tirole's model is extended to allow for an antitrust authority which can punish firms for collusive behavior.

2.2.1 Players

i. Firms

There are two firms in an industry, indexed by $i \in \{1, 2\}$. Firms compete in prices for an infinite number of periods $t \in \{0, 1, 2, .., \infty\}$ and produce a homogeneous product at constant marginal costs $c > 0$. In every period t, firm i sets the price p_i^t and observes its own demand D_i^t and profit Π_i^t, but neither the rival's price p_j^t nor demand D_j^t nor profit Π_j^t (with $j \neq i$).

[7] For a concise description of the original model see TIROLE (1988), pp. 262-264.

ii. Nature

The market demand D_k ($k \in \{l, h\}$) is stochastic and chosen by nature. Two states of demand are possible: With probability $1 - \alpha$, with $\alpha \in (0, 1)$ the market demand is strictly positive $D_h = D(p)$ (*high-demand state*). With probability α a demand shock accrues and market demand is zero $D_l = 0$, (*low-demand state*). The state of demand can not be observed by the firms directly.

To allow for correlated strategies later on, nature also chooses a random uniformly distributed signal $s \in [0, 1]$ which can be perfectly observed by the firms.

iii. Antitrust authority

The antitrust authority implements a law enforcement policy, which consists of an exogenously given lump-sum fine $F \in [0, \infty)$, possibly a leniency program and rules for information allocation. The fines have to be paid by the firms that are investigated and proven guilty with respect to collusive behavior. The success of an investigation depends on information about the collusion. It is assumed that this essential information can be revealed to the antitrust authority through *whistleblowing* by the firms only. Thus, if no firm does whistleblowing, the probability that the antitrust authority successfully proves firms guilty is equal to zero.[8] Otherwise, if at least one firm blows the whistle, the antitrust authority will investigate the industry, convict firm i of collusion if it observes $p_i^t > c$ in the current investigation period.[9]

To analyze the impact of different strategies of the antitrust authority the following policies will be discussed:

[8] This assumption is made for simplicity. It can be justified by invoking a budget-constraint for the antitrust authority and sufficiently high investigation costs. As a result, the antitrust authority would never investigate the industry without information from at least one firm. The assumption of a budget-constrained antitrust authority has also been made by Motta and Polo (2003) and Martin (2006). After the cartel case "Raw Tobacco Italy" (Case COMP/C.38.281/B.2) in October 2005, where a 50% (and 30% respectively) reduction of the actually fines where guaranteed to two cartel members, all decisions thereafter seem to have been based on essential information submitted by least one cartel member, since all decisions have seen full leniency (reduction of fine amounting to 100%) for one cartel member.

[9] As in Aubert, Rey, and Kovacic (2006) it is assumed that the antitrust authority only considers current period prices.

Information Policy: There are two possible information policies. In the first case, antitrust authority uses the revealed information to convict firms, but does not reveal the price setting of a firm to its rival. In the second case, the antitrust authority discloses the price setting in period t and informs each firm i about the price p_j^t of its rival. Denote by $\{nd, d\}$ the antitrust authority's set of options, where $\{nd\}$ stands for a *non-disclosing* and $\{d\}$ for a *disclosing* antitrust authority.

Leniency Policy: If no leniency program is in place, colluding firms have to pay a fine F, independent of whether a firm was helping the antitrust authority by blowing the whistle or not. If a leniency program is installed, the whistleblowing firm has to pay a reduced fine $R = (1 - r)F$ (with $r > 0$). Denote by $\{nl, l\}$ the antitrust authority's set of options, where $\{nl\}$ stands for *no leniency* and $\{l\}$ for *leniency*.

The fine F, the set of policies $\{d, nd\}$ and $\{l, nl\}$ are fixed before the firms start interacting.

The existence of a fine (full or reduced) and the policy of disclosing information extend the strategy space of the firms compared with the firms in Tirole's model by two important aspects: First, by the possibility to use a new punishment tool (fine) provided by the antitrust authority.[10] And second, the possibility to obtain (formerly) private information by blowing the whistle. This second aspect changes the collusive game from collusion under imperfect monitoring to a collusive game where monitoring is possible, but costly. The resulting changes in the structure of the game and in the firms' strategies are described in the following subsections.

[10] This aspect has also been discussed by Cyrenne (1999), who added a lump sum fine to the model of Green and Porter (1984).

2.2.2 Timing of the game

In period $t = 0$ the legal environment is defined: The antitrust authority sets the law enforcement policy parameters. It chooses a lump-sum fine F, commits to disclose the prices after investigation $\{d\}$ or not $\{nd\}$ and introduces leniency programs $\{l\}$ or not $\{nl\}$. The pricing game proceeds in period $t = 1, 2, ...$ and every period has the following structure:

Stage 1: Firms choose prices $p_i^t \in [c, p^M(c)]$.

Stage 2: Nature chooses the market demand D^t and the signal s^t. If $D^t > 0$, customers go to the firm with the lower price. In case both firms charges the same price, customers split equally between the firms.

Stage 3: Each firm i observes its own demand D_i^t with $i \in \{1, 2\}$ and the signal s^t, and obtains its profit Π_i^t. After that, each firm decides whether to blow the whistle or not. If no firm has chosen whistleblowing the game restarts at *Stage 1* in the next period $t + 1$. If at least one firm has blown the whistle, the game enters *Stage* 4.

Stage 4: The industry will be investigated by the antitrust authority. The authority observes the price setting of each firm i. If price p_i^t, with $i \in \{1, 2\}$, has exceeded c, firm i is convicted of collusion and has to pay the fine F (or the reduced fine R). Depending on the information policy commitment in $t = 0$, price p_i^t $i \in \{1, 2\}$ becomes public if $\{d\}$ was chosen or stays private knowledge for each firm $\{nd\}$. After that the game restarts at *Stage* 1 in the next period $t + 1$.

2.2.3 Firms' strategies

In order to sustain the collusive agreement while rival's price setting can not be observed directly, firms have to use a punishment mechanism which is independent of direct observation. In Tirole's model the only way of punishment is a price war of finite duration for T periods. In this model firms are able to choose between (or combine) punishment by a price war for T periods and the fine punishment. Thus, two different collusive strategies are analyzed, where in line with the literature on modeling collusion in a dynamic framework, the model concentrates on *Markov strategies*.[11]

TP (Temporary Punishment) This is the standard strategy firms play in Tirole's model without an antitrust authority. Firms collude from $t = 1$ on. If in period t neither deviation from $p_i^t = p^M$ nor a demand shock occurs, each firm realizes a profit of $\Pi_i^t = \frac{1}{2}\Pi^M$ at the end of the period. If in period t the demand of at least one firm is zero, firms start in $t+1$ a price war of T periods. In $t+1+T$, they revert to collusion.

TFP (Temporary and Fine Punishment) This is a combination of punishment by price war and fine punishment provided by the antitrust authority. Again, firms collude from $t = 1$ on. If in period t no deviation from $p_i^t = p^M$ or a demand shock occurs, each firm realizes a profit of $\Pi_i^t = \frac{1}{2}\Pi^M$ at the end of the period. If in period t the demand of at least one firm is zero, firms blow the whistle with probability γ and reveal information to the antitrust authority. Furthermore, firms start in $t+1$ a price war for T^γ periods. In $t+1+T^\gamma$, they revert to collusion. With probability $1-\gamma$ no firm does whistleblowing, but a price war of T' periods is started in the next period. In $t+1+T'$ firms revert to collusion. If a deviation from the equilibrium TFP strategy occurs, firms play "grim trigger" [Friedman (1971)], a price war with $p_i^t = c$ and profits $\Pi_i^t = 0$ in every following period.

[11]For details see Fudenberg and Tirole (1991) pp. 501 et sqq.

2.2.4 Benchmark

First the benchmark case similar to Tirole (1988) – where no antitrust authority exists – is described. Firms choose a price equal to the monopoly price p^M in period $t = 1$. In doing so, each firm receives half of the monopoly profit in a *high-demand state*, $\Pi_i^{h,t} = \frac{1}{2}\Pi^M$ and no profit in *low-demand state*, $\Pi_i^{l,t} = 0$. A firm that unilaterally defects from $p^t = p^M$ attracts in a *high-demand state* the whole market and gets the monopoly profit Π^M. In the punishment phase which occurs after a *low-demand state* or when a firm has deviated, firms set $p^t = c$ for T-periods and hence obtain in each period $\Pi_i^{k,t} = 0$. Let V^+ denote the firm value in period t when the game is in a collusive phase. Let δ be the discount factor which is the same for each firm, with $0 \leq \delta < 1$. Then it holds:

$$V^+ = (1-\alpha)\left(\frac{1}{2}\Pi^M + \delta V^+\right) + \alpha(0 + \delta^{T+1}V^+) \tag{2.1}$$

The first term of equation (2.1) reflects that in each *high-demand state* firms get the collusive profit. The second term shows that in a *low-demand state*, profits are equal to zero and a phase of a T-period price war will be started.

If one firm unilaterally defects from the collusion, its firm value is:

$$V^D = (1-\alpha)\left(\Pi^M + \delta^{T+1}V^+\right) + \alpha(0 + \delta^{T+1}V^+). \tag{2.2}$$

The first term of equation (2.2) reflects that a deviating firm gets the whole monopoly profit in a *high-demand state*. However, since its rival observes no demand in this period this triggers a price war of T periods. While the interpretation of the second term is equal to equation (2.1).

It is obvious that firms have an incentive to collude if the firm value of a colluding firm V^+ is weakly larger than the firm value of a defecting firm, V^D. Thus, $V^+ \geq V^D$ gives the following condition:

$$(\delta - \delta^{T+1})V^+ \geq \frac{1}{2}\Pi^M. \tag{2.3}$$

Condition (2.3) can be denoted as incentive compatibility constraint (IC), since the increase of the firm value by sticking to the collusion in period t has to be weakly larger than the additional profit $\frac{1}{2}\Pi^M$ from defecting in a *high-demand state*.

From equation (2.1) the firm value resulting from collusion can be determined:

$$V^+ = \frac{1}{2}\Pi^M \left(\frac{(1-\alpha)}{1-\delta+\alpha(\delta-\delta^{T+1})} \right). \tag{2.4}$$

Thus, the IC, condition (2.3), amounts to

$$\frac{1}{2}\Pi^M \left(\frac{(\delta-\delta^{T+1})(1-\alpha)}{1-\delta+\alpha(\delta-\delta^{T+1})} \right) \geq \frac{1}{2}\Pi^M \tag{2.5}$$

which can be reduced to

$$(1-2\alpha)(\delta-\delta^{T+1}) - (1-\delta) \geq 0. \tag{2.6}$$

From inequality (2.6) it is obvious that collusion is an equilibrium if, for a given α, δ is not too small: $\delta \in [\delta(\alpha), 1)$, or if, for a given δ, α is not too large: $\alpha \in [0, \alpha(\delta)]$. The resulting critical parameters are described by Tirole (1988). In order to make the results comparable to the results in the following sections, the following lemma summarizes:

Lemma 2.1 *In absence of an antitrust authority, a perfect Bayesian equilibrium exists in which firms collude by using a temporary price war as punishment if*

(i) $\alpha \leq 1 - \frac{1}{2\delta} \leq \frac{1}{2}$

or equivalently

(ii) $\delta \geq \frac{1}{2(1-\alpha)} \geq \frac{1}{2}$

Proof From inequality (2.6) it follows directly that the IC can not be satisfied if $\alpha > \frac{1}{2}$ holds. So it is sufficient to consider the case $\alpha \leq \frac{1}{2}$. As $\frac{\partial IC}{\partial \alpha} \leq 0$, $\frac{\partial IC}{\partial \delta} \geq 0$, and $\frac{\partial IC}{\partial T} = -(1-2\alpha)\delta^{T+1}\ln(\delta) \geq 0$ for $\alpha \leq \frac{1}{2}$, to calculate the minimal δ (maximal α) we set $T \to \infty$. Thus $IC \geq 0$ changes to $IC^{T\to\infty} = 2\delta(1-\alpha) - 1 \geq 0$ which holds if $\delta \geq \frac{1}{2(1-\alpha)}$ or equivalently $\alpha \leq 1 - \frac{1}{2}\delta$. ■

A specific industry is defined as two firms producing the same product under the same cost structure and the same market conditions. These conditions are reflected by the industry-specific α and δ. The curve in *Figure 2.1* displays the boundary of industries where collusion is sustainable. Industries which are located in the hatched area left to the curve are the candidates for collusive activities using TP.

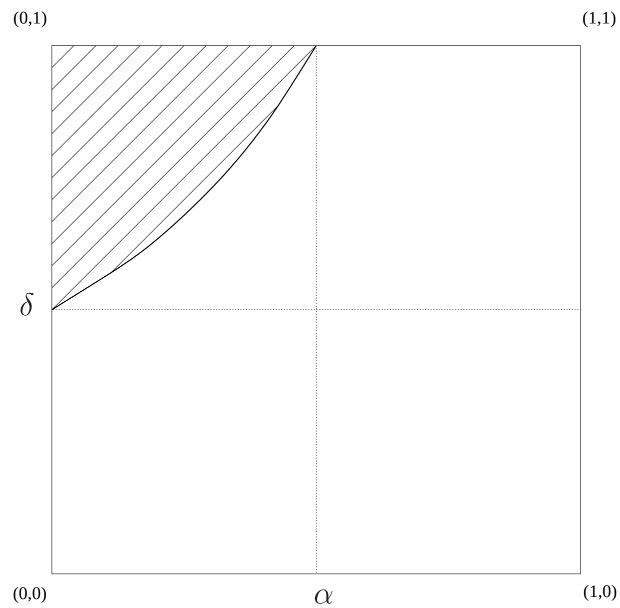

Figure 2.1: Sustainable collusion by the use of the TP strategy

The optimal strategy of firms using TP is easy to see. From inequality (2.3) it follows, that collusion is more likely to be stable if T is large. On the other hand, equation (2.4) implies $\frac{\partial V^+}{\partial T} \leq 0$. Thus, to maximize the collusive firm value, firms have to coordinate on a minimal T which is high enough to satisfy the IC. Thus, the optimization problem becomes:

$$\min T \equiv \arg\max V^+ \tag{2.7}$$

s.t.

$$(1-2\alpha)(\delta - \delta^{T+1}) - (1-\delta) \geq 0$$

2.3 The non-disclosing antitrust authority

Now the antitrust authority is added to the benchmark model. The antitrust authority commits to a lump sum fine $F \in [0, \infty)$ in period $t = 0$, no leniency program exists, $\{nl\}$, and the antitrust authority chooses a *non-disclosing* policy, $\{nd\}$. Thus, firms do not obtain any information about the price setting of its rival if they are investigated. As a result, they are again not informed about the reason when observing zero demand, independent of whether a firm blows the whistle or not.

If firms use the TP strategy no firm does whistleblowing in equilibrium and the outcome of the analysis is the same as in the benchmark. Thus, only the conditions for the TFP strategy have to be analyzed: If a firm faces no profit, it blows the whistle with probability γ. To coordinate on a certain frequency of whistleblowing, firms use the signal s^t provided in every period t. Only if $s^t \leq \gamma$ firms will in equilibrium (jointly) blow the whistle.

Recalling that the TFP strategy specifies that firms, given they observe zero demand, undertake a price war of T^γ (T') periods if they blow (do not blow) the whistle, the values of the firms under collusion and deviation[12] can be calculated:

$$V^+ = (1-\alpha)\left(\frac{1}{2}\Pi^M + \delta V^+\right) + \alpha\Big(\gamma\left[-F + \delta^{T^\gamma+1}V^+\right] + (1-\gamma)\delta^{T'+1}V^+\Big) \tag{2.8}$$

and

$$\begin{aligned} V^D \quad &= \quad (1-\alpha)\Big(\Pi^M + \gamma\left[-F + \delta^{T^\gamma+1}V^+\right] + (1-\gamma)\delta^{T'+1}V^+\Big) + \\ &+ \quad \alpha \quad \Big(\gamma\left[-F + \delta^{T^\gamma+1}V^+\right] + (1-\gamma)\delta^{T'+1}V^+\Big). \end{aligned} \tag{2.9}$$

To sustain collusion, the new IC, $V^+ \geq V^D$, has to hold again. Consequently, it turns out that

$$\Big(\delta - \Big[\gamma\delta^{T^\gamma+1} + (1-\gamma)\delta^{T'+1}\Big]\Big)V^+ \geq \frac{1}{2}\Pi^M - \gamma F. \tag{2.10}$$

[12] Note that if firm i deviates from the collusive strategy, it is indifferent in blowing the whistle with probability γ or not since firm j would do whistleblowing anyway.

The term in the angled brackets $\gamma\delta^{T^\gamma+1}+(1-\gamma)\delta^{T'+1}$ can be interpreted as the *effective* reduction of firm value due to periods of price wars. This reduction will be denoted by

$$\delta_{nd}^{eff} \equiv \gamma\delta^{T^\gamma+1} + (1-\gamma)\delta^{T'+1}. \tag{2.11}$$

Thus, inequality (2.10) changes to

$$\left(\delta - \delta_{nd}^{eff}\right) V^+ \geq \frac{1}{2}\Pi^M - \gamma F. \tag{2.12}$$

Compared to the corresponding inequality in the benchmark (2.3), the left hand side of inequality (2.12) represents again the difference of firm values in a *high-demand state* between staying in the collusion and after a deviation induced price war. Which is thus equal to the expected costs of defecting. While the right hand side is again the additional profit from defecting in a *high-demand state*, in this case reduced by the expected fine a deviating firm has to pay. To determine the range of parameters where collusion is stable equation (2.8) is rearranged to give

$$V^+ = \frac{(1-\alpha)\Pi^M - 2\alpha\gamma F}{2[1-\delta+\alpha(\delta-\delta_{nd}^{eff})]}. \tag{2.13}$$

By inserting (2.13) into condition (2.12), $V^+ \geq V^D$ holds if:

$$(1-2\alpha)\left(\delta - \delta_{nd}^{eff}\right) + \left(\gamma\frac{2F}{\Pi^M} - 1\right)(1-\delta) \geq 0. \tag{2.14}$$

Whether the IC, condition (2.12), holds or not depends on the exogenous parameters α and δ but, compared with the benchmark, additionally on the term $\frac{2F}{\Pi^M}$. This parameter is the ratio of the fine F and half of the monopoly profit $\frac{1}{2}\Pi^M$, the additional profit from defecting in a *high-demand state*. Let $\phi = \frac{2F}{\Pi}$ be the fine/profit-ratio. Thus the IC reduces to:

$$(1-2\alpha)\left(\delta - \delta_{nd}^{eff}\right) + (\gamma\phi - 1)(1-\delta) \geq 0 \tag{2.15}$$

By choosing the length of the punishment phases $T^\gamma, T' \in \{0, 1, 2, ...\}$, firms can again choose the effective reduction of the firm value after a price war, δ_{nd}^{eff}. Additionally they can choose the expected payment to the antitrust authority, γF, by choosing the frequency of blowing the whistle, $\gamma \in [0, 1]$. From inequality (2.15) it follows that for $\gamma\phi \geq 1$, firms do not need a reduction of firm value by choosing a δ_{nd}^{eff} to sustain collusion, as the IC holds anyway. However, from equation (2.13), using that $2F = \phi\Pi^M$, it can be seen that for a large expected fine/profit-ratio, $\gamma\phi$, and a high probability of demand shocks α, V^+ may become negative. Therefore, an additional constraint, $V^+ \geq 0$ has to be added. This condition can be called participation constraint (PC), as it reflects the fact that firms have to obtain at least non-negative firm value from collusion. Since the denominator of expression (2.13) never turns negative the PC can be written as:

$$(1 - \alpha) - \alpha\gamma\phi \geq 0. \tag{2.16}$$

The condition for the existence of a collusive equilibrium is given in the following lemma.

Lemma 2.2 *For $F > 0, \{nd\}$, and $\{nl\}$ a perfect Bayesian equilibrium exists where firms collude by using the TFP strategy if*

(i)

$$\alpha \leq \begin{cases} 1 - \frac{1-(1-\delta)\phi}{2\delta} & \text{if } \phi < 1 \\ \\ \frac{1}{2} & \text{if } \phi \geq 1 \end{cases}$$

or equivalently

(ii)

$$\delta \geq \begin{cases} \frac{1-\phi}{2(1-\alpha)-\phi} & \text{if } \phi < 1 \\ \\ 0 & \text{if } \phi \geq 1 \end{cases}$$

Proof The PC, condition (2.16), is satisfied if and only if $\gamma \leq \min\left[1, \frac{1-\alpha}{\alpha\phi}\right]$.
From inequality (2.15) it follows that $\frac{\partial IC}{\partial \delta_{nd}^{eff}} = -(1-2\alpha)$. To determine the border cases, for $\alpha \leq \frac{1}{2}$ we set $\delta_{nd}^{eff} = 0$ and for $\alpha > \frac{1}{2}$ we set δ_{nd}^{eff} to its maximal value, $\delta_{nd}^{eff} = \delta$. In both cases γ is also set to its maximum value.
Consider first the case $\alpha \leq \frac{1}{2}$: The IC then changes to $(1-2\alpha)\delta + \min\left[\phi, \frac{1-\alpha}{\alpha}\right] - 1)(1-\delta) \geq 0$. If $\phi \geq \frac{1-\alpha}{\alpha}(\geq 1)$ the IC holds. If $\phi < \frac{1-\alpha}{\alpha}$, the IC holds if $\alpha \leq 1 - \frac{1-(1-\delta)\phi}{2\delta}$ or $\delta \geq \frac{1-\phi}{2(1-\alpha)-\phi}$.
Next consider the case $\alpha > \frac{1}{2}$: As the PC requires that $\gamma\phi < 1$ and the IC now reads $(\gamma\phi - 1)(1-\delta) \geq 0$, one can see that both conditions can never hold simultaneously.■

Compared with the benchmark case, the number of industries which are able to sustain collusion is increasing in the fines provided by a *non-disclosing* antitrust authority, since $\frac{\partial\alpha}{\partial\phi} > 0$ and $\frac{\partial\delta}{\partial\phi} < 0$. *Figure 2.2* displays the boundaries for industries where collusion can be sustained for different values of $\phi \geq 0$. All industries which are located in the area left to the curves are able to use the TFP strategy in equilibrium.

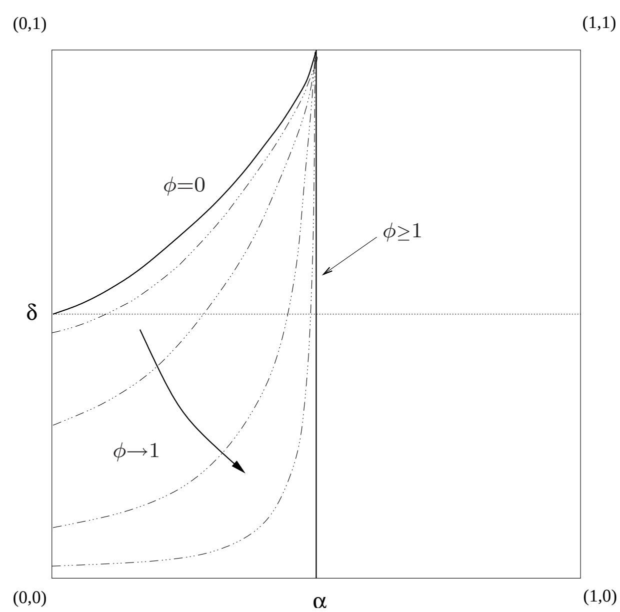

Figure 2.2: Sustainable Collusion under a regime of a *non-disclosing* antitrust authority

From comparing *Lemma 2.1* and *Lemma 2.2* it follows that if there is a *non-disclosing* antitrust authority, even firms with a relatively low discount factor ($\delta < \frac{1}{2}$) can sustain collusion. On the other hand, as in the benchmark only firms which face a demand shock with a relative low probability ($\alpha \leq \frac{1}{2}$) are able sustain collusion. The results are summarized in the following proposition:

Proposition 2.1 *Compared to a situation without an antitrust authority, introducing a non-disclosing antitrust authority with policy $F, \{nd\}$, and $\{nl\}$*

(i) leads to more collusive industries with $\alpha \leq \frac{1}{2}$,

(ii) has no effect on industries with $\alpha > \frac{1}{2}$.

Proof The proof follows immediately from *Lemma 2.1* and *Lemma 2.2.* ■

Next the welfare consequences of an antitrust authority are analyzed. First, allowing for $\phi > 0$ makes it possible for more industries to collude and leads to welfare losses since prices are (in some periods) above marginal costs, at leat as demand is elastic. Additionally, there is a second effect: Firms which are able to sustain collusion without a fine, might now use the fine punishment instead of the price war punishment. As the price war punishment brings with it a welfare gain due to marginal cost pricing for T periods instead of monopoly prices, reverting to a fine punishment would lead to a loss of welfare.

However, for this argument to hold through, it needs to be shown that firms indeed use the fine punishment if they have the choice between the two instruments. From the point of view of the firms it turns out that if collusion is sustainable both instruments are perfectly substitutable if the IC binds.[13] The result is shown in the following lemma:

Lemma 2.3 *Any combination of T', T^{γ}, and γ such that the IC binds yields the same collusive firm value, V^{+}.*

[13] At least if firms maximize their collusive profit, the IC will bind in equilibrium.

Proof To keep the IC constant, a decrease in the frequency of whistleblowing (decrease in γ) has to be compensated by a decrease of δ_{nd}^{eff}, i.e. $\frac{d\delta_{nd}^{eff}}{d\gamma} = \frac{2F(1-\delta)}{\Pi^M(1-2\alpha)} \geq 0$. The total change in V^+ is given by: $\frac{dV^+}{d\gamma} = \frac{\partial V^+}{\partial \delta_{nd}^{eff}} \frac{d\delta_{nd}^{eff}}{d\gamma} + \frac{\partial V^+}{\partial \gamma} =$ $-\frac{\alpha^2 F \Pi^M \left[(1-2\alpha)(\delta-\delta_{nd}^{eff})+(\gamma\phi-1)(1-\delta)\right]}{(1-\delta+\alpha(\delta-\delta_{nd}^{eff}))\Pi^M(1-2\alpha)}$. This expression is zero as the term in brackets in the numerator is just the IC, which is assumed to bind. ■

Thus, all relevant parameters can be freely chosen by the firms or can be adapted to any exogenous requirement without reducing the firm value.[14]

The results on the welfare consequences of an antitrust authority with a fine only are summarized in the next Proposition:

Proposition 2.2 *A fine reduces welfare through increasing the number of colluding industries. Even if collusion is sustainable without a fine, introducing a fine will lead to a reduction of welfare if firms blow the whistle with positive probability in equilibrium.*

Proof The first result immediately follows from *Lemma 2.1* and *Lemma 2.2*. For the second result, it still needs to be shown that the new combination of fine and price wars (i.e. T^γ, T' instead of T) indeed leads to a reduction in welfare. Denote by Δ the welfare gain per period of price war. The expected welfare gain through price wars is then given by

$$
\begin{aligned}
E[\Delta] &= \gamma \sum_{i=1}^{T^\gamma} \delta^i \Delta + (1-\gamma) \sum_{i=1}^{T'} \delta^i \Delta && (2.17)\\
&= \gamma \frac{(\delta - \delta^{T^\gamma+1})}{1-\delta} \Delta + (1-\gamma) \frac{(\delta - \delta^{T'+1})}{1-\delta} \Delta && (2.18)\\
&= \frac{\Delta}{1-\delta} \left[\delta - \left(\gamma \delta^{T^\gamma+1} + (1-\gamma) \delta^{T'+1} \right) \right] && (2.19)\\
&= \frac{\Delta}{1-\delta} \left[\delta - \delta_{nd}^{eff} \right] && (2.20)
\end{aligned}
$$

The benchmark is represented by $\gamma = 0$. From *Lemma 2.2* it is known that $\frac{\partial \delta_{nd}^{eff}}{\partial \gamma} =$

[14]An example for such a requirement could be, that firms have to make detailed reports about their activities for some periods after proven guilty for collusion ($T^\gamma \geq \underline{T}$). E.g. Motta and Polo (2003) introduced such a requirement in their model. They assume that firms have to interrupt the collusion for one period after the investigation of the antitrust authority.

$\frac{\phi(1-\delta)}{1-2\alpha} \geq 0$. Since $\frac{\partial E[\Delta]}{\partial \delta_{nd}^{eff}} < 0$, any $\gamma > 0$ reduces welfare. ■

2.4 The disclosing antitrust authority

Now the model is extended to analyze the effects of information spillovers from the antitrust authority to the colluding firms. If the antitrust authority informs each firm about the price of its rival in the current period t (commits to $\{d\}$ and $F > 0$ in $t = 0$), firms are able to monitor each other through whistleblowing. If colluding firms blow the whistle and observe that no firm has deviated they can immediately go back to collusion. There is no need to punish the other by starting a price war. On the other hand, if it is observed that one firm has deviated this will trigger the breakdown of collusion, thus price equal marginal costs would be set in every period thereafter.

The firm value from collusion is therefore given by

$$V^+ = (1-\alpha)\left(\frac{1}{2}\Pi^M + \delta V^+\right) + \alpha\Big(\gamma\left[-F + \delta V^+\right] + (1-\gamma)\delta^{T'+1}V^+\Big) \tag{2.21}$$

and the value of a firm which deviates is

$$\begin{aligned} V^D &= (1-\alpha)\Big(\Pi^M + \gamma\left[-F\right] + (1-\gamma)\left[\delta^{T'+1}V^+\right]\Big) + \\ &+ \alpha \Big(\gamma\left[-F\right] + (1-\gamma)\delta^{T'+1}V^+\Big). \end{aligned} \tag{2.22}$$

Compared to equations (2.8) and (2.9) under a *non-disclosing* antitrust authority, there are two relevant modifications in the corresponding equations (2.21) and (2.22). First, the firm value from collusion, V^+, is increased by $\alpha\gamma(\delta - \delta^{T^\gamma+1})V^+$: If firms blow the whistle, they are assured that the absence of demand was induced by nature. Thus, they are able to revert to collusion immediately if the antitrust authority informs them that deviation did not take place. Second, in the expression for the firm value from deviation, V^D, the term $\gamma\delta^{T^\gamma+1}V^+$ is missing. After a deviation is detected (with probability γ) there is no return to the collusive outcome (in effect $T^\gamma = \infty$). In analogy with the analysis of a *non-disclosing* antitrust authority the *effective* reduction of firm value when firms stick to the collusive strategy is defined by:

$$\delta_d^{eff} \equiv \gamma\delta + (1-\gamma)\delta^{T'+1}. \tag{2.23}$$

Proceeding as before and using definition (2.23) equation (2.21) can be simplified to:

$$V^+ = \frac{(1-\alpha)\Pi^M - 2\alpha\gamma F}{2\left[1-\delta+\alpha\left(\delta-\delta_d^{eff}\right)\right]}. \tag{2.24}$$

Both changes in the firms values and the definition of δ_d^{eff} lead to the new IC:

$$\left(\delta - \delta_d^{eff} + \frac{1}{1-\alpha}\gamma\delta\right) V^+ \geq \frac{1}{2}\Pi^M - \gamma F \tag{2.25}$$

The left hand side of inequality (2.25) represents again the difference of firm value between staying in the collusion and after a deviation induced price war. While the right hand side is again the additional profit from defecting in a *high-demand state* and its reduction by the expected fine a deviating firm has to pay. The first effect of a *disclosing* policy is given by $T^\gamma = 0$ in δ_d^{eff}. The second effect can be found in the positive term $\frac{1}{1-\alpha}\gamma\delta V^+$. This term reflects that a deviating firm has to forgo any additional collusive profits with probability γ. While in the benchmark and under a *non-disclosing* policy the costs and benefits from defecting are only relevant in a *high-demand state*, now the costs of defecting have to be borne additionally in a *low-demand state*. Thus the term is scaled by dividing through $1-\alpha$.

Plugging (2.24) into (2.25) and using $\phi = \frac{2F}{\Pi^M}$, the IC changes to

$$(1-2\alpha)\left(\delta-\delta_d^{eff}\right) + (\gamma\phi - 1)\left(1-(1-\gamma)\delta\right) + \frac{1}{1-\alpha}\gamma\delta\left(2(1-\alpha)-\gamma\phi\right) \geq 0. \tag{2.26}$$

As before, the PC, $V^+ \geq 0$, has to be considered as well. Again, the denominator of inequality (2.24) never turns negative. Thus, the PC can be written as before:

$$(1-\alpha) - \alpha\gamma\phi \geq 0. \tag{2.27}$$

The condition for the existence of a collusive equilibrium is shown in the following lemma.

Lemma 2.4 *For $F > 0, \{d\}$, and $\{nl\}$ a perfect Bayesian equilibrium where firms collude exists if*

(i)

$$\alpha \leq \begin{cases} 1 - \frac{1-(1-\delta)\phi-(1-\phi)}{2\delta-(1-\phi)} & \text{if} \quad \frac{\phi-1}{\phi-2} \leq \delta \leq \frac{\phi-2}{\phi-3} \quad \text{and} \quad \phi < 1 \\ \\ \frac{((1-\delta)\phi+\delta)^2}{((1-\delta)\phi+\delta)^2+4\delta(1-\delta)\phi} & \text{if} \quad \delta > \frac{\phi-2}{\phi-3} \quad \text{and} \quad \phi < 1 \end{cases}$$

$$\alpha \leq \begin{cases} \frac{1}{2} & \text{if} \quad \delta \leq \frac{\phi}{1+\phi} \quad \text{and} \quad \phi \geq 1 \\ \\ \frac{((1-\delta)\phi+\delta)^2}{((1-\delta)\phi+\delta)^2+4\delta(1-\delta)\phi} & \text{if} \quad \delta > \frac{\phi}{1+\phi} \quad \text{and} \quad \phi \geq 1 \end{cases}$$

or equivalently

(ii)

$$\delta \geq \begin{cases} \frac{(1-\alpha)(1-\phi)}{2(1-\alpha)-\phi} & \text{if} \quad \alpha < \frac{1}{1+2\phi-\phi^2} \quad \text{and} \quad \phi < 1 \\ \\ \frac{\left((3\alpha-1)+(1-\alpha)\phi+2\sqrt{2\alpha^2-\alpha}\right)\phi}{[2(3\alpha-1)+(1-\alpha)\phi]\phi+(1-\alpha)} & \text{if} \quad \alpha \geq \frac{1}{1+2\phi-\phi^2} \quad \text{and} \quad \phi < 1 \end{cases}$$

$$\delta \geq \begin{cases} 0 & \text{if} \quad \alpha \leq \frac{1}{2} \quad \text{and} \quad \phi \geq 1 \\ \\ \frac{\left((3\alpha-1)+(1-\alpha)\phi+2\sqrt{2\alpha^2-\alpha}\right)\phi}{[2(3\alpha-1)+(1-\alpha)\phi]\phi+(1-\alpha)} & \text{if} \quad \alpha > \frac{1}{2} \quad \text{and} \quad \phi \geq 1 \end{cases}$$

Proof The proof is delegated to the appendix (see *A.1.1*). ■

Lemma 2.4 shows that even for $\alpha > \frac{1}{2}$ collusion might be possible if the antitrust authority reveals information. The intuition for this can be most easily seen by assuming that the fine is zero, i.e. $\phi = 0$.[15] In this case whistleblowing is costless and the situation is as in an environment with perfect monitoring. Thus, the standard result for collusion of two firms is obtained: for all $\alpha \leq 1$ collusion can be sustained as long as $\delta \geq \frac{1}{2}$.

Moreover, *Lemma 2.4* shows that if the probability of demand shocks is relatively low ($\alpha \leq \frac{1}{2}$), the results are similar to the case of a regime of a *non-disclosing* antitrust authority: The number of industries which can sustain collusion is increasing in ϕ. However, as can be seen below, the overall range of parameters where collusion is possible is enlarged.

As before, if $\phi \geq 1$ all industries, with $\alpha \leq \frac{1}{2}$ and $\delta \geq 0$ can sustain collusion. If, in contrast, the probability of demand shocks is relatively high, ($\alpha > \frac{1}{2}$), the number of industries which can sustain collusion is decreasing in ϕ and sustainable collusion requires a larger δ if the fine/profit-ratio is increasing.[16] The limit, $\phi \to \infty$, is equal to an environment of an *non-disclosing* antitrust authority where no industry with $\alpha > \frac{1}{2}$ is able to sustain collusion. *Figure 2.3* displays the boundaries for sustainable collusion for any given $\phi \geq 0$. All industries in the areas left (and above) the curves are able to sustain collusion with the TFP strategy.

[15] A zero expected fine might even be a realistic assumption to be made if proposals of a reward for whistleblowing go through. See the next section for a discussion.

[16] These results are in the line with Ben-Porath and Kahneman (2003) who show that if perfect monitoring is possible, and even when the costs of monitoring are high, every payoff vector which is an interior point in the set of feasible and individually rational payoffs can be implemented in a repeated game if the discount factor is high enough.

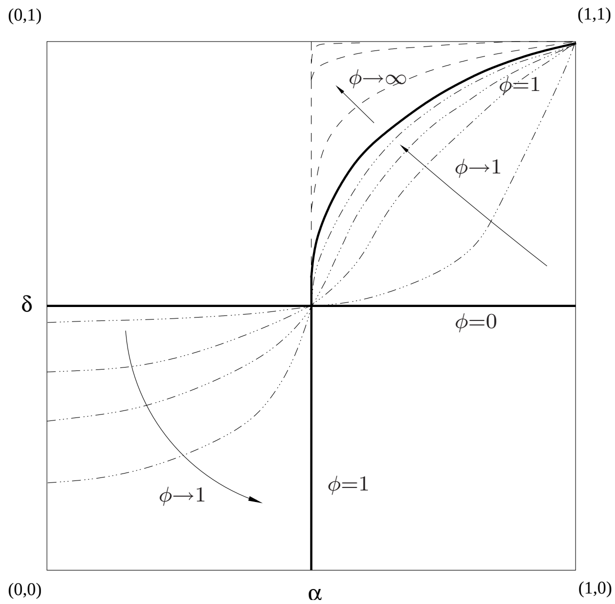

Figure 2.3: Sustainable Collusion under a regime of a *disclosing* antitrust authority

To compare between the outcomes of *Lemma 2.2* and *Lemma 2.4*, the two cases $\alpha > \frac{1}{2}$ and $\alpha \leq \frac{1}{2}$ will be discussed in turn. If the probability of a demand shock is relatively high, $\alpha > \frac{1}{2}$, industries are able to sustain collusion only if the antitrust authority commits to $\{d\}$ in $t = 0$. If the probability of a demand shock is relatively low, $\alpha \leq \frac{1}{2}$, for any $\phi < 1$, then the critical discount rate where collusion can barley be sustained for a given ϕ is weakly lower for a *disclosing* than for a *non-disclosing* antitrust authority.[17] *Figure 2.4* gives an example comparing the critical discount rates in the two scenarios for a given α.

[17] *Lemma 2.2* gives that a *non-disclosing* antitrust authority requires a critical discount rate of $\delta \geq \frac{1-\phi}{2(1-\alpha)-\phi}$. While *Lemma 2.4* shows that under a *disclosing* antitrust authority collusion can be sustained if $\delta \geq \frac{(1-\alpha)(1-\phi)}{2(1-\alpha)-\phi}$.

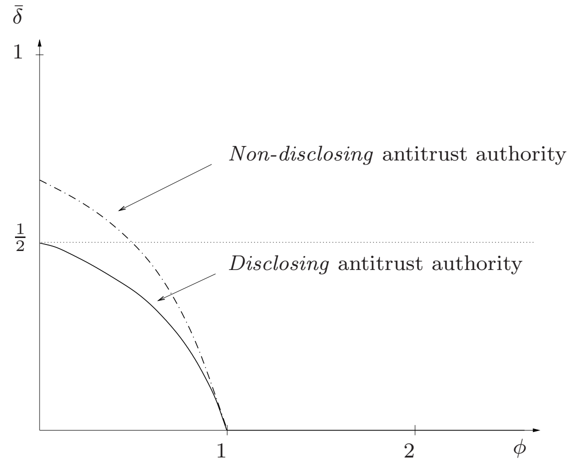

Figure 2.4: Critical discount rates under regime of a *non-disclosing* and a *disclosing* antitrust authority, for $\alpha = \frac{1}{4}$

In case $\phi \geq 1$ (and still $\alpha \leq \frac{1}{2}$) collusion can be sustained for any $\delta \geq 0$, independent of the information policy. These results are summarized in the following proposition:

Proposition 2.3 *Compared to a non-disclosing antitrust authority, a disclosing antitrust authority, which commits to* $F \geq 0$, $\{d\}$ *and* $\{nl\}$ *in* $t = 0$, *increases the number of colluding industries.*

Proof The proof immediately follows from the discussion above. ■

Before turning to the welfare analysis, it has to be analyzed whether firms will use indeed the fine as a punishment if they have the choice between different instruments. While under a *non-disclosing* policy the firms are indifferent between the two instruments, in the case of a *disclosing* antitrust authority firms always prefer to blow the whistle and price wars will no longer be observed. This yields the following proposition:

Proposition 2.4 *In the case of a disclosing policy, firms will never use price wars to sustain collusion.*

Proof In the discussion above *Proposition 2.2* it was shown that in the case of a *non-disclosing* policy an increase in γ can be compensated by an increase in δ_{nd}^{eff} such that V^+ and the IC do not change. By comparing the respective firm values from collusion in the cases of a *non-disclosing* and a *disclosing* policy (equations (2.13) and (2.24)), it follows that the same change in γ and δ_d^{eff} would yield again no change in V^+, since both equations are equal. Comparing the respective $IC's$, we know that for a corresponding increase of γ and δ_{nd}^{eff} that the IC in the case of a *non-disclosing* policy (inequality (2.12)) does not change. However, the IC in the case of a *disclosing* policy (inequality (2.25)) becomes slack, since the additional term in inequality (2.25), $\frac{1}{1-\alpha}\gamma\delta$, is increasing in γ. Thus, due to maximizing V^+ firms choose γ as large as necessary to keep the IC just binding and δ_d^{eff} as large as possible (T' as low as possible), i.e. $\frac{dV^+}{d\gamma} = \frac{\partial V^+}{\partial \delta_d^{eff}} \frac{d\delta_d^{eff}}{d\gamma} + \frac{\partial V^+}{\partial \gamma} > 0$. Moreover, if γ reaches its maximum ($\gamma = 1$), T' becomes irrelevant. ■

Since it is never optimal to choose $T' > 0$ and thus $\delta_d^{eff} = \delta$, the optimization problem becomes:

$$\min \gamma \equiv \arg \max_{\gamma \in (0,1]} V^+ \tag{2.28}$$

$$\text{s.t.}$$

$$(\gamma\phi - 1)(1 - (1-\gamma)\delta) + \frac{\gamma\delta}{1-\alpha}(2(1-\alpha) - \gamma\phi) \geq 0$$

$$(1-\alpha) - \alpha\gamma\phi \geq 0$$

Now the consequences of a *disclosing* antitrust authority on the welfare can be analyzed. There are three different effects.

First, as discussed above, both for $\alpha \leq \frac{1}{2}$ and for $\alpha > \frac{1}{2}$ there will be more parameter values for which collusion is stable, if the antitrust authority commits to disclose information.

Second, even if industries could collude anyway, there will be less price war periods. As shown above, under a *disclosing* antitrust authority profit maximizing colluding firms will never resort to price wars, while with a *non-disclosing* antitrust authority price wars might either be necessary or firms are at least not worse off by using a price war than by using the fine punishment. As price wars lead to marginal cost pricing and thus to a welfare gain compared to monopoly prices, using fines reduces welfare.

If paying fines is positive for welfare (e.g. due to welfare losses in raising taxes which might be avoided by obtaining the fine), then there is a third welfare reducing effect: With a *disclosing* antitrust authority, firms pay less fines on average. To see this, assume that parameter values are such that firms are able to sustain collusion under a regime of a *non-disclosing* antitrust authority without price wars.[18] For such industries, the number of price war periods is unaffected by the disclosing of information. However, since $T^{\gamma} = T' = 0$ and thus $\delta_{nd}^{eff} = \delta_{d}^{eff} = \delta$, comparing the $IC's$ (inequality (2.12) and (2.25)) implies that for a given ϕ the frequency of whistleblowing under a regime of a *disclosing* antitrust authority is lower than the frequency of whistleblowing under a regime of a *non-disclosing* antitrust authority.

These three effects are summarized in the following proposition.

Proposition 2.5 *Compared to a regime of a non-disclosing antitrust authority, introducing a disclosing antitrust authority is always welfare reducing.*

Proof The proof follows immediately from the discussion above. ■

2.5 Leniency policy

In this section the model is extended to analyze an antitrust authority which commits to a leniency policy $\{l\}$ in $t = 0$. In doing so, a firm that has blown the whistle will get a reduced fine $R = (1 - r)F$ with leniency parameter $r > 0$. In line with the current antitrust policy of the European Commission and the US Department of Justice, rewards for whistleblowing firms are assumed to be not allowed.[19] Thus, the leniency parameter is limited to $r \leq 1$. Furthermore, the antitrust authority is assumed to commit the fine reduction only for the first firm which blows the whistle.[20] If both firms blow the whistle simultaneously, one of them is randomly chosen as the first whistleblower. For this analysis, where firms either do not blow the whistle at all or

[18] For example if $\phi > 1$.

[19] An overview of the similarities and varieties of the leniency policy in the EU and in the US is given in Section 3 of Spagnolo (2007).

[20] These two assumptions will be relaxed in section 2.5.3.

do it simultaneously, a whistle blowing firm thus expects a fine of

$$E[F] = \left(1 - \frac{1}{2}r\right) F \tag{2.29}$$

From $r \in (0, 1]$ it is obvious that $E[F] < F$.

Again, two cases has to be analyzed: The first, where a *non-disclosing* antitrust authority commits to leniency $\{l\}$ for whistleblowing firms. And second, the case of a *disclosing* antitrust authority commits to $\{l\}$.

2.5.1 The non-disclosing antitrust authority

If the antitrust authority commits to $F > 0$, $\{nd\}$, and $\{l\}$ with $r > 0$ in $t = 0$, the expected fine/profit-ratio is $E[\phi_l] = \frac{2E[F]}{\Pi^M}$ which is lower than $\phi_{nl} = \frac{2F}{\Pi^M}$. From *Lemma 2.2* it follows that sustainability of collusion requires for any given $\alpha \leq \frac{1}{2}$ and $\phi < 1$ a discount rate of

$$\delta \geq \frac{1 - \phi}{2(1 - \alpha) - \phi}. \tag{2.30}$$

Since $\frac{\partial \delta}{\partial \phi} < 0$, introducing a leniency programs with $r > 0$ always decreases sustainability of collusion under a regime of a *non-disclosing* antitrust authority if $E[\phi_l] < 1$. This is shown in *Figure 2.5*.

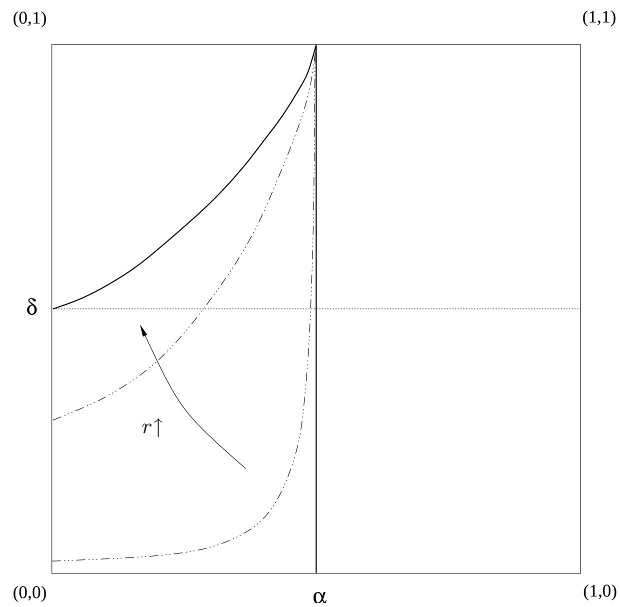

Figure 2.5: Effect of leniency programs on sustainability of collusion under a regime of a *non-disclosing* antitrust authority with $E[\phi_l] < 1$

On the other hand, following *Lemma 2.2*, if $\phi \geq 1$, all industries with $\delta \geq 0$ and $\alpha \leq \frac{1}{2}$ are able to sustain collusion. For $r \leq 1$, the fine/profit-ratio a firm expects when blowing the whistle, $E[\phi_l]$, is equal or larger than $\frac{1}{2}\phi_{nl}$. Consequently, the number of colluding industries is not affected by leniency if $\phi_{nl} > 2$. Under such an environment, leniency only reduces the fine/profit-ratio firms expect to pay, $\frac{\partial E[\phi_l]}{\partial r} < 0$, and thus ceteris paribus[21] increases the frequency of whistleblowing which is necessary to sustain collusion, $\frac{\partial \gamma}{\partial \phi} < 0$.

These results are summarized in the following proposition.

[21]Holding δ_{nd}^{eff} constant.

Proposition 2.6 *Introducing a leniency program under a regime of a non-disclosing antitrust authority*

(i) leads to less collusion if the expected fine is not too large ($E[\phi_l] < 1$),

(ii) has no effect on the sustainability of collusion if the expected fine is large ($E[\phi_l] \geq 1$),

(iii) increases the frequency of whistleblowing γ for holding the number of price war periods constant.

Proof The proof follows immediately from the discussion above. ■

2.5.2 The disclosing antitrust authority

A *disclosing* antitrust authority which commits to $\{l\}$ with $r > 0$ in $t = 0$ has the same effect on reduction of fines as discussed above, $\frac{1}{2}\phi_{nl} \leq E[\phi_l] < \phi_{nl}$. From *Lemma 2.4* it follows, for a relatively low probability of demand shocks, $\alpha \leq \frac{1}{2}$, and as long as the fine/profit-ratio without leniency was relatively low, $\phi < 1$, sustainable collusion requires a discount rate of

$$\delta \geq \frac{(1-\alpha)(1-\phi)}{2(1-\alpha)-\phi}. \tag{2.31}$$

In such an environment it follows that $\frac{\partial \delta}{\partial \phi} < 0$. Thus, leniency leads to less collusion if $\phi = E[\phi_l] < 1$. For a relatively high fine/profit-ratios, $\phi \geq 1$, the same results as for a *non-disclosing* antitrust authority holds: If $\alpha \leq \frac{1}{2}$, all industries with $\delta \geq 0$ are able to sustain collusion. Thus, the number of colluding industries which faces an $\alpha \leq \frac{1}{2}$ is not affected by leniency if $E[\phi_l] \geq 1$.

On the other hand, industries with a relatively high probability of demand shocks, $\alpha > \frac{1}{2}$, sustainable collusion requires a discount rate of

$$\delta \geq \begin{cases} \frac{(1-\alpha)(1-\phi)}{2(1-\alpha)-\phi} & \text{if } \alpha < \frac{1}{1+2\phi-\phi^2} \text{ and } \phi < 1 \\ \\ \frac{\left((3\alpha-1)+(1-\alpha)\phi+2\sqrt{2\alpha^2-\alpha}\right)\phi}{[2(3\alpha-1)+(1-\alpha)\phi]\phi+(1-\alpha)} & \text{if } \alpha \geq \frac{1}{1+2\phi-\phi^2}. \end{cases}$$

One can show that for $\alpha > \frac{1}{2}$, $\frac{\partial\delta}{\partial\phi} > 0$ always holds. So as a consequence, if the probability of demand shock is relatively high, $\alpha > \frac{1}{2}$, introducing a leniency program leads to more collusion.

Figure 2.6 shows the trade-off a *disclosing* antitrust authority faces when introducing a leniency program starting from a relative low fine/profit-ratio.

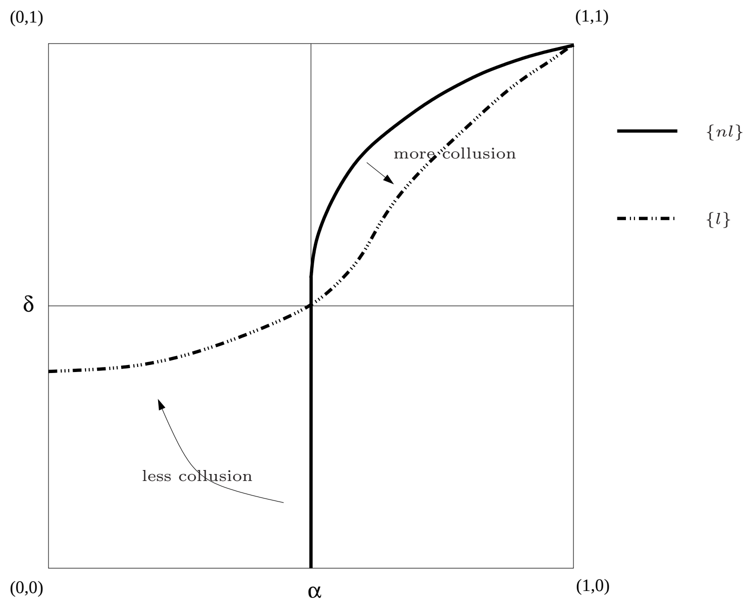

Figure 2.6: Effect of a leniency program on sustainability of collusion under a regime of a *disclosing* antitrust authority with $\phi_{nl} = 1$, $r = 1$ and $E[\phi_l] = \frac{1}{2}$

From the discussion above it is known that the number of colluding industries facing a relatively low probability of demand shocks, $\alpha \leq \frac{1}{2}$, is unaffected if the fine/profit-ratio is high enough that $E[\phi_l] \geq 1$ holds. In contrast to that, the number of colluding industries which face $\alpha > \frac{1}{2}$, is always increased by a leniency program. Consequently, introducing a leniency program with $E[\phi_l] \geq 1$ always increases the number of industries which are able to sustain collusion. An example for this result is given in *Figure 2.7*.

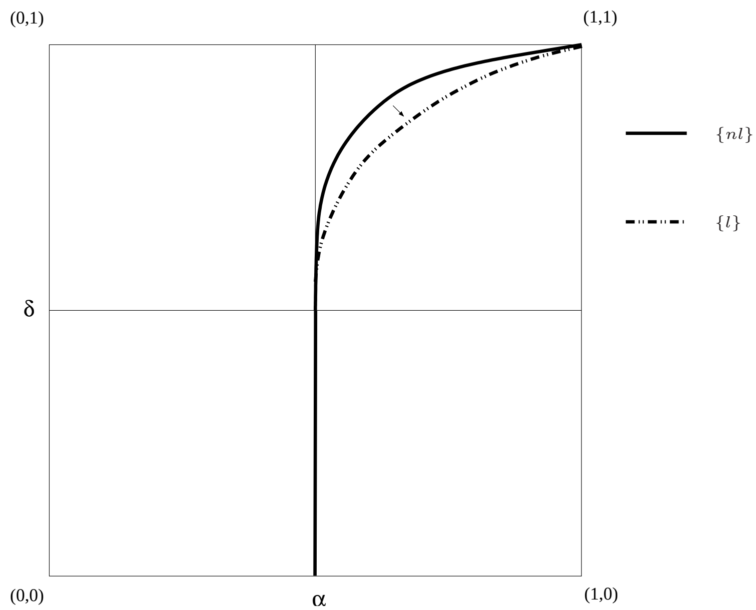

Figure 2.7: Effect of a leniency program on sustainability of collusion under a regime of a *disclosing* antitrust authority with $\phi_{nl} = 2$, $r = 1$ and $E[\phi_l] = 1$

A further effect of introducing a leniency program is that reducing fines increases the expected firm value of collusive firms in equilibrium. From the previous section and from the discussion above, it is known that the firm value from collusion is given by $V^+ = \frac{\Pi^M[(1-\alpha)+2\alpha\gamma E[\phi_l]]}{2(1-\delta)}$. It is easy to see that the expected fine/profit-ratio reduced by a leniency program, requires an increase in the frequency of whistleblowing γ to hold V^+ (and at the same time $\gamma E[\phi_l]$) constant. Following the same argument as used in the proof of *Proposition 2.4*, the relevant IC (inequality (2.25)) becomes slack, since $\frac{1}{1-\alpha}\gamma\delta$ is increasing in γ. Thus, firm are able to increase V^+ in equilibrium via reducing γ.

The results are summarized in the following proposition.

Proposition 2.7 *Introducing a leniency program under a regime of a disclosing antitrust authority*

(i) leads to less collusion in industries with a relative low probability of demand shocks ($\alpha \leq \frac{1}{2}$), if the expected fine is not to large ($E[\phi_l] < 1$),

(ii) has no effect in industries with a relative low probability of demand shocks ($\alpha \leq \frac{1}{2}$), if the expected fine is large ($E[\phi_l] \geq 1$),

(iii) leads to more collusion in industries with a relative high probability of demand shocks ($\alpha > \frac{1}{2}$),

(iv) increases the frequency of whistleblowing,

(v) increases the firm value of collusive firms.

Proof The proof follows immediately from the discussion above. ■

2.5.3 Extension: rewards for whistleblowers

Following the public discussion and the discussion in the literature around leniency programs two extensions are considered: First, as e.g. argued in Aubert, Rey, and Kovacic (2006) rewards ($r > 1$) for whistleblowers are introduced.[22] Second, as practised in the European leniency program and being discussed in Feess and Walzl (2005) and Motchenkova and van der Laan (2005), leniency will not only be granted to the first firm which blows the whistle, but, possibly with a lower reduction in the fine, also for later firms.

In this framework, both changes have the same effect: they reduce the expected fine even further. Consider first the reward. As $E[F] = (1 - \frac{1}{2}r)F$, allowing for larger r reduces the fine.

Granting leniency not only to the first firm (with leniency parameter r_1) but also to the second firm (with leniency parameter r_2) reduces the expected fine in case of

[22] It is assumed that r is restricted to be smaller than 2, since otherwise firms would have the incentive to launching cartels over and over again with the aim to be jointly rewarded for whistleblowing.

simultaneous whistleblowing to

$$E[F] = (1 - \frac{1}{2}r_1 - \frac{1}{2}r_2)F. \tag{2.32}$$

Both changes have the effect of reducing the expected fine. In the extreme case (full rewards for whistleblowing, $r = 2$) or full leniency for the second whistleblower ($r_1 = r_2 = 1$) the expected fine is reduced to zero: $E[F] = 0$. In any case, these changes strengthen the effects of a leniency program as discussed in the previous subsections.

2.6 Conclusions

The developed model identifies the effects of different antitrust policies if firms are not able to observe the market outcome directly. The main result is that information spillovers from the antitrust authority to the collusive firms strongly matters. The information spillovers enable firms to monitor each other and thus make collusion more likely.

In general, the model shows that charging a fine for collusive behavior allows firms in industries with a relative low probability of demand shocks to collude, even if the industry-specific discount rate is so low that the threat of punishment through a price war would be too weak to facilitate collusion. Thus, a non-disclosing antitrust authority which charges fines from collusive firms enables more industries to collude.

An antitrust authority that discloses information about firms' behavior further increases the number of colluding industries. Then, the antitrust authority acts like an independent monitoring instrument. This monitoring instrument makes the punishment through a price war periods unnecessary and unprofitable. If firms have the choice between starting a price war or blowing the whistle and triggering the fine, they will never choose price wars to sustain collusion. The reason is that whistleblowing provides additional valuable information. This allows industries with a low probability of demand shocks to collude more effectively, i.e. with a lower discount rate. In addition, even industries with a high probability of demand shocks are able to sustain collusion. The fine can be interpreted both as a punishment tool and as the price for the information about the behavior of the rival, i.e. as monitoring costs. Thus, the effect of a modification of the total amount of the fine is ambiguous. On the one hand, increasing the fine provides a harder punishment and thus increases the number of colluding industries with a relative low probability of demand shocks. Furthermore, a larger fine decreases the necessary frequency of whistleblowing of firms which had the ability to collude even without an increase of the fine. On the other hand, an increase of the fine is equivalent to an increase of the monitoring costs. These higher costs reduce the sustainability of collusion in industries with a relative high probability of demand shocks.

This implies in turn that a reduction of the fines - or the expected fine, as is the case with a leniency program - has ambiguous consequences in general. If the probability of demand shocks is relatively low and fines are not too high, a leniency program reduces the number of colluding industries. However, if in contrast the fine is relatively high, a leniency program only increases the necessary frequency of whistleblowing. On the other hand, the number of industries which collude in an environment of a high probability of demand shocks is always increasing if a leniency program is implemented.

These different polices have different consequences for welfare. This is not only because the policies might decrease or increase the number of colluding industries, but also because the use of whistelblowing as a colluding device instead of a price war enables industries to reduce the number of periods where the competitive price prevails. This lowers welfare even further.

These findings have implications for antitrust policy. The antitrust authority should become aware of the adverse effects of the leniency program in combination with the information provided to the firms during the prosecution of the cartels. The more generous leniency programs are, the lower are the expected costs for the useful information firms get during an interaction with the antitrust authority. Leniency programs may indeed lead to more cartel cases via whistleblowing, i.e. increase the necessary frequency of whistleblowing. Thus, more information exchange between these two adversaries can be expected. Since the information may just facilitate collusion in uncertain environments and leniency programs make information cheaper to get, the antitrust authority should restrict the information flow to cartel members as much as possible.

Chapter 3

The deterrence effect of excluding ringleaders from leniency programs

3.1 Introduction

In the context of cartels, ringleaders seem to play a crucial role. They often guarantee the stability and the functioning of a cartel. They organize initial meetings, collect data, and ensure a safe and repeated communication between the cartel members. There are many examples of such ringleaders in the history of cartel cases.[23]

For example, the leader of the "Alloy cartel", Usinor, did the calculations at the first meeting and sent the conclusions of the meeting together with the definitive calculation to the producers after the meeting.[24] In the "Amino-acid (lysine) cartel", the Archer Daniels Midland Company (ADM) and Ajinomoto organized the secretariat of the quantity-monitoring system.[25] ADM – together with Hoffmann-La Roche – also was at the helm of the "Citric-acid cartel" where it chaired the meetings and organized the collection and distribution of data.[26] In the cartel concerning gas-insulated switchgear,

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[23] Ganslandt, Persson, and Vasconcelos (2008) suggest that during the period between 2002 and 2007 a ringleader was explicitly identified in approximately 23 percent of the European cartel cases.

[24] Case *IV/35.814 – Alloy surcharge* (1998), paragraph 81.

[25] Case *COMP/36.545/F3 – Amino acids (Lysin)* (2000), paragraph 330.

[26] Case *COMP/E-1/36 604 – Citric acid* (2001), paragraph 273.

Siemens and Alstom acted as (cartel) secretaries. As such, they arranged contacts between the cartel members and had a crucial role in the organization of meetings and in the compilation of information submitted by and passed on to the members. Moreover, they managed the communication on behalf of the European undertakings with the Japanese secretariat. They also convened and chaired meetings, took care of the quotas, and managed the system of 'E-mails Secure Transmission'.[27]

These examples illustrate that activities to run a cartel had to be organized by at least one of the cartel members. The characteristics of these activities *per se* do not require a special market position, size, or knowledge of the firm which acts as a ringleader.[28] Therefore, even if a reliable ringleader is crucial to run a successful and stable cartel, it appears that any firm of an industry could be a possible ringleader under such circumstances. In any case, this essay will focus on the consequences of excluding the ringleader from leniency programs and not on the evolution of ringleaders.

Before thinking about the question how to treat ringleaders, it seems important to point out that identifying initiators of cartels is actually possible. For instance, in the cartel case of the *Fédération Nationale Bovine* in France, it became "[...] clear from the documents [...] that the initiative for a price scale [...] came from the Fédération Nationale Bovine (FNB). The FNB was especially emphatic in support of an oral agreement, as statements *(in the press)* made by its vice-president show."[29] An antitrust authority may also rely on evidence provided by cartel members, as was often the case in the cartel cases described above, or it identifies the instigator of the cartel as the

[27]Case *COMP/F/38.899 – Gas insulated switchgear* (2007), paragraphs 147, 173, 511–513.

[28]Ganslandt, Persson, and Vasconcelos (2008) argue that ringleaders tend to be large firms since they have firm-specific indivisible cost associated with collusion, e.g. the cost of protecting the cartel by buying out potential entrants. There are further characteristics which may determine leadership and which are more firm-specific. For example, Hoffmann-La Roche and BASF as two instigators of the vitamins cartel – due to a wide range of products – had a stronger position in relation to their customers than other firms selling a single or limited number of products only. They also had a greater flexibility to structure prices, promotions, as well as discounts, and had a much greater potential for tying. Moreover, they enjoyed greater economies of scale and scope and an implicit (or explicit) threat of a refusal to supply would have been much more credible (Case *COMP/E-1/37.512 — Vitamins* (2001), paragraphs 712–718). In the Nintendo case, Nintendo enjoyed a unique position as the manufacturer of the products (Cases *COMP/35.587, COMP/35.706, COMP/36.321 – Nintendo* (2002), paragraphs 406, 228–238). However, the model developed in this essay will not focus on the evolution of ringleaders, though.

[29]Case *COMP/C.38.279/F3 – Viandes bovines françaises* (2003), paragraph 175.

leader.

The fact that ringleaders play an important role for collusive agreements raises the question how antitrust authorities should deal with them. Having a closer look at the legal approaches of the EU Competition Commission and of the US Department of Justice reveals that ringleaders are indeed treated differently in both jurisdictions.[30] The leniency program established in the US law in 1978, stipulates that it is not possible for ringleaders to obtain a fine reduction through leniency. To be eligible for leniency requires that "the corporation did not coerce another party to participate in the illegal activity and clearly was not the leader in, or the originator of the activity".[31] When the EU set up its leniency program in 1996, this ringleader-discrimination rule was adopted.[32] However, due to the changes in the EU regulations in 2002 and 2006, ringleaders now have the possibility to participate in the leniency program.[33] Nevertheless, both antitrust regimes specify a fine load for ringleaders.[34]

Concerning the implications of these different approaches, it is often argued that excluding ringleaders from leniency programs is detrimental as it hinders the detection and the deterrence of cartel activities. As Aubert, Rey, and Kovacic (2006) point out, this was indeed the idea of the new EU leniency law which now gives ringleaders the opportunity to benefit from leniency. In a similar vein, Spagnolo (2007) argues that allowing ringleaders to apply for leniency may seed distrust among cartel members which may finally deter cartelization.[35] Also, Leslie (2006) argues that extending

[30] See e.g., Aubert, Rey, and Kovacic (2006), Spagnolo (2007), and Feess and Walzl (2005) for more detailed comparisons of the different approaches of the leniency program in the EU and in the US.

[31] United States Department of Justice (1993), Corporate Leniency Policy, August 10, 1993, paragraph A.6.

[32] European Commission (1996), Commission Notice on the non-imposition or reduction of fines in cartel cases, OJ C 207, 18/07/1996, pp. 4–6, paragraph B (e).

[33] European Commission (2002), Commission Notice on immunity from fines and reduction of fines in cartel cases, OJ C 45, 19/02/2002, pp. 3–5, paragraph A 11 (c) and European Commission (2006), Commission Notice on immunity from fines and reduction of fines in cartel cases, OJ C 298, 08/12/2006, p. 17–22, paragraph II A (13).

[34] E.g., European Commission (2006), Guidelines on the method of setting fines imposed pursuant to Article 23 (2) (a) of Regulation No 1/2003, OJ C 210, pp. 2–5, and United States Sentencing Commission (2008), Guidelines Manual, November 2008, paragraph 3 B 1.1. Fine loads for ringleaders will be discussed in this essay in *Section 3.5*.

[35] On the other hand, the author also observes that "in an adversarial system [like the one in the US], where testimony is crucial to persuade juries, testimony by a ringleader may not be convincing."

amnesty to ringleaders may increase deterrence since cartel members will than find it harder to trust even trust the ringleader.

Apart from these few qualitative arguments, there is one experimental paper by Bigoni, Fridolfsson, Le Coq, and Spagnolo (2008) who test the effect of excluding ringleaders from leniency. They show that if the ringleader is excluded from the leniency program, the deterrence effect of leniency decreases. However, they point out that this unambiguous result might be due to the experimental design. In the experiment "subjects were matched pairwise into duopolies to avoid social preferences effects towards non-defecting third parties. This, however, is the worst conceivable situation [..] of excluding ringleaders, as the ban leaves only one cartel member with the option to self-report obtaining leniency, eliminating the incentives to 'race to report' generated by the risk that another cartel member could do it before. With more than two firms, therefore, it is likely that the [ringleader] treatment will show more desirable properties."

There has been no rigorous formal study to theoretically analyze the effect of ringleader exclusion on the sustainability of collusion. The developed model, aims to fill this gap by setting up a model to allow for both scenarios in order to get a better understanding of the effects described above. It is found that both regimes, i.e. the ones with and without ringleader discrimination, may be superior. More specifically, it is found that a regime where ringleaders are treated in the same way like other cartel members (symmetric case) is always superior if the antitrust authority reviews industries with a relatively small probability only. In such a situation, giving ringleaders an incentive to reveal information (to blow the whistle) leads to a higher probability that the antitrust authority successfully prosecutes the cartel and thus decreases the sustainability of collusion in general.

On the other hand, an antitrust authority which forgoes this additional information – by giving ringleaders no incentives to reveal information (asymmetric case) – would therefore run the risk of more cartel activity. However, if the antitrust authority reviews the industries with a relatively high probability, the effect that more information leads to less collusion decreases in importance. Excluding the ringleader (asymmetric case) may be the better option now. These ambiguity results from the three different effects of excluding one potential whistleblowing firm.

First, as argued in the literature above, if the ringleader is excluded from the leniency program, the probability that the antitrust authority is able to convict the cartel decreases. *Ceteris paribus* the lower probability of being convicted leads to more collusive activity of all firms.

Second, since the number of firms competing in the "race to report" is reduced when ringleaders are excluded from this "race", the expected fine of each (whistleblowing) ordinary cartel member decreases. This is due to the fact that the probability that one of them gets the full fine reduction increases if less firms are able to apply for a fine reduction. The resulting lower expected fine results – *ceteris paribus* – in more collusion.

Third, if the ringleader is excluded from leniency, it faces a higher expected fine than an ordinary cartel member. As a consequence, firms would face asymmetric expected profits from collusion if the ringleader and the members where to share the collusive industry profit equally. At the margin, the cartel has an incentive to reallocate the collusive profit to account for the difference. A ringleader requires a compensation for the higher expected fines which increases its share of the collusive industry profit per period. Such a reallocation of the collusive profit decreases *ceteris paribus* the sustainability of collusion. This effect becomes stronger if the probability that industries are reviewed increases. Generally speaking, a higher probability of being reviewed by the antitrust authority decreases the expected profit from collusion through the reduction of the expected number of collusive periods. If the expected number of collusive periods becomes smaller, the compensation scheme for the ringleader has to go up, which increases the asymmetry of the industry and the sustainability of collusion decreases even more.

Thus, if the probability that a industry is reviewed is sufficiently high, the asymmetry – resulting from ringleader exclusion – may outweigh the two cartel-enhancing effects of excluding the ringleader argued before.

The chapter is organized as follows. In the next section, the model is developed. In *Sections 3.3* and *3.4*, the cases without and with ringleader discrimination are analyzed. *Section 3.5* discusses briefly an extension of the model to allow for a higher fine for ringleaders compared to the ordinary cartel members. The last section concludes.

3.2 The model

3.2.1 Players

i. Firms

Consider an infinite number of industries where each industry consists of $n \geq 3$ ex-ante perfectly identical firms. The industry-specific market is made up of an infinitely large number of submarkets.[36] Firms compete in prices for an infinite number of periods $t \in \{0, 1, 2, .., \infty\}$ and sell an industry-specific homogeneous product at constant marginal costs $c > 0$ by placing selling bids on the submarkets. The monopoly industry profit is given by Π.

If firms form a cartel, one of the firms has to act as a ringleader. An exogenously given ringleader is considered, i.e. the evolutionary forces (or the strategic options) which lead to a specific firm's status as a ringleader will not be analyzed. Thus, it is assumed that one of the *ex ante* identical firms is chosen randomly as the ringleader. Furthermore, it is assumed that any collusive agreement produces evidence about the organization of the cartel. Thus, when deciding on collusion, firms have to take into account the enforcement policy of the antitrust authority.

[36]This assumption can be justified when considering a global economic environment with a large number of regional submarkets. The aim of this assumption is to allow for allocations of even every small market shares to firms.

ii. Antitrust authority

The antitrust authority commits to an enforcement policy targeting collusive behavior. The authority is assumed to be constrained in the number of investigations per period. Thus, in any period the authority reviews a specific industry with probability $\rho \leq 1$. Once the review is under way and if firms have colluded in this period or in any period before the review has started, the antitrust authority finds evidence to convict all firms of the cartel with probability $\hat{\mu} < 1$. The fact that $\hat{\mu} < 1$ can be explained by pointing out that usually antitrust authorities employ both economists who "look for smoke" and lawyers who help convict firms. The first group would be in charge of the initial review whose results are then used by the second group. As a consequence, even if the first group finds evidence that a specific industry output is driven by cartel behavior, the lawyers *per se* do not have no enough evidence to convict the cartel for collusion any time.

In the case that the cartel is found guilty of collusion, the antitrust authority levies a fine f. The fine is proportional to the collusive per-period profit of the convicted firm. Indeed, a proportional fine seems to be more realistic than a lump-sum fine which is often used in the literature. As such, firms which have benefited more from the cartel have to pay larger fines which is true for antitrust case laws all over the world.[37]

Furthermore, the antitrust authority commits to a leniency program. The program is captured by the fine reduction ϕ (with $0 < \phi \leq 1$).[38] It is assumed that only one firm (the first whistleblower) is allowed to benefit from the leniency program.[39] Moreover,

[37]E.g. in European antitrust law, the basic amount of the fine is calculated as a percentage of the value of the sales linked to cartel activity. (European Commission (2006), Guidelines on the method of setting fines imposed pursuant to Article 23(2)(a) of Regulation No 1/2003, OJ C 210, pp. 2–5, paragraphs 13.–18.)

[38]Several authors (e.g., Aubert, Rey, and Kovacic (2006)) argue that an optimally defined leniency program requires rewards for whistleblowing firms. However, no leniency program so far allows such rewards for firms that reveal information. Thus, $\phi = 1$ is the limit, which is equal to full immunity from fines.

[39]The European and the US leniency program differ in that point. In the US, only the first whistleblowing firm is eligible for the leniency program. The EU does not use such a "the-winner-takes-it-all" approach. Even the second and the third whistleblower may be eligible for leniency if they come up with sufficient enough additional evidence to the authority. For a detailed discussion of these different regimes see, Feess and Walzl (2005).

the antitrust authority must decide whether or not a ringleader is eligible to apply for leniency. Note that it is assumed that the identification of the ringleader is not subject to controversy due to the evidence the antitrust authority has access to.

To account for the information revealed to the antitrust authority by the ringleader – as an additional whistleblowing firm – it is assumed that each whistleblowing firm leads to an increase in the probability $\hat{\mu}$ that the cartel is indeed convicted in case of a review by κ, i.e. $\mu = \hat{\mu}(1 + \kappa\hat{n})$, where $\hat{n}$ represents the number of the whistleblowing firms (with $\hat{n} \in \{0, 1, .., n-1, n\}$). Note that even if one firm decides to blow the whistle, the conviction probability must not necessarily be equal to one. This may be justified by procedural problems or a time and budget constraint of the antitrust authority.[40]

Furthermore, it is assumed that the authority is able to ensure that if firms (or a specific industry) are convicted once, they will never have the chance to collude again.[41]

3.2.2 Timing of the game

The timing of the game is as follows: In period $t = 0$, the legal environment is defined: The antitrust authority commits to a specific law-enforcement policy, i.e. it chooses ρ,

[40] These constraints are indeed relevant as pointed out by practitioners: *"Seit 2002 sind in Brüssel so viele Selbstbeschuldigungen eingegangen, daß die Kartellbeamten sie längst nicht alle bearbeiten können. Nur einem Bruchteil der Selbstbezichtigungsschreiben folgten weitere Schritte der Kommission, kritisiert der Brüsseler Kartellanwalt Ulrich Soltész. 'Die Verfolgung erfolgt nach dem Zufallsprinzip. Einige Fälle bleiben jahrelang unbearbeitet liegen, während in manchem Sektor jeder Verstoß gnadenlos und konsequent verfolgt wird' [..] Claus Dieter Ehlermann, langjähriger Chef der Generaldirektion Wettbewerb in der Kommission und heute als Anwalt tätig, schätzt, daß die Kommission etwa zehn Kartellfälle im Jahr entscheiden kann. Die Zahl der jährlichen Anträge liege um ein 'Vielfaches' darüber."* (Since 2002 Brussels has received so many self-reportings that cartel officials have not been able to process all of them. The Commission initiated further steps only in a fraction of the cases, criticizes the Brussels cartel lawyer Ulrich Soltész. 'The prosecution is according to a random choice. Some cases are not processed for years while in some industry sectors, every infringement is prosecuted without mercy and with determination'. Claus Dieter Ehlermann, long-time head of the Commission's DG Comp and a lawyer today, estimates that the Commission can decide on around ten cartel cases per year. The number of yearly self-reportings is several times above.), Frankfurter Allgemeine Zeitung (FAZ), December 5, 2006, no. 283, p. 22, *'Mehr Rechtssicherheit für Kronzeugen'*.

[41] There is a discussion in the literature if a firm which has been convicted once will be able to revert to collusion in the future. E.g. Aubert, Rey, and Kovacic (2006) assume that collusion will break down forever after a conviction, Motta and Polo (2003) assume that firms have to interrupt the collusive activity for one period after the antitrust authority finds them guilty, and in Herre and Wambach (2008) it is argued that firms are able to revert to collusion immediately after conviction.

$\hat{\mu}$, ϕ, and f as well as its ringleader policy. The subsequent periods $t = 1, 2, ..., \infty$ all have the same structure given by:

Stage 1: Firms decide whether or not to collude as well as whether and how to split the collusive industry profits between the ringleader and the ordinary cartel members by allocating submarkets.

Stage 2: Firms place bids on the submarkets.

Stage 3: The antitrust authority reviews the industry with probability ρ.

Stage 4: Firms decide whether or not to reveal information to the antitrust authority (whistleblowing).

Stage 5: The antitrust authority proceeds as committed to in period 0.

3.2.3 Firms' strategies

Since this model is aimed at analyzing the effect of excluding the ringleader from the leniency program, it concentrates on an equilibrium strategy where indeed all firms would be willing to blow the whistle. The other cases where not all or even no firm has an incentive to blow the whistle in equilibrium are discussed in detail below. First, the following equilibrium strategy is analyzed:

AW (All firms blow the whistle) Firms collude from $t = 1$ on as long as no firm deviates. If in period t the antitrust authority reviews the industry, all firms which have the possibility to benefit from the leniency program blow the whistle and reveal information to the antitrust authority. If the authority is not able to convict the cartel, firms revert to collusion in period $t + 1$. If the authority successfully convicts the cartel or if one firm has deviated, firms choose a price equal to marginal costs, $p = c$, in every submarket in every subsequent period (grim-trigger strategy, see Friedman (1971)).

Before turning to the equilibrium analysis, the the following assumption – regarding the value an additional whistleblowing firms means for the antitrust authority – is made:

Assumption 3.1 $\kappa \leq \bar{\kappa} = \min \left\{ \frac{\phi f}{n(n-1+(1-\phi)f)}; \frac{1-\hat{\mu}}{n\hat{\mu}} \right\}$.

This assumption ensures two important specifications of the model. The first term ensures that the increase in the conviction probability $\hat{\mu}$ through whistleblowing is not too large so that the AW strategy as described above is an equilibrium. We will comment on the derivation of this upper bound for κ in the next section. The second term ensures that if all firms in an industry blow the whistle, the total probability of conviction is not larger than one, i.e. $\hat{\mu}(1 + n\kappa) \leq 1$.

3.3 Symmetric case: no ringleader discrimination

If the antitrust authority decides not to make a difference between a ringleader and an ordinary cartel member when designing a leniency program – as it has been the policy of the EU since 2002 – firms are symmetric ex post as well.

3.3.1 Joint whistleblowing as an equilibrium strategy

Consider a situation where collusion can be sustained in equilibrium and AW is an equilibrium strategy: Thus, all n firms will blow the whistle if the antitrust authority reviews the industry. Then, the collusive firm value of each firm amounts to

$$V^+_{\{n\}} = \frac{\Pi}{n} + (1-\rho)\,\delta V^+_{\{n\}} + \rho \Bigg(- \hat{\mu}(1+\kappa n)\frac{\Pi f}{n}\left(\frac{1-\phi}{n} + \frac{n-1}{n}\right) + \\ + (1 - \hat{\mu}(1+\kappa n))\,\delta V^+_{\{n\}} \Bigg). \quad (3.1)$$

Since the firms are identical, each of them gets the same share of the monopoly industry profit, $\frac{\Pi}{n}$, in every collusive period. With probability $(1-\rho)$ the antitrust authority does not review the industry and the firms continue to collude in the following period.

This is represented by the second term of equation (3.1). The third term of equation (3.1) reflects the case when the antitrust authority reviews the industry with probability ρ. This term consists of two elements. First, the antitrust authority manages to convict the cartel with probability $\hat{\mu}(1+\kappa n)$. Remember that $\hat{\mu}$ is the probability of conviction which is increased by each of the n whistleblowing firms by the value of κ. By assumption, only the first whistleblowing firm is allowed to benefit from the leniency program. If n firms blow the whistle simultaneously, it is assumed that one of them is chosen randomly as the first whistleblower. Therefore, a firm gets a reduction of $(1-\phi)$ of the full fine $\frac{\Pi f}{n}$ with probability $\frac{1}{n}$. Consequently, with probability $\frac{n-1}{n}$ a firm has to pay the full fine even if it has blown the whistle. If the antitrust authority convicts the cartel, collusion breaks down. Second, with probability $(1-\hat{\mu}(1+\kappa n))$ the antitrust authority is not able to convict the cartel – even with the help of the whistleblowing firms. In this case, firms continue to collude in the following period.

For expositional simplicity the total probability of conviction in the symmetric case is defined as

$$\mu_n \equiv \hat{\mu}(1+\kappa n) \tag{3.2}$$

and the expected realization of the fine reduction as

$$\psi_n \equiv \frac{1-\phi}{n} + \frac{n-1}{n} = \frac{n-\phi}{n}. \tag{3.3}$$

Then, equation (3.1) can be rearranged to give

$$V^{+}_{\{n\}} = \frac{\Pi}{n}\left(\frac{1-\rho\mu_n f\psi_n}{1-\delta(1-\rho\mu_n)}\right). \tag{3.4}$$

Next, the value of a firm that deviates from collusion is analyzed. The realization of the deviating profit depends on the incentives of the firms to blow the whistle if one firm has deviated. Note that if one firm has deviated, due to the collusive strategy defined above, collusion breaks down and there is no returning to the collusive outcome in any of the following periods.

Lemma 3.1 *Under Assumption 3.1 it is an equilibrium that all firms blow the whistle if the industry is reviewed in case of deviation. Thus, the firm value of a deviating firm amounts to*

$$V^D = \Pi - \frac{\Pi}{n}(\rho\mu_n f\psi_n). \tag{3.5}$$

Proof We have to compare the individual expected realization of the fine. To this end, we have to consider four different scenarios. First, if no firm blows the whistle, firms expect a fine of

$$E[F]_{\{0\}} = -\rho\hat{\mu}f\frac{\Pi}{n}. \tag{3.6}$$

If all firms blow the whistle, the expected fine is given by

$$E[F]_{\{n\}} = (1+\kappa n)\frac{n-\phi}{n}E[F]_{\{0\}}. \tag{3.7}$$

Next, if the other firms do not blow the whistle, a firm that does so faces an expected fine of

$$E[F]_{\{1\}} = (1+\kappa)(1-\phi)E[F]_{\{0\}}. \tag{3.8}$$

Last, a firm that does not blow the whistle – while the other firms do – expects a fine of

$$E[F]_{\{n-1\}} = (1+\kappa(n-1))E[F]_{\{0\}}. \tag{3.9}$$

Suppose that given one firm deviated, no other firm blows the whistle. Then, blowing the whistle for a single firm would be optimal whenever $E[F]_{\{1\}} \leq E[F]_{\{0\}} \Leftrightarrow \kappa \leq \frac{\phi}{1-\phi}$. Comparing this value with $\frac{\phi f}{n(n-1+(1-\phi)f)}$ which is one of the two possible values of $\bar{\kappa}$ from *Assumption 3.1* reveals that $E[F]_{\{1\}} \leq E[F]_{\{0\}}$ holds for all $n \geq 1$. Thus, consider the case where all firms blow the whistle after deviation by one firm. Then, not blowing the whistle must not be optimal for a single firm, i.e. $E[F]_{\{n-1\}} \geq E[F]_{\{n\}} \Leftrightarrow \kappa \leq \frac{\phi}{n(1-\phi)}$. Again, we have $E[F]_{\{n-1\}} \geq E[F]_{\{n\}}$ holds for any $n \geq 1$ when compared with $\kappa \leq \frac{\phi f}{n(n-1+(1-\phi)f)}$. As the other value for $\bar{\kappa}$, $\frac{1-\hat{\mu}}{n\hat{\mu}}$, is either even lower or not relevant, we can conclude that all firms blow the whistle if one firm has deviated and if the antitrust authority has started to review the industry. ■

Equation (3.5) implies that a firm that deviates gets the whole monopoly industry profit, Π, and expects a total fine of $\frac{\Pi}{n}(\rho\mu_n f\psi_n)$ since all firms have an incentive to blow the whistle.[42]

Collusion can be sustained if the firm value from collusion, $V^{+}_{\{n\}}$, is larger than the firm value from deviation, V^{D}. Thus, the critical discount factor above which collusion can be sustained is given by:

$$\bar{\delta}_{\{n\}} = \frac{n-1}{(n-\rho\mu_n f\psi_n)(1-\rho\mu_n)}. \tag{3.10}$$

3.3.2 Whistleblowers and silent firms

If firms collude and the industry-specific discount factor is lager than $\bar{\delta}_{\{n\}}$ and no firm has deviated, not all firms (in every industry) have an incentive to blow the whistle if a review is started. Thus, AW may no be equilibrium strategy in every industry, or more precisely for every critically industry-specific discount factor, $\bar{\delta}$. The main reason for this is that each whistleblowing firm increases the probability of conviction – and thus for an end of collusive profits – by κ.

If the industry-specific discount factor converges to one and if firms face a relatively small probability of being reviewed, not all firms (or even no firm) may have an incentive to blow the whistle and thus stay silent if the review is under way. This is due to the fact that the firm value from collusion, equation (3.4), goes to infinity if $\delta \to 1$ and $\rho \to 0$. Then, firms face a trade-off between reducing their own expected fine when blowing the whistle and increasing the probability of getting collusive profits in the next periods if they do not blow the whistle. At the same time, this includes a second trade-off: When blowing the whistle, firms may reduce their expected individual fine through the possibility of benefiting from the leniency program but they also increase

[42]Note that if one firm has deviated, this period is excluded from the collusive phase as collusion breaks down by assumption. Thus, it is assumed that the single deviation profit, Π, is not considered by the antitrust authority when evaluating the fine. This makes sense as the antitrust authority should not punish the deviating firm more than the other cartel members in order to increase its incentives to deviate. On the other hand, in order to leave the model as general as possible a per-se fine reduction for the deviating firm is not assumed.

the probability of being convicted – and thus of having to pay the fine – by the amount of κ.

To account for this, two additional critical discount factors have to be calculated. The first one, denoted by $\bar{\bar{\delta}}_{\{n-1\}}$, reflects a situation where it is not optimal for some firms – or at least one of them – to blow the whistle. The second one, denoted by $\bar{\bar{\delta}}_{\{0\}}$, represents a value of the discount factor above which no firm has an incentive to blow the whistle.

i. Some firms blow the whistle

To account for the cases where at least one firm has no incentive to blow the whistle, consider the following equilibrium strategy:

SW (Some firms blow the whistle) Firms collude from $t = 1$ on as long as no firm deviates. If in period t the antitrust authority reviews the industry, at least one (but not all firms which have the possibility to benefit from the leniency program) blows the whistle and reveals information to the antitrust authority. If the authority is not able to convict the cartel, firms revert to collusion in period $t+1$. If the authority successfully convicts the cartel or if one firm has deviated, firms set prices equal to marginal costs in every submarket in every subsequent period.

As described above, to identify the parameter space where SW is an equilibrium strategy, the border above which at least one firm has no incentive to blow the whistle has to be calculated. To calculate this border the one-stage deviation principle is used. Due to this, it is sufficient to prove that the collusive firm value of a firm – unlike the other firms – which does not blow the whistle once (when the collusive industry is reviewed) is larger when being *silent once*, $\{s1\}$. Such a silent firm has the following collusive firm value:

$$V^+_{\{n,s1\}} = \frac{\Pi}{n} + (1-\rho)\,\delta V^+_{\{n\}} + \rho\Big(- \hat{\mu}(1+\kappa(n-1))\frac{\Pi f}{n} + \\ + (1-\hat{\mu}(1+\kappa(n-1)))\,\delta V^+_{\{n\}}\Big). \quad (3.11)$$

A silent firm faces a smaller probability of conviction, $\hat{\mu}(1+\kappa(n-1))$, compared to the probability under the AW strategy in equation (3.1), $\hat{\mu}(1+\kappa n)$. At the same time, this means that the probability of getting collusive profits in the future, $(1-\hat{\mu}(1+\kappa(n-1)))$, is increased. On the other hand, it forgoes the possibility of getting a reduced fine through leniency and has to pay the full fine, $\frac{\Pi f}{n}$, when convicted. This strategy is profitable if $V^+_{\{n,s1\}} \geq V^+_{\{n\}}$ which holds if

$$\delta \geq \frac{((1+\kappa n)\phi - \kappa n)f}{((1+\kappa n)(1-\rho\hat{\mu}(1+(n-1)\kappa))\phi - \kappa n)f + \kappa n} \equiv \bar{\delta}_{\{n-1\}}. \quad (3.12)$$

Given this expression *Assumption 3.1* can be justified. As matter of fact, comparing $\bar{\delta}_{\{n-1\}}$ and $\bar{\delta}_{\{n\}}$ reveals that $\bar{\delta}_{\{n\}} \leq \bar{\delta}_{\{n-1\}}$ for all $\hat{\rho} \leq \frac{((1+\kappa n)\phi - \kappa n)f - \kappa n(n-1)}{((1+\kappa n)\phi - \kappa n)f(1+\kappa n)\hat{\mu}}$. Note that $\hat{\rho} = 0$ for $\kappa = \frac{\phi f}{n(n-1+(1-\phi)f)}$. This means that only for a κ lower than this value, there exists a region where all colluding firms have an incentive to blow the whistle and thus AW always is the collusive strategy.

ii. No firm blows the whistle

If no firm has an incentive to blow the whistle in equilibrium, the equilibrium strategy has to be defined as follows:

NW (No firm blows the whistle) Firms collude from $t = 1$ on as long as no firm deviates. If in period t, the antitrust authority reviews the industry, no firm blows the whistle. If the authority is not able to convict the cartel, firms revert to collusion in period $t+1$. If the authority successfully convicts the cartel or if one firm has deviated, firms set a price equal to marginal costs in every submarket in every subsequent period.

If NW is the equilibrium strategy, the collusive firm value of each firm amounts to

$$V^+_{\{0\}} = \frac{\Pi}{n} + (1-\rho)\,\delta V^+_{\{0\}} + \rho\left(-\hat{\mu}\frac{\Pi f}{n} + (1-\hat{\mu})\,\delta V^+_{\{0\}}\right). \tag{3.13}$$

Thus, all firms have to pay the full fine, they do not increase the probability of being convicted, and they do not decrease the probability of getting collusive profits in the future. Again, due to the one-stage deviation principle, a single firm which – unlike the other firms – blows the whistle once, $\{b1\}$, has the following collusive firm value:

$$V^+_{\{0,b1\}} = \frac{\Pi}{n} + (1-\rho)\,\delta V^+_{\{0\}} + \rho\Bigg(- \hat{\mu}(1+\kappa)\frac{\Pi f(1-\phi)}{n} + \\ + (1-\hat{\mu}(1+\kappa))\,\delta V^+_{\{0\}}\Bigg). \tag{3.14}$$

The single whistleblower increases the probability of being convicted by κ. However, this firm can be sure to benefit from the leniency program in the case of conviction. On the other hand, whistleblowing reduces the probability of getting future profits from collusion from $(1-\hat{\mu})$ to $(1-\hat{\mu}(1+\kappa))$. A firm would choose this strategy if $V^+_{\{0,b1\}} \geq V^+_{\{0\}}$. To calculate the corresponding critical discount factor, equation (3.13) can be rearranged to

$$V^+_{\{0\}} = \frac{\Pi}{n}\left(\frac{1-\rho\hat{\mu}f}{1-\delta(1-\rho\hat{\mu})}\right). \tag{3.15}$$

Thus, the critical discount factor above which no firm blows the whistle is given by:

$$\delta = \frac{((1+\kappa)\phi-\kappa)f}{((1+\kappa)(1-\rho\hat{\mu})\phi-\kappa)f+\kappa} \equiv \bar{\delta}_{\{0\}}. \tag{3.16}$$

Note that the existence of the SW and NW strategies is not discussed in detail since they are not the focus of this model. However, the existence and the size of these regions depend on the value of κ. If the additional value by which a firm increases the probability of being convicted goes to zero, firms no longer face the trade-offs as described above, i.e. equations (3.12) and (3.16) show that if $\kappa \to 0$ and if the antitrust authority reviews the industry, it is always an equilibrium strategy that all firms blow the whistle.

3.3.3 Numerical example

Now a numerical example is considered to illustrate the findings so far. To this end, let $n = 3$, $\hat{\mu} = \frac{1}{2}$, $f = 10$, $\phi = 1$, and $\kappa = \frac{1}{10}$. Note that $f = 10$ implies that firms have to pay a fine ten times their collusive per-period profit. This seems to be an adequate assumption since if ρ is smaller than one, firms enjoy collusive profits for some periods before being convicted. The fine then accounts for the profits made during these periods.[43] Furthermore, $\phi = 1$ implies that the case where the first whistleblowing firm gets full leniency is investigated. The resulting characteristics of the critical discount factors are shown in the following figure:

[43] Moreover, e.g., the Guidelines of the EU require the basic amount of the fine to be multiplied by the number of years of infringement (European Commission (2006), Guidelines on the method of setting fines imposed pursuant to Article 23(2)(a) of Regulation No 1/2003, OJ C 210, pp. 2-5, paragraph 19.).

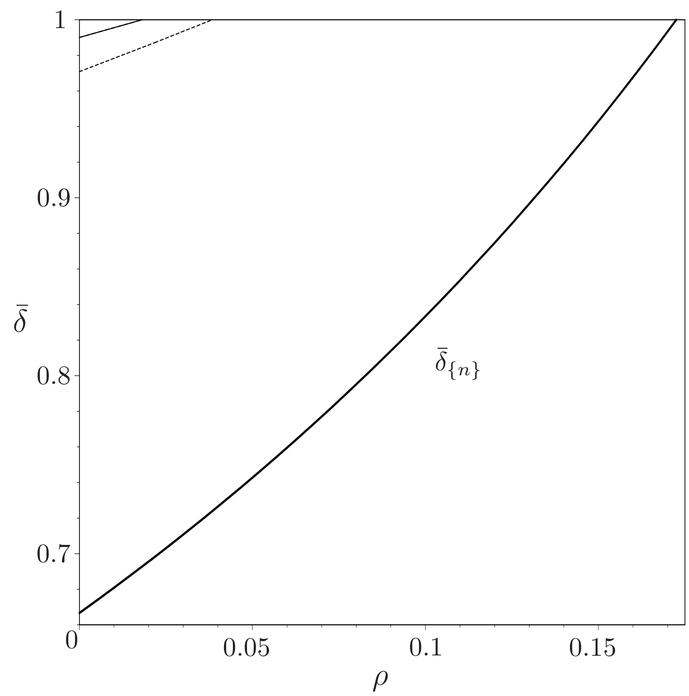

Figure 3.1: Critical discount factor without ringleader discrimination

The critical discount factor is given by the thick solid line in *Figure 3.1.* For any discount rates below the dashed line, AW is an equilibrium strategy. If the industry-specific discount factor lies in between the dashed line and the thin solid line, SW is an equilibrium. Whenever the discount factor is larger than the one represented by the thin solid line, firms opt for the NW strategy and no firm will blow the whistle in equilibrium.

Now the asymmetric case where the ringleader cannot apply for leniency is investigated.

3.4 Asymmetric case: ringleader discrimination

As mentioned in the introduction, the US Department of Justice (just like the former EU leniency program) excludes ringleaders from the leniency program. Intuitively, from the discussion of the symmetric case, one would expect that a smaller number of firms that are eligible for leniency would have the effect of reducing the expected fine for the whistleblowing firms and that the probability of conviction decreases by κ. These two effects should increase the sustainability of collusion and thus decrease the critical discount factor for these firms. This reasoning, however, falls short of one important aspect: The excluded ringleader faces a higher expected fine. Ceteris paribus, if firms share the collusive industry profit equally as in the symmetric case, the sustainability of collusion is reduced and the critical discount factor of the ringleader rises due to the higher expected fine. Using the identical parameters values from the numerical example in section 3.3.3, these two opposing effects are illustrated in *Figure 3.2*.

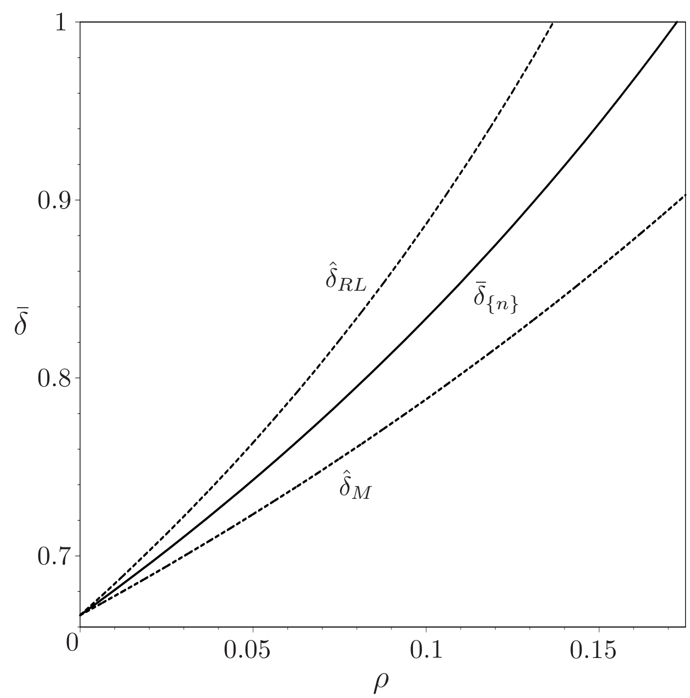

Figure 3.2: Critical discount factors with ringleader discrimination and symmetric profit sharing

The solid line represents the critical discount factor for the symmetric case. The upper dotted line gives the *unadjusted* critical discount factor for the ringleader. As such, it must lie above the one for the symmetric case as the expected fine for the ringleader is larger. The lower dotted line shows that a symmetric sharing of the industry profit would result in a lower critical discount factor for the ordinary cartel members. At the margin, though, firms may now agree on a shifting of profits from the members to the ringleader such that the ringleader's critical discount factor may be reduced – which comes at the cost of a higher critical discount factor for the ordinary cartel members. It is a priori not clear whether the resulting profit-sharing rule will actually lead to a higher or a lower critical discount factor than in the symmetric case.

More specifically, on the one hand, the adjusted critical discount factor may be lower than in the symmetric case since the total probability of conviction will be lower. Furthermore, the expected fine for a colluding ordinary cartel member decreases. The ordinary members have a higher probability of benefiting from the leniency program, since the number of firms which "race to report" is reduced. In addition they face a lower fine, due to the effects of the proportional fine f in the context of the profit shifting. These effects increase the sustainability of collusion.

On the other hand, the need to compensate the ringleader for the higher expected fine decreases the collusive firm value of an ordinary cartel member. Furthermore, the firm value of a deviating cartel member increases since – as already discussed – the probability of being the firm which benefits from the leniency program increases. This decreases the sustainability of collusion.

Given these considerations and the assumption that the leniency program is designed in a way such that AW is the equilibrium strategy, the collusive firm values of a ringleader, $V^{+}_{RL,\{n-1\}}$, and a cartel member,$V^{+}_{M,\{n-1\}}$, can be written as

$$V^{+}_{RL,\{n-1\}} = \lambda\Pi + (1-\rho)\delta V^{+}_{RL,\{n-1\}} + \rho\Big(- \hat{\mu}\left(1+\kappa(n-1)\right)\lambda\Pi f + \\ + \left(1-\hat{\mu}\left(1+\kappa(n-1)\right)\right)\delta V^{+}_{RL,\{n-1\}}\Big) \quad (3.17)$$

and

$$V^{+}_{M,\{n-1\}} = \frac{(1-\lambda)\Pi}{n-1} + (1-\rho)\delta V^{+}_{M,\{n-1\}} + \\ + \rho\Big(- \hat{\mu}\left(1+\kappa(n-1)\right)\frac{(1-\lambda)\Pi f}{n-1}\left(\frac{1-\phi}{n-1}+\frac{n-2}{n-1}\right) + \\ + \left(1-\hat{\mu}\left(1+\kappa(n-1)\right)\right)\delta V^{+}_{M,\{n-1\}}\Big). \quad (3.18)$$

As described above, the collusive firm values may be asymmetric now. The ringleader gets a share λ of the collusive industry profit, Π, in every collusive period. Consequently, since a ringleader never benefits from the leniency program, it always has to pay the full fine, $\lambda\Pi f$, in the case of conviction. The remaining profit, $(1-\lambda)\Pi$, is shared equally between the $n-1$ ordinary cartel members. Thus, every cartel member gets a per-period profit of $\frac{(1-\lambda)\Pi}{n-1}$ and has to pay f times this value if the cartel is convicted. Since the ringleader has no incentive to blow the whistle, the total probability of conviction is reduced from $\hat{\mu}(1+\kappa n)$ to $\hat{\mu}(1+\kappa(n-1))$ compared to the symmetric case. Furthermore, as the ringleader will never have an incentive to blow the whistle, the members' expected realization of the fine is reduced from $\frac{1-\phi}{n}+\frac{n-1}{n}$ to $\frac{1-\phi}{n-1}+\frac{n-2}{n-1}$.

To take both effects into account the total probability of conviction is defined as

$$\mu_{n-1} \equiv \hat{\mu}(1+\kappa(n-1)) \quad (3.19)$$

and the expected realization of the fine reduction as

$$\psi_{n-1} \equiv \frac{1-\phi}{n-1} + \frac{n-2}{n-1} = \frac{n-1-\phi}{n-1}. \quad (3.20)$$

Then, equations (3.17) and (3.18) can be rearranged to give

$$V^{+}_{RL,\{n-1\}} = \lambda\Pi\left(\frac{1-\rho\mu_{n-1}f}{1-\delta(1-\rho\mu_{n-1})}\right) \tag{3.21}$$

and

$$V^{+}_{M,\{n-1\}} \quad = \quad \frac{(1-\lambda)\Pi}{n-1}\left(\frac{1-\rho\mu_{n-1}f\psi_{n-1}}{1-\delta(1-\rho\mu_{n-1})}\right). \tag{3.22}$$

Now the analysis can be turned to the differences between the firm values of a deviating ringleader and a deviating cartel member. As in the symmetric case, the result is recorded in the following lemma:

Lemma 3.2 *Under Assumption 3.1 it is an equilibrium that all ordinary cartel members blow the whistle if the industry is reviewed in case of deviation. Thus, the firm values of a ringleader that deviates from the collusive agreement,* V^{D}_{RL}*, and of a cartel member that deviates,* V^{D}_{M}*, amount to*

$$V^{D}_{RL} = \Pi - \lambda\Pi(\rho\mu_{n-1}f) \tag{3.23}$$

and

$$V^{D}_{M} = \Pi - \frac{(1-\lambda)\Pi}{n-1}(\rho\mu_{n-1}f\psi_{n-1}). \tag{3.24}$$

Proof The proof is similar to the proof of *Lemma 3.1.* We only have to compare a cartel member's individual expected realization of the fine. The ringleader will never have an incentive to blow the whistle. Therefore, the ringleader's firm value from deviation is only influenced by the cartel members incentives to blow the whistle. To this end, we have to consider four different scenarios. First, if no cartel member blows the whistle, each member expects a fine of

$$E[F]_{M,\{0\}} = -\rho\hat{\mu}f\frac{(1-\lambda)\Pi}{n-1}. \tag{3.25}$$

If all $n-1$ cartel members blow the whistle, the expected fine is given by

$$E[F]_{M,\{n-1\}} = (1+\kappa(n-1))\frac{n-1-\phi}{n-1}E[F]_{M,\{0\}}. \tag{3.26}$$

Next, a cartel member that is the only one to blow the whistle faces an expected fine of

$$E[F]_{M,\{1\}} = (1+\kappa)(1-\phi)E[F]_{M,\{0\}}. \tag{3.27}$$

Last, a cartel member that is the only one not to blow the whistle expects a fine of

$$E[F]_{M,\{n-2\}} = (1+\kappa(n-2))E[F]_{M,\{0\}}. \tag{3.28}$$

Suppose now that given one cartel member deviated, no other member blows the whistle. Then, blowing the whistle for a single member would be optimal whenever $E[F]_{M,\{1\}} \leq E[F]_{M,\{0\}} \Leftrightarrow \kappa \leq \frac{\phi}{1-\phi}$. Comparing this value with $\frac{\phi f}{n(n-1+(1-\phi)f)}$ which is one of the two possible values of $\bar{\kappa}$ reveals that $E[F]_{M,\{1\}} \leq E[F]_{M,\{0\}}$ holds for all $n \geq 1$. Thus, consider the case where all members blow the whistle after deviation by one firm. Then, not blowing the whistle must not be optimal for a single member, i.e. $E[F]_{M,\{n-2\}} \geq E[F]_{M,\{n-1\}} \Leftrightarrow \kappa \leq \frac{\phi}{(n-1)(1-\phi)}$. Again, this means that $E[F]_{M,\{n-2\}} \geq E[F]_{M,\{n-1\}}$ holds for any $n \geq \frac{1}{2} + \frac{\sqrt{1-4f(1-\phi)}}{2} < 1$ when compared with $\frac{\phi f}{n(n-1+(1-\phi)f)}$. As the second value for $\bar{\kappa}$, $\frac{1-\hat{\mu}}{n\hat{\mu}}$, is either even lower or not relevant, we can conclude that all members of the cartel blow the whistle if one firm has deviated and if a review is under way. ■

Equations (3.23) and (3.24) point to the fact that a ringleader or a cartel member that deviates appropriates the whole industry profit, Π. However, they expect a different total fine. A cartel member is able to apply for leniency and hence expects a fine of $\frac{(1-\lambda)\Pi}{n-1}(\rho\mu_{n-1}f\psi_{n-1})$. Since a convicted ringleader always has to pay the full fine, it expects a fine of $\lambda\Pi(\rho\mu_{n-1}f)$.

Then, the critical discount factors for the ringleader as well as the members are given by

$$\delta = \frac{1-\lambda}{(1-\lambda\rho\mu_{n-1}f)(1-\rho\mu_{n-1})} \equiv \bar{\delta}_{RL,\{n-1\}} \tag{3.29}$$

for the ringleader and

$$\delta = \frac{1-\lambda-(n-1)}{((1-\lambda)\rho\mu_{n-1}f\psi_{n-1}-(n-1))(1-\rho\mu_{n-1})} \equiv \bar{\delta}_{M,\{n-1\}}. \tag{3.30}$$

for the ordinary cartel members.

As discussed above, intuitively the ordinary cartel members will be willing to forgo some of their collusive profits at the margin in order to induce the ringleader to participate in the collusive agreement. This is indeed always true if AW is the equilibrium strategy, as can be seen from the proof of *Proposition 3.1* below. To this end, the equilibrium profit-sharing rule at the margin is such that $\bar{\delta}_{RL,\{n-1\}} = \bar{\delta}_{M,\{n-1\}}$. The resulting profit share of the ringleader then equals

$$\begin{aligned}\lambda^* = \frac{1}{2\rho\mu_{n-1}f(1-\psi_{n-1})}\Big(&2\rho\mu_{n-1}f(1-\psi_{n-1})+(1-\rho\mu_{n-1}f)n- \\ &-\sqrt{(1-\rho\mu_{n-1}f)[(1-\rho\mu_{n-1}f)n^2+4\rho\mu_{n-1}f(1-\psi_{n-1})(n-1)]}\Big).\end{aligned} \tag{3.31}$$

Having a closer look at the ringleader's profit share reveals the following:

Lemma 3.3 *The ringleader's profit share increases with the probability of being reviewed by the antitrust authority, i.e.* $\frac{\partial\lambda^*}{\partial\rho} > 0$, *if the AW strategy is an equilibrium.*

Proof The derivative is given by
$\frac{\partial\lambda^*}{\partial\rho} = \frac{2\rho\mu_{n-1}f(1-\psi_{n-1})(n-1)+(1-\rho\mu_{n-1}f)n^2-n\sqrt{(1-\rho\mu_{n-1}f)[(1-\rho\mu_{n-1}f)n^2+4\rho\mu_{n-1}f(1-\psi_{n-1})(n-1)]}}{2\rho^2\mu_{n-1}f(1-\psi_{n-1})\sqrt{(1-\rho\mu_{n-1}f)[(1-\rho\mu_{n-1}f)n^2+4\rho\mu_{n-1}f(1-\psi_{n-1})(n-1)]}}$. From equation (3.31), one can show that $\lambda^* \leq 1$ if and only if $\rho \leq \frac{1}{\mu_{n-1}f}$. Furthermore, the denominator of $\frac{\partial\lambda^*}{\partial\rho}$ is always non-negative for all $\rho \leq \frac{1}{\mu_{n-1}f}$. The numerator is equal to zero if and only if $\rho = 0$ and is always negative if $\rho \geq \frac{1}{\mu_{n-1}f}\frac{n^2}{n^2-4(1-\psi_{n-1})(n-1)} = \frac{1}{\mu_{n-1}f}\frac{n^2}{n^2-4\phi}$ which is always larger than $\frac{1}{\mu_{n-1}f}$ for any $n > 2$. Thus, $\frac{\partial\lambda^*}{\partial\rho} > 0$ for all $\lambda^* \leq 1$. ■

Making use of these results the following proposition can be stated.

Proposition 3.1 *If all firms blow the whistle in the case of an industry review and if the ringleader is discriminated from leniency, ordinary cartel members shift profits to the ringleader at the margin until their critical discount factors are the same.*

Proof Consider $\rho = 0$. Then, (3.29) changes to $\bar{\delta}_{RL,\{n-1\}} \geq 1 - \lambda$ and (3.30) to $\bar{\delta}_{M,\{n-1\}} = -\frac{1-\lambda-(n-1)}{n-1}$. Consequently, the profit-sharing scheme amounts to $\lambda = \frac{1}{n}$. Together with *Lemma 3.3*, we get $\lambda^* > \frac{1}{n}$ if $\rho > 0$. If $\bar{\delta}_{RL,\{n-1\}} \neq \bar{\delta}_{M,\{n-1\}}$ there exists a set of industries $i = (\rho, \bar{\delta})$ where, at the margin, ringleader and ordinary cartel members could adjust λ to coordinate on a critical discount factor between $\bar{\delta}_{RL,\{n-1\}}$ and $\bar{\delta}_{M,\{n-1\}}$ if $\lambda < \lambda^*$ or on a critical discount factor between $\bar{\delta}_{M,\{n-1\}}$ and $\bar{\delta}_{RL,\{n-1\}}$ if $\lambda > \lambda^*$. ■

Lemma 3.3 and *Proposition 3.1* point to the fact that the per-period profit of a ringleader always exceeds its share in the non-discriminating case, i.e. $\lambda^* \geq \frac{1}{n}$. Furthermore, the new share is increasing in the probability that the antitrust authority reviews the industry.

These results indeed depend on the equilibrium AW strategy which will be obvious from the discussion of the SW and NW strategies below.

3.4.1 Whistleblowers and silent firms

Again, it has to be taken into account that the value of an additional whistleblowing firm, κ, significantly affects the equilibrium strategy. Since the ringleader will never blow the whistle, only the incentives of the cartel members have to be considered. The analysis is started with the SW strategy where at least one member does not have an incentive to blow the whistle.

i. Some firms blow the whistle

Due to the one-stage deviation principle, a cartel member that is the only one not to blow the whistle once (being *silent once*, $\{s1\}$) if the industry is reviewed has a collusive firm value of

$$V^+_{M,\{n-1,s1\}} = \frac{(1-\lambda)\Pi}{n-1} + (1-\rho)\,\delta V^+_{M,\{n-1\}} + \\ + \rho\bigg(- \hat{\mu}(1+\kappa(n-2))\frac{(1-\lambda)\Pi}{n-1} + (1-\hat{\mu}(1+\kappa(n-2)))\,\delta V^+_{M,\{n-1\}}\bigg). \quad (3.32)$$

By doing so, this cartel member forgoes the possibility of benefiting from the leniency program but does not increase (decrease) the probability that the cartel is convicted (the probability of collusive profits in the next period). This strategy is profitable if $V^+_{M,\{n-1,s1\}} \geq V^+_{M,\{n-1\}}$ which holds if

$$\delta \geq \frac{((1+\kappa(n-1))\phi - \kappa(n-1))f}{((1+\kappa(n-1))(1-\rho\hat{\mu}(1+\kappa(n-2)))\phi - \kappa(n-1))f + \kappa(n-1)} \equiv \bar{\delta}_{\{n-2\}}. \quad (3.33)$$

Comparing (3.33) with the analogous critical discount factor in the symmetric case given by equation (3.12), shows that both only differ in $-\kappa$, the additional value of the probability of conviction which is missing here due to the exclusion of the ringleader. This is intuitively straightforward since the number of firms which are able to blow the whistle is reduced from n to $n-1$.

Last, the boundary for the NW strategy where no firm blows the whistle has to be checked.

ii. No firm blows the whistle

If no cartel member has an incentive to blow the whistle, the corresponding collusive firm value of a cartel member amounts to

$$V^+_{M,\{0\}} = \frac{(1-\tilde{\lambda})\Pi}{n-1} + (1-\rho)\,\delta V^+_{M,\{0\}} + \rho\bigg(- \hat{\mu}\frac{(1-\tilde{\lambda})\Pi}{n-1} + (1-\hat{\mu})\,V^+_{M,\{0\}}\bigg). \quad (3.34)$$

Note that the new profit share for the ringleader, $\tilde{\lambda}^*$, will differ from the equilibrium profit share, λ^*, under the AW strategy. Moreover, $\tilde{\lambda}^*$ will be different from the symmetric profit share as well. As no ordinary cartel member blows the whistle under a NW strategy, the ringleader and the cartel members have the same collusive firm value under collusion. On the other hand, due to the finding in *Lemma 3.2* that cartel members always blow the whistle if one firm has deviated and if a review is under way, a ringleader has a lower firm value from deviation and thus a lower incentive to deviate. As this results in a lower critical discount factor, the profit has to be shifted in the other direction than under the AW strategy, i.e. from the ringleader to the ordinary cartel members.

Then, the collusive firm value of a ringleader amounts to

$$V^{+}_{RL,\{0\}} \quad = \quad \tilde{\lambda}\Pi \;+\; (1-\rho)\,\delta V^{+}_{RL,\{0\}} \;+\; \rho\Big(\;-\; \hat{\mu}\tilde{\lambda}\Pi \;+\; (1-\hat{\mu})\,V^{+}_{RL,\{0\}}\Big). \quad (3.35)$$

To calculate $\tilde{\lambda}$, the new critical discount factors for the ringleader and for the cartel members, $\bar{\delta}_{RL,\{0\}}$ and $\bar{\delta}_{M,\{0\}}$ have to be calculated. Equations (3.35) and (3.34) and as well as *Lemma 3.2* gives that

$$\delta = \frac{1-\tilde{\lambda}(1+\rho f(\mu_{n-1}-\hat{\mu}))}{(1-\tilde{\lambda}\rho\mu_{n-1}f)(1-\rho\hat{\mu})} \equiv \bar{\delta}_{RL,\{0\}} \quad (3.36)$$

and

$$\delta = \frac{(1-\tilde{\lambda})(1+\rho f(\mu_{n-1}\psi_{n-1}-\hat{\mu}))-(n-1)}{((1-\tilde{\lambda})\rho\mu_{n-1}f\psi_{n-1}-(n-1))(1-\rho\mu_{n-1})} \equiv \bar{\delta}_{M,\{0\}}. \quad (3.37)$$

As $\bar{\delta}_{RL,\{0\}} = \bar{\delta}_{M,\{0\}}$ has to hold at the margin, the new equilibrium profit share for the ringleader is

$$\tilde{\lambda}^{*} = \frac{1}{2\rho\mu_{n-1}f(1-\psi_{n-1})}\Big(\rho\mu_{n-1}f(1-\psi_{n-1})+n- \\ -\sqrt{[\rho\mu_{n-1}f(1-\psi_{n-1})+n]^2-4\rho\mu_{n-1}f(1-\psi_{n-1})}\Big). \quad (3.38)$$

Note that, from comparing equations (3.38) and (3.31) reveals that both profit-sharing parameters are indeed different. Furthermore, one can show that $\tilde{\lambda}^{*}$ is always decreasing in ρ as argued above.[44] Now the analysis can be turned to the resulting critical discount

[44] Setting $\frac{\partial\tilde{\lambda}^{*}}{\partial\rho}$ equal to zero and solving it for any of the parameter values, does not give a solution.

factor. An ordinary cartel member would deviate from the SW strategy if the associated profit is higher than in the case where the firm is the only one to blow the whistle once, $\{b1\}$, if the collusive industry is reviewed. Such a deviating member would have a collusive firm value of

$$V^{+}_{M,\{0,b1\}} = \frac{(1-\tilde{\lambda}^{*})\Pi}{n-1} + (1-\rho)\,\delta V^{+}_{M,\{1\}} + \rho\Bigg(- \hat{\mu}(1+\kappa)\frac{(1-\tilde{\lambda}^{*})\Pi f(1-\phi)}{n-1} + \\ + (1-\hat{\mu}(1+\kappa))\,\delta V^{+}_{M,\{1\}}\Bigg). \quad (3.39)$$

At least one cartel member would choose to deviate from NW if $V^{+}_{M,\{0,b1\}} \geq V^{+}_{M,\{0\}}$. To calculate the corresponding critical discount factor, equation (3.34) can be rearranged such that

$$V^{+}_{M,\{0\}} = \frac{(1-\tilde{\lambda}^{*})\Pi}{n-1}\left(\frac{1-\rho\hat{\mu}f}{1-\delta(1-\rho\hat{\mu})}\right). \quad (3.40)$$

Thus, the critical discount factor above which no firm would blow the whistle if the industry is reviewed is then given by

$$\delta = \frac{((1+\kappa)\phi-\kappa)f}{((1+\kappa)(1-\rho\hat{\mu})\phi-\kappa)f+\kappa} \equiv \bar{\delta}_{\{0\}}. \quad (3.41)$$

Interestingly, equation (3.41) is equal to the corresponding boundary of the symmetric case given in equation (3.16). This means in turn that the the critical discount factor for the NW strategy, is independent of the equilibrium profit-sharing rule, since $\tilde{\lambda}^{*} \leq \frac{1}{n}$.[45]

Note that all these calculations have to be done to prove that the AW strategy can be an equilibrium. However, the results are important to specify the parameter values of the analysis below. On the other hand, the existence of the parameter spaces where SW and NW are equilibrium strategies is a second-order problem in the evaluation if ringleader discrimination is superior or not. If in equilibrium not all firms have an incentive to blow the whistle if the cartel is reviewed, then excluding one firm has no

Moreover, using the parameter values from section 3.3.3 give $\tilde{\lambda}^{*} = \frac{6+6\,\rho-\sqrt{36+24\,\rho+36\,\rho^2}}{12\rho}$. From this numerical example it is easy to see that $\frac{\partial\tilde{\lambda}^{*}}{\partial\rho} < 0$. Thus, $\frac{\partial\tilde{\lambda}^{*}}{\partial\rho} < 0$ in any case.

[45]This results from $\lim_{\rho\to 0}\tilde{\lambda}^{*} = \frac{1}{n}$ and $\frac{\partial\tilde{\lambda}^{*}}{\partial\rho} < 0$.

effect. Of course, it affects the deviation profits since all firms would have an incentive to blow the whistle if one firm has deviated and if the antitrust authority starts a review.

Now it can be turned to the comparison of both scenarios.

3.4.2 Comparison with the non-discrimination case

Consider a situation where the antitrust authority has chosen an enforcement policy such that AW maximizes the number of industries which are able to sustain collusion. Note that this does by no means imply that the leniency program has a strictly adverse effect; it just excludes those cases where for a relatively high value of κ, firms would be able to collude for a larger ρ through the use of NW.[46] Hence, the boundaries calculated above, from which on firms switch from AW to SW and from SW to NW, only affect the strategy by which collusion is sustained in equilibrium, but not the sustainability of collusion in general. Under this condition only the slope of the critical discount factor of the AW strategy determines the sustainability.

Concerning the AW strategy, however, the effects of discriminating ringleaders on the sustainability of collusion may be ambiguous. Consider again the numerical example from section 3.3.3. Plugging the parameter values into the equilibrium profit share of a ringleader given by equation (3.31), results in

$$\lambda^*(\rho) = \frac{3 - 12\rho - \sqrt{180\rho^2 - 84\rho + 9}}{6\rho}. \tag{3.42}$$

Making use of $\lambda^*(\rho)$, the critical discount factors for the asymmetric case, $\bar{\delta}_{RL,\{n-1\}} = \bar{\delta}_{M,\{n-1\}}$, and the other relevant discount factors $\left(\bar{\delta}_{\{n\}}, \bar{\delta}_{\{n-1\}}, \bar{\delta}_{\{n-2\}}, \text{ and } \bar{\delta}_{\{0\}}\right)$ can be calculated. They are drawn by *Figure 3.3*.

[46] Technically that means $\bar{\delta}_{\{0\}} < \bar{\delta}_{\{n\}} \gtreqless \bar{\delta}_{RL,\{n-1\}} = \bar{\delta}_{M,\{n-1\}}$. We will no go into detail but numerical simulations suggest that this condition does not hold if κ is so large (a single whistleblowing firm is very valuable) that excluding the ringleader from the leniency program would unambiguously increase the sustainability of collusion, i.e. $\bar{\delta}_{\{n\}} \geq \bar{\delta}_{RL,\{n-1\}} = \bar{\delta}_{M,\{n-1\}}$.

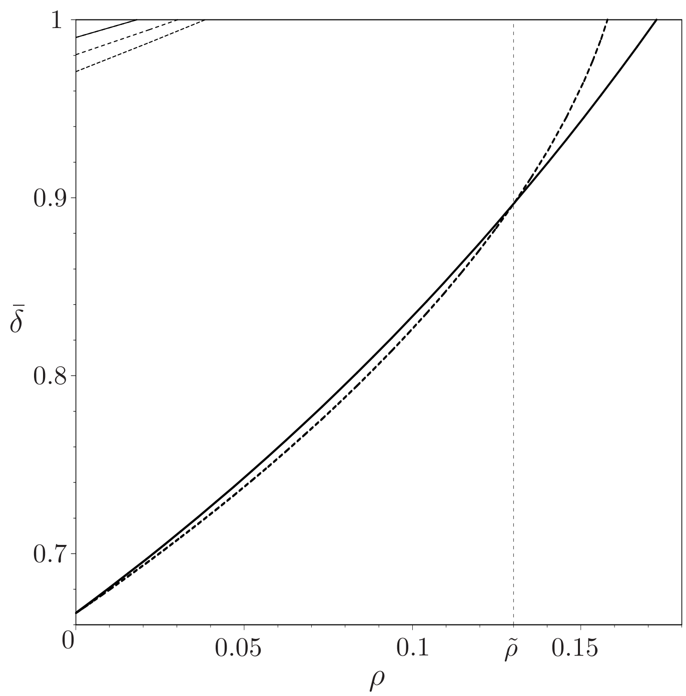

Figure 3.3: Comparison of both regimes ($\kappa = \frac{1}{10}$)

Again, the solid line represents the critical discount factor for the regime where all firms are able to benefit from the leniency program and where firms share the monopoly industry profit equally. The dotted line represents the critical discount factor for the asymmetric case, given the adjustment of the ringleader per-period profit to $\lambda^*(\rho)$. As can be seen from the figure both discount factors are the same for $\rho = \tilde{\rho}$ (with $\tilde{\rho} \in [0, 1]$) and $\tilde{\rho} \approx 0.13$, in our example.

If the probability that the authority reviews the industry is small ($\rho \leq \tilde{\rho}$) a regime where the ringleader is discriminated results in a lower critical discount factor and thus in more collusion. This is due to the lower total probability of conviction when the antitrust authority excludes the ringleader. From *Proposition 3.1* it is known that for $\rho \rightarrow 0$ firms shift a smaller share of the monopoly industry profit to the ringleader, $\lambda \rightarrow \frac{1}{n}$. So if ρ is small, the expected profit from deviation for excluded ringleaders and ordinary cartel members is more or less equal to the symmetric case. At the same time, the expected fine is increasing if firms are treated equally since this would result in a higher probability of conviction and less profitability of collusion. Consequently, an antitrust authority which can only commit to review an industry with a relatively small probability will be better off when allowing ringleaders to benefit from leniency programs.

On the other hand, if ρ increases, it holds that $\lambda \to 1$. If the probability that the industry is reviewed becomes larger, the ringleader will obtain a larger part of the collusive monopoly industry profit. This increases the asymmetry between the ringleader and the cartel members by reducing the per-period profit of the ordinary cartel members (and their expected fines) and thus increases their incentives to deviate even if the discount rate is high. As can be seen in *Figure 3.3*, this effect on the sustainability of collusion may dominate the sustainability-reducing effect of a larger probability of conviction in the case where the ringleader may join the leniency program (for $\rho > \tilde{\rho}$).

Note that for $\kappa = 0$, it is obvious that excluding the ringleader has to be always superior. The antitrust authority would forgo nothing by excluding the ringleader while the internal stability of the cartel decreases in ρ, since – as discussed in *Lemma 3.3* and *Proposition 3.1* – the profit of a ringleader has to rise since the probability of been reviewed ρ is increasing, $\frac{\partial \lambda^*(\rho)}{\partial \rho} > 0$.

The effect of a more asymmetric cartel does not necessarily outweigh the effect of a larger probability of conviction. *Figure 3.4* gives an example for the case where κ is so large such that excluding the ringleader would always result in more collusive industries.

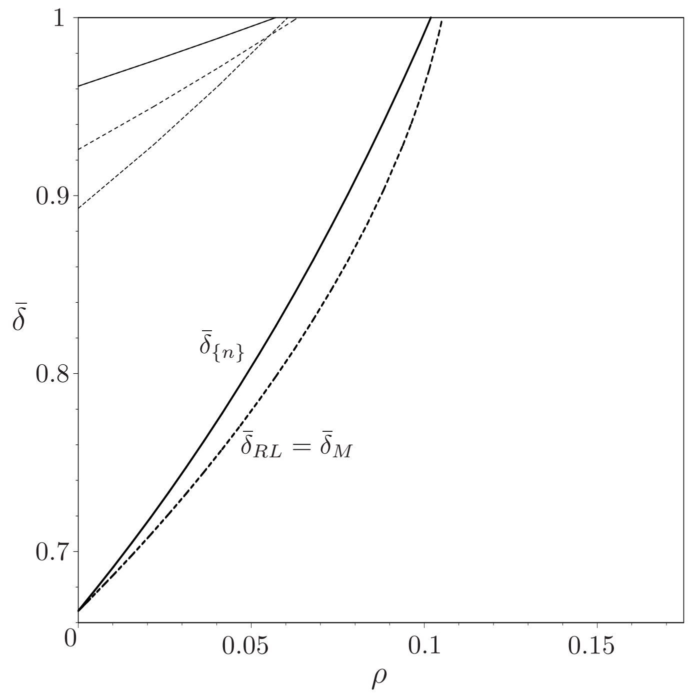

Figure 3.4: Ringleader exclusion fares always worse (c.p. κ increased from $\frac{1}{10}$ to $\frac{2}{5}$)

Compared to the situation before, as κ increases, the antitrust authority would forgo very valuable information by excluding the ringleader. Such a large κ would increase the probability of conviction to such an extent that non-discrimination is superior in any case for the antitrust authority, since it results in less collusion.

The considerations above can be summarized in the following proposition.

Proposition 3.2 *If $\kappa > 0$ and if AW is the collusive strategy, there may exist a $\tilde{\rho}$ such that for any $\rho > \tilde{\rho}$ ringleader discrimination by the antitrust authority reduces the sustainability of collusion. If $\rho < \tilde{\rho}$ non-discrimination is optimal for the antitrust authority.*

Proof Follows from a comparison of equations (3.10) and (3.29) (or (3.30)) given the expression for λ in equation (3.31). ■

The comparison of *Figures 3.3* and *3.4* also reveals the assessment of both regimes it quite involved. All of the relevant parameters, i.e. the value by which a whistleblower increases the probability that the antitrust authority finds enough evidence to convict the cartel, κ, the scope of the leniency program, ϕ, the fine, f, the probability that the antitrust authority finds enough evidence to convict the cartel without the help of a single firm, $\hat{\mu}$, and the number of firms within the cartel, n, affect the sustainability of collusion for a given probability of review, $\bar{\delta}(\rho)$. At the same time, these parameters also affect the differences between the two different legal environments – and thus the position (or the existence) of a $\tilde{\rho}$.Since the effect of ρ on λ^* is present only under ringleader discrimination, the equilibrium share of the industry profit that a ringleader gets, $\lambda^*(\rho)$, affects the position of $\tilde{\rho}$ significantly.

Numerical simulations based on the example from section 3.3.3 give some insight into how the different parameters affect the optimality of one regime or the other. The tentative results are given in *Table 3.1* below.

Table 3.1: Comparative statics on $\bar{\delta}$, λ^*, and $\tilde{\rho}$

x	f	$\hat{\mu}$	ϕ	n	κ
$\frac{\partial\bar{\delta}(\rho)}{\partial x}$	≥ 0	≥ 0	≤ 0	> 0	≥ 0
$\frac{\partial\lambda^*(\rho)}{\partial x}$	≥ 0	≥ 0	≥ 0	$\lesseqgtr 0$	≥ 0
$\frac{\partial\tilde{\rho}}{\partial x}$	< 0	< 0	< 0	> 0	$\lesseqgtr 0$

If $\tilde{\rho}$ decreases, the parameter space where a regime that discriminates ringleaders is superior (for the antitrust authority) extends. Antitrust authorities should then again favor excluding ringleaders instead of counting on the additional information ringleaders have even if they have a relatively low probability of investigating the industry. On the other hand, if $\tilde{\rho}$ increases, the parameter space where a regime that does not discriminates against ringleaders is superior becomes larger.

By making use of numerical simulations, the results of the comparative statics will be characterized and described in the following section.

3.5 Numerical simulations

3.5.1 Impact of f

If the fine increases, collusion becomes less valuable and thus sustainability of collusion decreases in general in both regimes, i.e. $\frac{\partial\bar{\delta}(\rho)}{\partial f} > 0$ for all $\rho > 0$. At the same time, for a given probability of review, the ringleader will ask for a higher compensation than under lower fines, i.e. $\frac{\partial\lambda^{*}(\rho)}{\partial f} \geq 0$. This increases the asymmetry between the ringleader and the ordinary cartel members and additionally decreases the sustainability of collusion, since the ringleader ask for nearly the whole monopoly profit for a lower ρ now (see *Figure 3.5*).

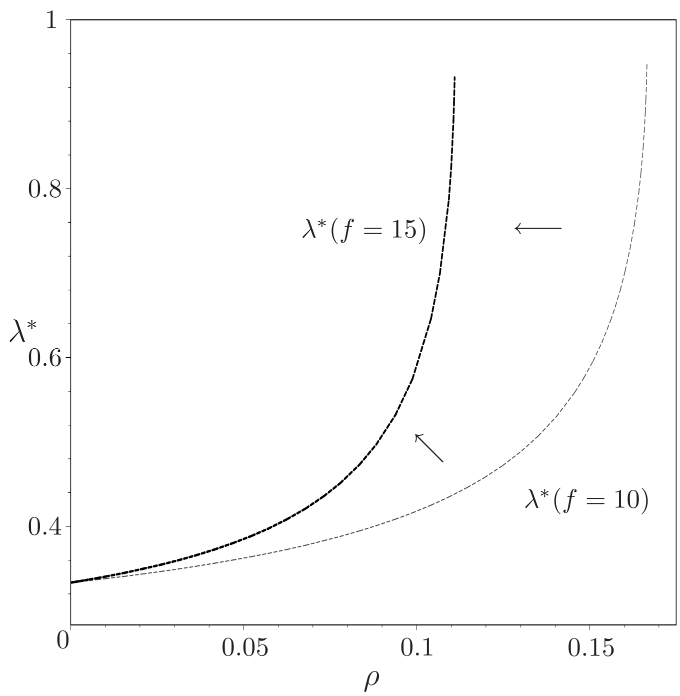

Figure 3.5: Example for $\frac{\partial \lambda^*(\rho)}{\partial f} \geq 0$ (f increases from 10 to 15)

Regarding the position of $\tilde{\rho}$, the argumentation above yields that both effects go in the same direction. Consequently, $\tilde{\rho}$ has to decrease if fines increase (and vise versa), i.e. $\frac{\partial \tilde{\rho}}{\partial f} < 0$. For an example, see *Figure 3.6*.

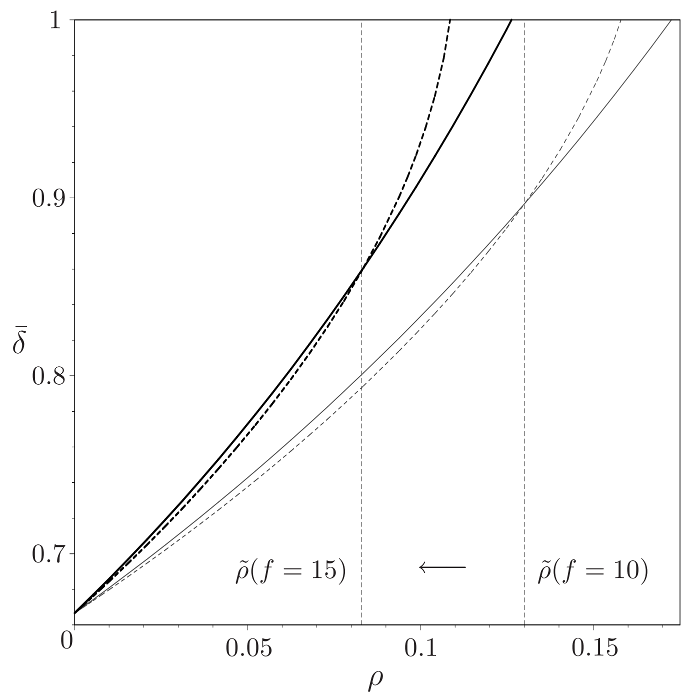

Figure 3.6: Example for $\frac{\partial \tilde{\rho}}{\partial f} < 0$ (f increases from 10 to 15)

3.5.2 Impact of $\hat{\mu}$

The probability that the antitrust authority is able to convict the cartel without the help of any firm, $\hat{\mu}$, is related to the probability that the industry is reviewed, ρ. The total probability that a cartel is convicted depends on both probabilities. If the antitrust authority becomes stronger in finding enough evidence, sustaining collusion becomes harder – no matter if the ringleader is excluded or not, i.e. $\frac{\partial \bar{\delta}(\rho)}{\partial \hat{\mu}} \geq 0$. At the same time, the ringleader has to get a larger part of the monopoly industry profit, $\frac{\partial \lambda^*(\rho)}{\partial \hat{\mu}} \geq 0$ and asymmetry increases in the same way the fine f increases asymmetry. Again, both effects affect $\tilde{\rho}$ in the same way. Thus, an increase in $\hat{\mu}$ results in a decrease in $\tilde{\rho}$ (and vice versa), i.e. $\frac{\partial \tilde{\rho}}{\partial \hat{\mu}} < 0$. For an example, see *Figure 3.7* below.

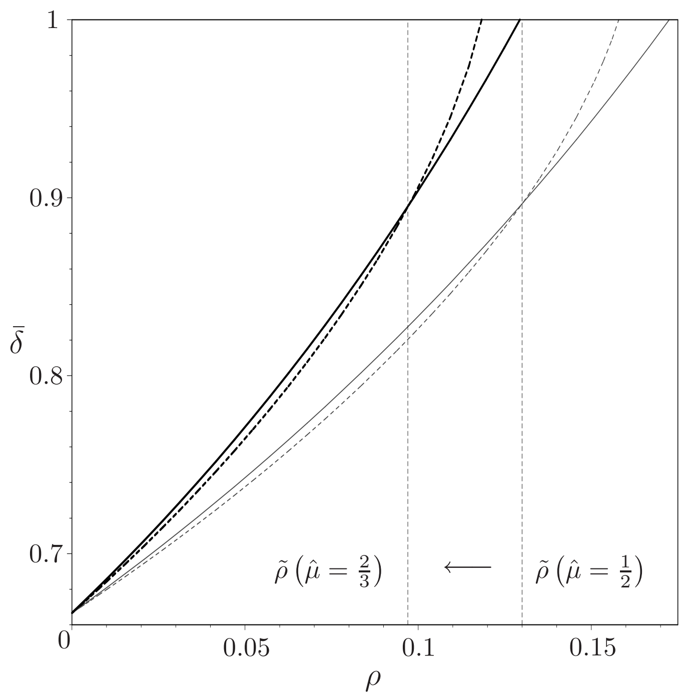

Figure 3.7: Example for $\frac{\partial \tilde{\rho}}{\partial \hat{\mu}} < 0$ ($\hat{\mu}$ increases from $\frac{1}{2}$ to $\frac{2}{3}$)

3.5.3 Impact of ϕ

If the leniency program becomes less generous (e.g. the fine reduction decreases from $\phi = 1$ ("full immunity") to $\phi = \frac{3}{4}$) the expected total fine of each cartel member (that is eligible to apply for leniency) increase. As a result, the critical discount factors under both regimes are larger for all $\rho > 0$ if ϕ decreases, i.e. $\frac{\partial \bar{\delta}(\rho)}{\partial \phi} \leq 0$.[47] However, this effect on the critical discount factors differ in their strength under both regimes.

In contrast to all other parameters of the model, ϕ affects only the critical discount

[47] This is the standard adverse effect of the fine reduction in the context of leniency programs. Leniency programs could 'in principle [..] increase cartel activity' (Spagnolo, 2004). That the leniency policy can have the perverse effect of making collusion more stable is also shown by Spagnolo (2000), Chen and Harrington (2007), as well as Herre and Wambach (2008). In the context of fines, Becker (1968) is the first to argue, that infinite fines would always prevent individuals (or firms) from illegal activities. These findings do not imply that starting a leniency program is fundamentally wrong. It allows the antitrust authorities to collect information about cartel activity and thus gives the authority the information it needs to detect cartels and may help to prevent firms from forming cartels in the future.

factor of cartel members which are eligible for leniency. Thus, if the ringleader is excluded the critical discount factor of the ringleader is (initially) not affected by such a change (see equations (3.29) and (3.30)). Different from that, under a regime where the ringleader is eligible for leniency, all firms are affected by an change in ϕ.

Under a regime of ringleader exclusion, the firm value of the ringleaders is however affected indirectly by the new profit sharing due to higher expected fines for the ordinary cartel members. Since ceteris paribus only the expected profits of ordinary cartel members decrease, the critical discount factor of the ringleader does not change. Only the critical discount factor of the ordinary cartel members moves upwards. From the discussion in *Section 3.4* it is known that firms with the lower critical discount factor always have an incentive to transfer shares of the collusive industry profit to firms with a higher critical discount factor as long as the critical discount factors are not equal. Consequently, the equilibrium profit share a ringleader gets decreases weakly at the margin if ϕ decreases, i.e. $\frac{\partial \lambda^*(\rho)}{\partial \phi} \geq 0$.

However, since the critical discount factor of the ringleader is not directly affected by a change in ϕ[48], it is obvious that the profit sharing rule at the points where $\delta = \frac{1}{n}$ ($\rho = 0$) and $\delta \rightarrow 1$ has the be equal irrespective of ϕ. Thus, asymmetry between ringleaders and ordinary cartel member decreases if the leniency program becomes less generous, but the asymmetry decreases only very weakly since the change in $\lambda^*(\rho)$ is limited (see *Figure 3.8*).

[48]Since $\lambda^*(\rho)$ has to be adjusted when ϕ is changed, the critical discount factor of the ringleader is only affected indirectly after this adjustment.

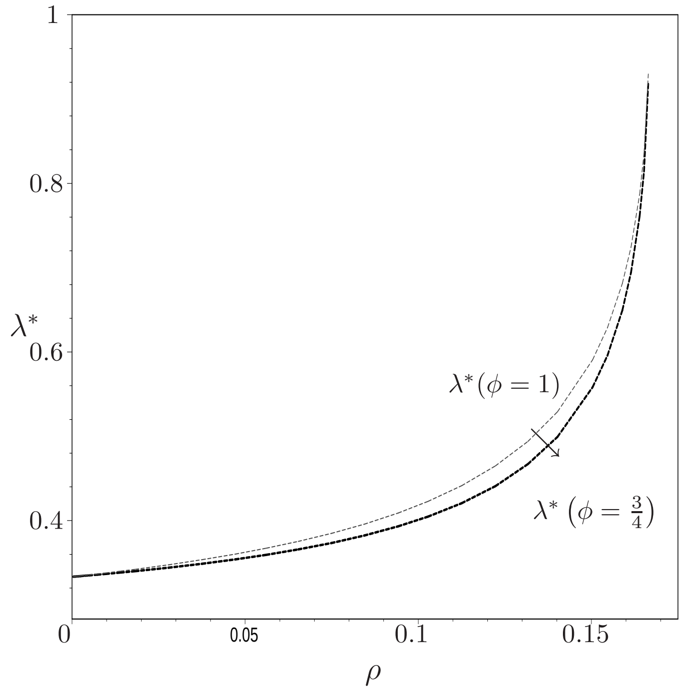

Figure 3.8: Example for $\frac{\partial \lambda^*(\rho)}{\partial \phi} \geq 0$ (ϕ decreases from 1 to $\frac{3}{4}$)

Knowing that the critical discount factor of the ringleader is not affected directly by ϕ, it is clear that the effect of ϕ on the critical discount factor in a regime of ringleader exclusion has to be very limited. The relatively weak change in ϕ on $\lambda^*(\rho)$ is the reason, why the effect of a decreasing sustainability of collusion if ringleaders are eligible for the leniency program outweighs the effect of the weakly increasing asymmetry if ringleaders are excluded. Thus $\tilde{\rho}$ increases if the leniency program becomes less generous (and vice versa), i.e. $\frac{\partial \tilde{\rho}}{\partial \phi} < 0$ (see *Figure 3.9*).

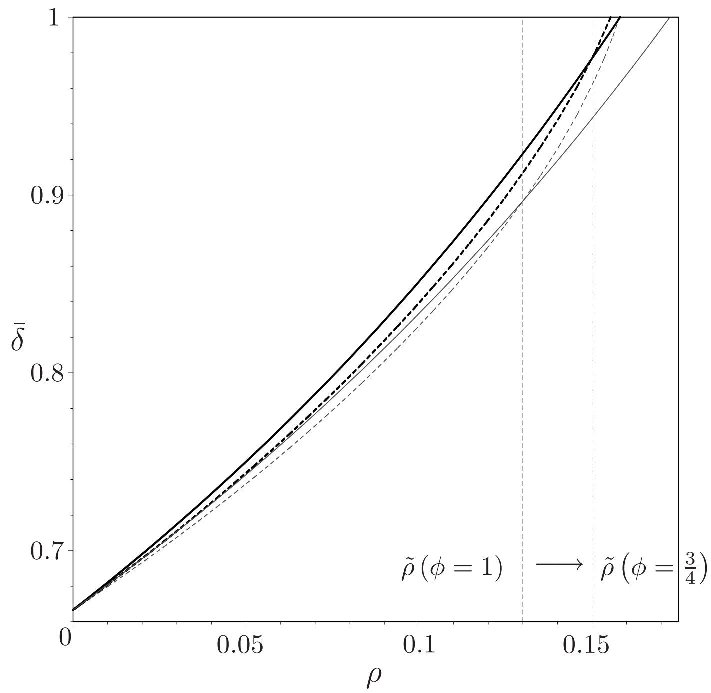

Figure 3.9: Example for $\frac{\partial \tilde{\rho}}{\partial \phi} < 0$ (ϕ decreases from 1 to $\frac{3}{4}$)

3.5.4 Impact of n

A change in the size of the collusive industry changes the terms of sustainable collusion significantly. In particular, adjusted profit sharing leads to significant changes in the firm values from collusion and deviation. If the number of the colluding firms increases, all firms have to forgo a part of the their former collusive profit share since the industry profit is shared between more firms now. Thus, sustainability of collusion is reduced under both regimes in general by a larger incentive to deviate, i.e. $\frac{\partial \bar{\delta}(\rho)}{\partial n} > 0$.

Note that even for $\rho = 0$ sustainability of collusion is reduced if n increases. Hence, the ringleader should get a smaller part of the monopoly industry profit now. On the other hand, as sustainability of collusion is reduced in general, the ringleader would get a larger part of the monopoly industry profit in equilibrium if ρ is large: The ringleader will ask for nearly the whole monopoly industry profit ($\lambda^*(\rho) \to 1$) for a lower ρ than in collusive industries with less firms, since the antitrust authority has access to more evidence now if all ordinary cartel members blow the whistle. Thus, the effect of an increase in the number of colluding firms on the collusive profit sharing between ringleaders and ordinary cartel members is ambiguous, i.e. $\frac{\partial\lambda^*(\rho)}{\partial n} \lesseqgtr 0$, which can bee seen in *Figure 3.10* below.

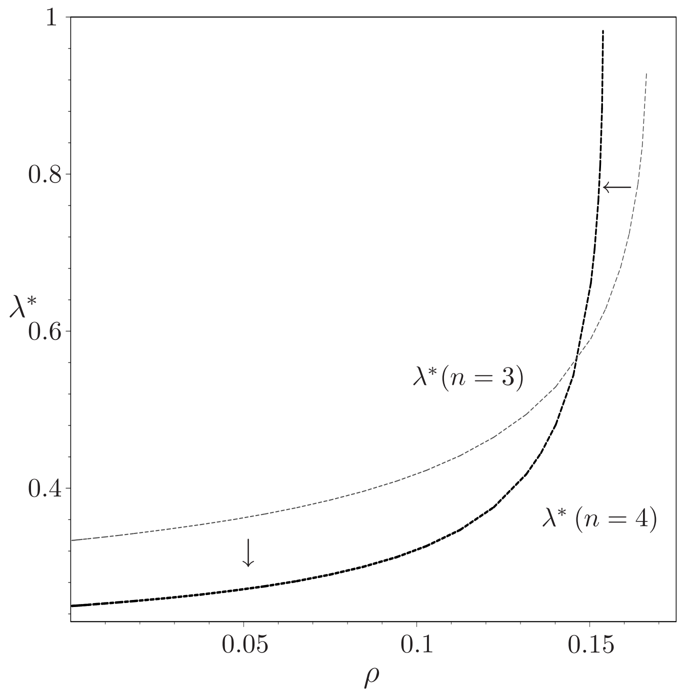

Figure 3.10: Example for $\frac{\partial\lambda^*(\rho)}{\partial n} \lesseqgtr 0$ (n increases from 3 to 4)

Again, as already observed in the analysis of the impact of ϕ, the effect of the number of collusive firms on λ^* is relatively weak (in particular if ρ is high). This can be seen from a comparison of *Figure 3.5, 3.8,* and *3.10.* Moreover, if the number of firms increases, the probability of conviction increases too. This effect is stronger the more firms are eligible for leniency. Thus, the effect of reducing sustainability due to more firms should be stronger in a regime where all firms are able to pass on information to the antitrust authority. Numerical simulations suggest that this effect on the position of $\tilde{\rho}$ is always stronger than the effect of reducing sustainability due to the larger share of the industry profits firms shift to the ringleader if ρ is large. Thus, $\tilde{\rho}$ increases in n, i.e. $\frac{\partial\tilde{\rho}}{\partial n} > 0$.

Note that changes in the number of colluding firms have to be – in reality – always integer. In the example, this has the effect that with one additional whistleblowing firm a regime which allows the ringleader to blow the whistle becomes superior now (see *Figure 3.11*).

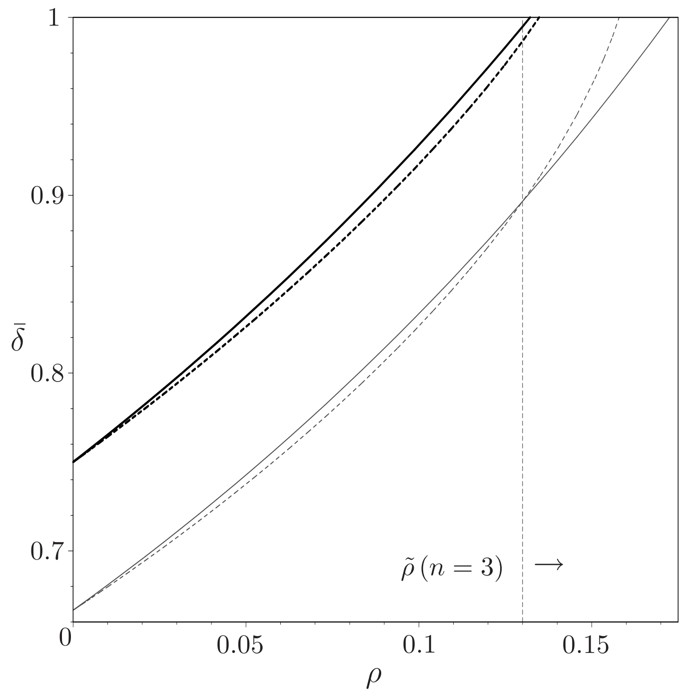

Figure 3.11: Example for $\frac{\partial \tilde{\rho}}{\partial n} > 0$ (n increases from 3 to 4)

3.5.5 Impact of κ

The effect of a change in the value by which an additional whistleblowing firm increases the probability that the antitrust authority finds enough evidence to convict the cartel, κ, on $\tilde{\rho}$ is ambiguous. A larger κ makes it harder to sustain collusion since the expected fine increases if more firms blow the whistle. As a result, the sustainability of collusion has to decrease in general and the ringleader would ask for a larger share of the monopoly industry profit since the effect on $\lambda^*(\rho)$ and $\bar{\delta}(\rho)$ is similar to the effect of f and $\hat{\mu}$.[49] Independent of this, *Figure 3.12* illustrates that the affect of κ on $\tilde{\rho}$ is

[49]Thus $\frac{\partial \bar{\delta}(\rho)}{\partial \kappa} > 0$ and $\frac{\partial \lambda^*(\rho)}{\partial \kappa} > 0$ if $\rho > 0$ has to hold again.

ambiguous and thus differs from the affects of f and $\hat{\mu}$ (see *Table 3.1*).

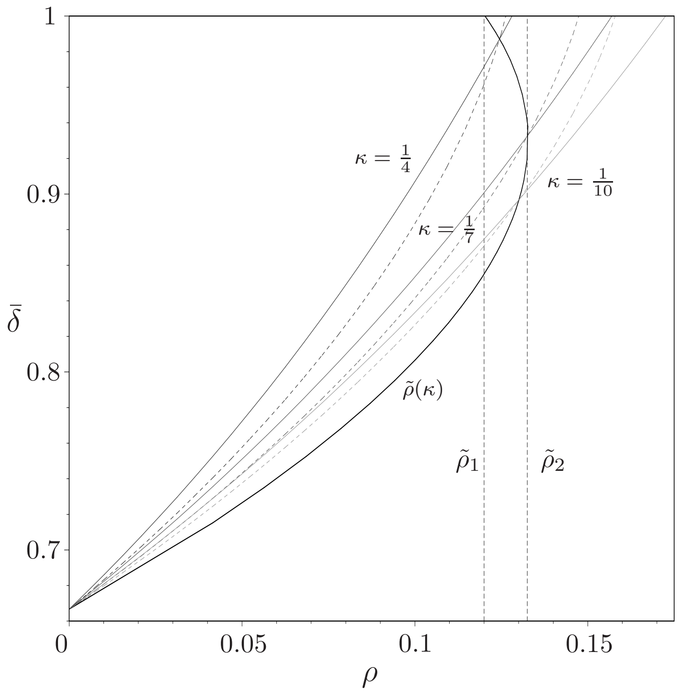

Figure 3.12: Impact of κ on $\tilde{\rho}$ with three numerical examples

The thick solid line indicates a change of the optimality of both regimes subject to κ. From the discussion above it is known that if $\kappa = 0$ the antitrust authority is always better of with ringleader discrimination. If the antitrust authority has only limited resources to investigate a specific industry (i.e. if ρ is small) then the parameter space where a regime of no ringleader discrimination is superior widens as κ increases. In this case, the evidence every firm can pass on to the authority can be viewed as a substitute for the low probability of review. Now if ringleaders are not eligible for leniency, then the antitrust authority forgoes a good opportunity to convict the cartel. As a result, $\tilde{\rho}$ increases. However, from *Figure 3.12* it can be seen that if a review is very likely already (e.g., $\rho = \tilde{\rho}_2$) and κ is large at same time (e.g., $\kappa = \frac{1}{7}$) then $\tilde{\rho}$ decreases if κ increases further. The antitrust authority would rather want to exclude the ringleader from the leniency program in order to increase the asymmetry between the firms. This is due to the effect which was already discussed above. If the value of the information of an additional firm is sufficiently high, the sustainability-reducing effect of an additional whistlblowing firm is stronger than the effect of reducing the sustainability through an asymmetric sharing of monopoly profits between ringleader and ordinary cartel members (see e.g. *Figure 3.4* and the example for $n = 4$ in *Figure 3.11*).

3.6 Extension: fine load for ringleaders

The discussions in the sections above have shown that the exclusion of ringleaders may result in more collusion. Leslie (2006) discusses this effect (intuitively) and suggests a way to deal with the stabilizing effect of ringleader exclusion: He notes that "a proper way to signal antitrust law's particular displeasure with cartel instigators and ringleaders is to assign higher penalties to them, as the Sentencing Guidelines currently do. This allows greater punishment for the offender who has done something worse. [..] To the extent that making ringleaders eligible for amnesty may reduce the expected cost of cartelization (and thus reduce deterrence), increasing ringleader penalties compensates for this effect and maintains deterrence."

In the model developed above one could think of doing so by introducing a fine load of $(1+l)f$ (with $l > 0$) for the ringleader. In both cases put forward above, this would mean that the sustainability of collusion would be reduced since the total fine for the industry would increase in general. However, this would lead to a greater asymmetry within the industry which would require an asymmetric profit-sharing rule in the non-discriminating case as well. Such a rule would shift more profits to the ringleader. If levying a fine load is possible in the non-discriminating case, it is also feasible in the discriminating case. Then, however, there will be parameter regions where the result affiliated above

3.7 Conclusions

This chapter has focused on whether ringleaders of illegal cartels should be given the chance to apply for leniency or not. The model identifies the different forces at work which make one regime appear more favorable than the other. It was shown that both approaches may be a useful means to curb cartel activity. Indeed, the model shows that giving ringleaders the opportunity to participate in the leniency program is the better option if the antitrust authority reviews industries with a relatively small probability. In such a situation, the additional information provided by ringleaders leads to a higher probability of conviction and thus decreases the sustainability of collusion in general. However, if the antitrust authority commits to a relatively high probability of review, the exclusion of the ringleader from the program may fare better. This is due to the fact that the ringleader faces a higher expected fine, which calls for a compensation by ordinary cartel members. The resulting asymmetry between the firms reduces the sustainability of the cartel.

The analysis is based on specific assumptions concerning the functioning and the homogeneity of the firms. The model assumes that firms are symmetric and that one of these firms takes on the role of a ringleader. As a result, firms become asymmetric since they are treated differently. However, as mentioned in the introduction, while certain ringleader activities do not seem to require a specific type of firm, other firm-specific factors (profit, revenue, size, etc.) may be crucial for firms to become ringleaders. It would be interesting to analyze the characteristics which make cartel leadership more likely and how they finally affect collusive stability. Clearly, introducing heterogeneous firms into the model would imply that there is an a priori asymmetry in the market which negatively affects the sustainability of collusion in general. Depending on the ringleader's characteristics, granting access to the benefits of the leniency programs only to ordinary cartel members, will anyhow still have the effects discussed above.

Chapter 4

Vertical integration and (horizontal) side-payments – asymmetric vertical integration in a successive duopoly

4.1 Introduction

Industries differ with respect to the degrees of vertical integration and separation of the firms on markets. The co-existence of vertically integrated and separated firms can be found, e.g., in the U.S. petroleum-refining industry[50], in the U.K. beer industry[51], in cable television networks in the U.S.[52], in the Mexican footwear industry[53], and in the retail gasoline market in Vancouver[54]. One further example of co-existence can be found in the upper tiers of the German natural gas market as well. This market is interesting not only because of the existence of an asymmetric vertical market structure, its story how it came into being is remarkable as well.

[50] See, e.g., Bindemann (1999) and Aydemir and Buehler (2002).
[51] See, e.g., Slade (1998a).
[52] See, e.g., Waterman and Weiss (1996) and Chipty (2001).
[53] See, e.g., Woodruff (2002).
[54] See, e.g., Slade (1998b).

Before 30 January 2003, the first and the second tier of the German natural gas market could be described as a separated successive oligopoly. On the first tier of the market (upstream) there were five importing gas companies: Ruhrgas, VNG Verbundnetz Gas, Wingas, Thyssengas, and BEB.[55] On the second tier, about ten – so called 'regional gas transmission companies' – sold natural gas to the downstream customers.[56] The market shares of the firms on the both tiers were, however, very unequally distributed. There were two players on the market with significantly large market shares. On the upstream tier, Ruhrgas had a dominant position. Ruhrgas imported (and was producing) around 60 % for the natural gas on the German market. On the downstream tier, a company called E.ON had an almost dominant position as well. At the beginning of 2003, these two main players integrated to the only fully integrated gas company in the German market: E.ON Ruhrgas. There were strong resistances against this vertical merger from the competition authority, the monopoly commission and some competitors. They feared a further increase of the already dominant positions of the upstream supplier Ruhrgas and the downstream supplier E.ON. On the other hand, the willingness to merge was strongly – and decisive – supported by the German Ministry of Economics.[57] However, some of the (smaller) market players went to court and launched a legal complaint to prevent the takeover. The court decided that the merger should be delayed until a final decision of the court. Finally, E.ON reached an out-of-court settlement with the complaining firms. To this end, all firms withdrew from the complaint and the merger was permitted.

The main characteristics of the out-of-court settlements where horizontal 'side-payments' to downstream competitors of E.ON. The 'side-payments' included asset sales and asset swaps, one agreement on a common development of a power plant based

[55] In addition, there were six smaller producers of natural gas, which also supplied the lower tiers of the market.

[56] Actually, they sold most of the natural gas to a third tier of the market, that consist of about 700 smaller distribution companies. These companies could be described as the final customers of the two tiers above, even if there where some gas distribution of the first and the second tier that sold directly to the final consumers. For a more detailed description of the complex structure of the German natural gas market, see Lohmann (2006), Chapter 2.

[57] The main arguments both, in favor of and against the takeover can be found in Lohmann (2006), Chapter 7, pp. 113.

on natural gas, marketing contributions and even pure transfers of money. According to E.ON, the costs of of these agreements amounted to around 90 million Euros.[58] No details of the agreements were ever published. Thus, the real economic value of the agreements is still ambiguous. The 'side-payments' were reviewed by the German antitrust authority. The authority, however, "has not seen any harm of competition law, regarding to these agreements".[59]

Horizontal 'side-payments' seem to have played a critical role by establishing an asymmetric vertical market structure, where some firms (or at least one firm) are (is) vertically integrated, while other firms remain separated. *Figure 4.1* shows the arising market structure and the agreement of horizontal side-payments of the E.ON Ruhrgas merger.

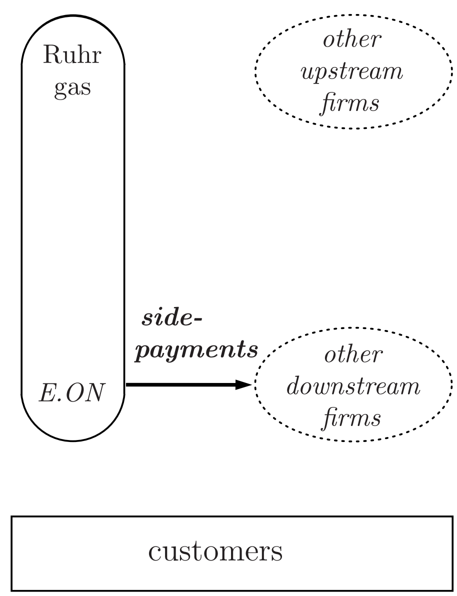

Figure 4.1: Stylized structure of the German natural gas market at 30 January 2003

Ruhrgas and E.ON each ruled – due to their historically determined market shares – around half of the tiers in the German natural gas market. Thus, for modeling purposes one can assume that there are only one large player on every tier of the

[58]See. LOHMANN (2006) and E.ON AG press release, 30 January 2003, *'E.ON kann Ruhrgas-Übernahme vollziehen'*.

[59]See 'Die Welt', 3 May 2003, *'Ruhrgas-Übernahme durch E.ON beschäftigt erneut die Gerichte'*.

market[60]: Ruhrgas and the 'other upstream competitors' on the upstream tier, and E.ON and its 'other competitors' on the downstream tier.

The model presented below focuses on the question how E.ON could make it sure to be the only fully integrated firm through the use of horizontal side-payments. It is shown how horizontal side-payments can be crucial to explain the development of such a market structure where vertically integrated firms co-exist with fully separated competitors. By assuming linear pricing in both tiers of the market, a simple model of a successive Cournot duopoly is developed. In equilibrium one downstream firm ends up in a position of being the only firm that is vertically integrated. The result is driven by the fact that a downstream firm has an incentive to transfer side-payments to the downstream competitor. This leads to an asymmetric vertical market structure since side-payments prevent counter-mergers of the rivals. However, firms will pay side-payments only to the downstream tier, while the upstream tier will never receive any side-payments. Furthermore it is shown that antitrust authorities may allow for such side-payments, since they increase the overall welfare compared to a market structure where no firm is integrated. This results from the reduction of the welfare-decreasing effects of *double marginalization* in the context of vertical market structures. However, if firms would integrate anyway, the antitrust authority should ban side-payments since they prevent a market structure where all firms are vertically integrated. A market structure of full integration would increase welfare compared to a partially integrated market that arises from side-payments. Thus a ban on side-payments would then increase welfare.

Several papers in the literature analyze the co-existence of vertically integrated firms and separated upstream and downstream firms in one specific market. The presented model differs from these papers by explicitly investigating the effect of the possibility to offer side-payments to the competitors.

Assuming linear pricing and Cournot competition in the upstream and the downstream market, e.g., Gaudet and Long (1996) and Abiru et. al. (1998) show

[60]Even if in reality, there is a much more complex market structure. See Lohmann (2006).

that asymmetric equilibria may exist even if firms are perfectly symmetric ex-ante. The co-existence of integrated and separated firms depends on the number of firms on the upstream and downstream markets. If the number of firms on the different tiers is the same, full integration is the only equilibrium with regards to these models. Elberfeld (2002) also obtains asymmetric integration equilibria in a symmetric setting. Jansen (2003) analyzes the conditions where vertical separation is chosen by some firms, while vertical integration is chosen by others in equilibrium. The decision whether integration is chosen in equilibrium depends on costs of writing exclusive vertical contracts.[61] However, for a successive duopolistic industry, there are no contracting costs so that vertical separation and integration coexist in his model. A similar argument to explain asymmetric vertical market structures in equilibrium is used by Bühler and Schmutzler (2005). They present a model of vertical backward integration in a reduced-form model of successive Cournot oligopolies with linear pricing. They show that if downstream firms have to bear some acquisition costs to integrate with an upstream firm, these costs might be the reason why in a successive duopolistic industry only one pair of firms integrates. Their model is to the author's knowledge the first one to explain asymmetric vertical integration in a successive duopolistic industry with quantity competition and linear pricing.

Most of the literature does not investigate the process of the vertical integration in detail. It is usually assumed that firms are willing to integrate if it is unilateral profitable for them. Furthermore, the resulting profits of the integrated firm are assumed to be shared between the former independent units anyhow. In addition, a static game of the integration decision is often modeled. This may result in a prisoners-dilemma, so that firms integrate even if this is unprofitable in the end, e.g. due to counter-mergers of the other firms.

By contrast, Ordover et. al. (1990) model the process of bidding for the upstream supplier explicitly. They analyze a symmetric vertical duopoly with Bertrand

[61] Jansen (2003) uses a variant of a model proposed by Gal-Or (1990), where the downstream demand is linear, firms face Cournot competition, and upstream firms are able to provide non-linear contracts (two-part tariffs).

competition in the upstream market and differentiated downstream products. They show that asymmetric vertically integration is an equilibrium if the revenues of the downstream industry is increasing in the input price and the integration of one pair of the firms raises the upstream price not excessively. Otherwise, the separated downstream firm has an incentive to integrate as well. They also show, however, that if downstream firms face Cournot competition, the only equilibrium in their model is a separated industry.

This chapter is organized at follows. In the next section, the model and the timing of the integration game are introduced. In *Sections 4.3* the equilibrium is derived. The welfare analysis, policy implications and two extensions of the model are discussed in *Section 4.4*. *Section 4.5* discusses the assumptions of the model. The last section concludes.

4.2 The model

4.2.1 Firms and the market structures

Consider a 2×2 successive model of ex-ante symmetric firms.[62] In such an industry, initially, there are two downstream firms D_k with $k \in \{1, 2\}$ and two upstream firms, U_i with $i \in \{A, B\}$, on a fully separated market. The upstream firms produce an intermediate product which is bought by the downstream firms by an equilibrium per-unit price of ω. Each unit of the intermediate product is transformed by the downstream firms into one unit of the final product. For simplicity, it is assumed that the marginal cost of producing the intermediate product is constant and normalized to c. The marginal cost of transforming the intermediate product into the final product is normalized to zero. On both tiers of the market, firms compete in quantities and set linear prices. The demand of final consumers is linear and given by $t(Q) = a - bQ$, where t is the price of the final product, Q is defined by $Q = q_{D_1} + q_{D_2}$, and $a, b > 0$.

[62] Most of the literature on vertical integration focuses on vertical duopolies and on symmetric vertical market structures, e.g., Ordover et. al. (1990), Hart and Tirole (1990), Jansen (2003), and Bühler and Schmutzler (2005).

The resulting outcomes of the different possible market structures are as follows: After an integration, a firm produces the intermediate product *in-house* at costs of c, whereas a vertically separated downstream firm buys the intermediate product from the upstream market at the equilibrium price ω. Furthermore, integrated firms neither supply the input to non-integrated downstream firms, nor purchase inputs from non-integrated upstream firms.[63] Thus, if both firms are separated (SP), duopoly Cournot competition is present in both tiers of the market. If both firms are integrated (full integration, FI), the model corresponds to a standard Cournot competition duopoly with marginal costs of c. If only one firm is separated (partial integration, PI) the remaining upstream firm sets a linear monopoly price ω^{PI} for the remaining separated downstream firm. All these possible market structures are shown in *Figure 4.2* below.

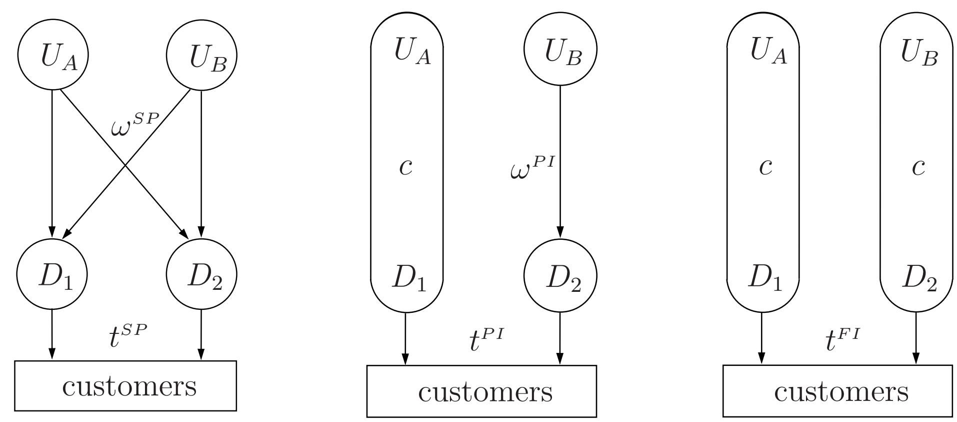

Figure 4.2: Possible vertical market structures in a successive Cournot duopoly

Just like Bühler and Schmutzler (2005) – and following the example of the E.ON Ruhrgas merger – the developed model focuses on backward vertical integration only. Thus, it is assumed that only a downstream firm is able offer a payment to take over the assets of one upstream firm.[64] Even if only the downstream firms are able to make offers, the integration cause some *expenditures* for the downstream firms[65]: The

[63] Salinger (1988) shows that, with final good Cournot competition, a vertically integrated firm prefers not to supply to a second downstream firm. Whether integrated firms stay in the market for intermediate products depends on the conjectures of integrated firms about the behavior of the remaining upstream monopolist, see, e.g., Schrader and Martin (1998).

[64] This assumption will be discussed and justified in *Section 4.5*

[65] With respect to the costs of integration, Bühler and Schmutzler (2005) assume that down-

downstream firm has to pay an endogenous compensation payment p to the owner(s) of the upstream assets, to take over these assets, since the profit from the market of an integrated upstream unit is equal to zero. Thus, the owner(s) of the upstream assets will ask for at least a price as high as their out-side option(s). The offer of such a payment is assumed to be common knowledge, i.e. if D_k offers p_{ki} to integrate with U_i, all other firms are able to observe this offer.

i. Market outcomes

Summing up, *Table 1* gives all relevant payoffs of the firms U_i and D_k within the three possible market structures discussed above, i.e SP, PI, and FI. All calculations can be found in the *Mathematical appendix, A.2.1.* To keep the table well arranged, payoffs are normalized by $\frac{(a-c)^2}{1296b}$, thus, e.g., 96 in the SP case (separation) stands for 96 $\frac{(a-c)^2}{1296b}$. Furthermore, in the case of PI (partial integration), one example is shown where D_k and U_i are integrated. To compensate the owner(s) of the upstream assets of U_i, D_k has to pay p_{ki} to U_i. Moreover, in the FI case (full integration), D_l has to pay p_{lj} when integrating with U_j.[66]

Table 4.1: Market outcomes under different market structures

	SP	PI	FI
U_i	96	p_{ki}	p_{ki}
U_j	96	54	p_{lj}
D_k	64	$225 - p_{ki}$	$144 - p_{ki}$
D_l	64	36	$144 - p_{lj}$

stream firms have to pay lump-sum acquisition costs, $F > 0$. These costs are the driving forces of an asymmetric vertical market structure in their model. In the model analyzed here, such lump-sum costs do not exist.

[66]Note that the p_{ji}'s do not have to be the same in equilibrium in the different market structures of PI or FI.

It can be seen that a downstream firm has an incentive to be the integrated firm in the PI-market structure as long as $225 - p_{ki} \geq 64 \geq 144 - p_{ki} \geq 36$. Furthermore, if for example D_k and U_i have integrated, D_l has an incentive to propose a counter-merger with U_j as long as $144 - p_{lj} \geq 36$ in equilibrium. To prevent such a counter-merger, side-payments seem to be useful. For instance, D_k could offer D_l a side-payment that would lead to a profit larger than the profit D_k could get after a counter-merger.

ii. Side-payments

It is assumed that firms can make side-payments among each other during the process of integration. A side-payment is characterized by a transfer of (some) profits from one (downstream) firm to the other firms on the same or a different tier of the market. More specifically, h_{kl} is defined as a horizontal side-payment of D_k to D_l, and h_{lk} as a horizontal side-payment in the other direction. A vertical side-payment from a downstream firm to an upstream firm is defined by v_{ki}, if D_k transfers profits to a upstream firm U_i. Side-payments are assumed to be common knowledge, i.e. if one firm announces side-payments to another firm, all players in the market are able to observe these offers. At last, firms are not restricted to offer (and to pay) side-payments to one tier only: i.e. it is possible to pay both, h to rivals at the same tier and v to firms at the other tier.

iii. Antitrust policy

To account for antitrust law, it is assumed that mergers are forbidden if one of the following standard rules[67] is violated: Firms can only integrate pairwise, i.e. only one downstream firm is able to integrate with one upstream firm. Firms within the same tier are not allowed to merge. Thus, ex-post monopolization of one horizontal tier of the market is not allowed. Consequently, ex-post monopolization of the market as a whole is forbidden as well. This assumption will be relaxed in *Section 4.5* where side-payments in a market structure of ex-post monopolization are discussed in detail.

[67] To concentrate on the effects of vertical mergers only, all the literature presented and discussed above make these assumptions on possible integration decisions.

Policy implications due to side-payments are discussed later in *Section 4.5* as well. Initially, it is assumed that the antitrust authority is not able to forbid any kind of side-payments as long as they do not lead to a violation of the standard rules mentioned above.

4.2.2 Timing of the integration game

The integration game consists of seven stages and four (active) players which act sequential: One downstream firm D_k makes an initial integration offer – which may include offering side-payments to other firms – to each U_i, with $i \in \{A, B\}$.[68] More precisely, each downstream firm is the first mover who can start to makes offers in *Stage 1* with probability $\frac{1}{2}$. Later in the game, the downstream rival (the second mover), D_l, can start making offers to the upstream firms as well, i.e. if the offers of D_k are rejected by each upstream firm U_i or/and it is able to bid for a counter-merger with the remaining upstream firm. Thus, the timing of the game is as follows:

Stage 1: One D_k offers contracts to take over the assets of an upstream firm U_i. It offers a contract $C_{ki} = (p_{ki}, \{v_{kj}, h_{kl}\})$ to U_i and a contract $C_{kj} = (p_{kj}, \{v_{ki}, h_{kl}\})$ to U_j.

Stage 2: Each U_i chooses between accepting $\{a\}$ or rejecting $\{r\}$ the contract.

Since it is possible that both upstream firm reject or accept the offered contracts, the following assumptions are made:

Assumption 4.1 *If both upstream firms reject $\{r\}$ the contract, D_k looses its first-mover advantage to D_l and the games restarts in Stage 1.*

[68] The model developed in this section will not focus on the evolution of such a first moving downstream firm.

Assumption 4.2 *If both upstream firms accept* $\{a\}$ *the contract,* D_k *chooses* U_i *as a partner if* $171 - p_{ki} - (h_{kl} + v_{kj}) \geq 171 - p_{kj} - (h_{kl} + v_{ki})$ *with* $i \neq j$.[69]

Due to the assumptions, the game restarts in *Stage 1* if both upstream units reject and D_l starts to offer contracts. Otherwise the game continues in *Stage 3*:

Stage 3: D_k chooses (one) U_i as integration partner.

Stage 4: D_k offers h_{kl} to the seperated downstream firm D_l and v_{kj} to the seperated upstream firm U_j.

Stage 5: D_l chooses between accepting h_{kl} and staying separated; or offering a takeover of the assets of the remaining upstream firm U_j by offering p_{lj}.

Stage 6: U_j chooses between accepting v_{kj} and staying separated; or selling its assets to D_l for a price of p_{lj}.

Stage 7: All payments are reviewed by the antitrust authority and payoffs are realized.

In the following section the equilibrium is derived.

4.3 Derivation of the equilibrium

The game is sequential, thus it has to be solved by backward induction, starting in *Stage 7*.

[69] *Assumption 4.2* ensures that the downstream firm sticks to the antitrust policy described above: Integration is permitted pairwise only.

Stage 7: payoffs

Suppose that partial integration can be sustained in equilibrium by the use of side-payments. Hence, the game ends with a market structure where only one pair of firms is vertically integrated, e.g. D_k and U_i. Due to antitrust considerations, there has to be one separated firm on each tier of the market left, e.g. D_l and U_j. The downstream unit of the integrated firm, D_k, owns all assets of the integrated firm, has to pay p_{ki} to U_i, and may pay some side-payments, h_{kl} and v_{kj}, to the remaining separated firms to prevent a counter-merger. Then the equilibrium market structure and the possibility of side-payments results in the following payoff matrix:

$$U_i = p_{ki} \tag{4.1a}$$

$$U_j = 54 + v_{kj} \tag{4.1b}$$

$$D_k = 225 - p_{ki} - (h_{kl} + v_{kj}) \tag{4.1c}$$

$$D_l = 36 + h_{kl} \tag{4.1d}$$

Stage 6: counter-merger acceptance

In *Stage 6*, the separated upstream firm, U_j, could either accept the vertical side-payment v_{kj}, and thus stand back from any possibility of integrating with the remaining downstream firm, D_l. On the other hand, the asset owner(s) of U_j could accept the merger offer, p_{lj}, from D_l.

It can bee seen, that the owner(s) of U_j accept to forgo the counter-merger, if (and only if) the following (upstream) incentive compatibility constraint (IC U) holds:

$$54 + v_{kj} \geq p_{lj}. \tag{IC U}$$

Constraint (IC U) ensures that U_j decides to stay separated on the market as an upstream monopolist, if the price the downstream firm offers for its assets is lower than the stand-alone profit of U_j as a remaining monopolist on the market for the intermediate product plus the vertical side-payments it may receive from D_k.

Stage 5: counter-merger offer

In *Stage 5*, the separated downstream firm, D_l, has the possibility to offer a price for the assets of U_j, i.e. p_{lj}.[70] A counter-merger at price p_{lj} would create a fully integrated market, where D_l receive a profit of $144 - p_{lj}$: the profit from the downstream market under a fully integrated market structure minus the costs of taking over U_j's assets.

Alternatively, it could accept the horizontal side-payment h_{kl}, and thus commits not to merge, i.e. not to offer p_{lj}. This results in a profit of $36 + h_{kl}$: the profit from the downstream market under an asymmetric integrated market structure plus the side-payments from D_k. Note that *Stage 5* ends directly after the offering of p_{lj} or after D_l accepted the side-payments, h_{kl}. It is not possible to do both: receiving h_{kl} and offering $p_{lj} > 0$.

Again, it can be seen that D_j would accept the side-payment, if the following (downstream) incentive compatibility constraint (IC D) holds:

$$36 + h_{kl} \geq 144 - p_{lj}. \tag{IC D}$$

Constraint (IC D) says that D_l would choose to accept the horizontal side-payment and thus to forgo a counter-merger, if (and only if) the profit from the market as a separated downstream firm plus the side-payment is larger than the profit as an integrated firm, but by anticipating that p_{lj} has to be offered to (and to be excepted by) to the owner(s) of the remaining upstream monopolist, U_j, in equilibrium.

Stage 4: side-payment offers

In *Stage 4*, D_k offers the side-payments to prevent a potential counter-merger.[71]

In order to maximize its profit in *Stage 7*, D_k has to choose a minimal sum of the side-payments, $v_{kj} + h_{kl}$, which guarantees to be the only vertically integrated firm at the end of the game. Thus, constraints (IC U) and/or (IC D) has to hold. The vertical

[70] It is defined that if D_l do not offer a payment to take over the assets of U_j, then p_{lj} is set to zero.

[71] If D_k does not offer any vertical or horizontal side-payments then v_{kj} or h_{kl} are assumed to be equal to zero.

side-payment has to be chosen so that U_j accepts v_{kj} and forgo any counter-merger offer it expects in *Stage 5*. Or equivalently, the horizontal side-payment has to be such high that it is not profitable for D_l to go for the counter-merger.

The condition for this to hold are given in the following lemma.

Lemma 4.1 *To prevent a counter-merger, D_k offers a set of side-payments, $\{v_{kj}, h_{kl}\}$, which satisfies:*

$$v_{kj} + h_{kl} \geq 54. \tag{4.2}$$

Proof From constraint (IC D) it is known that $h_{kl} \geq 108 - p_{lj}$. Constraint (IC U) gives that D_l has to offer $p_{lj} \geq 54 + v_{kj}$ to go for a counter-merger. Thus, $h_{kl} \geq 108 - (54 + v_{kj}) \Leftrightarrow h_{kl} + v_{kj} \geq 54$. ■

Lemma 4.1 says that if the sum of the side-payments, $v_{kj} + h_{kl}$, is larger or equal 54, the owner(s) of U_j can not expect to receive an (adequate) offer for its assets ($p_{lj} \geq 54 + v_{kj}$) in *Stage 5*. If condition (4.2) holds, D_l has no incentive to offer a counter-merger contract in *Stage 5* since the horizontal side-payments plus the profit from the downstream market as a separated firm ($h_{kl} + 36$) is larger than the downstream profit it gets from the market in a full integrated market minus the price it has to pay for the assets of U_j, $144 - (54 + v_{kj})$.

Stage 3: downstream firm chooses upstream unit

In *Stage 3*, D_k chooses one upstream firm as integration partner.

From *Lemma 4.1* and from the payoff matrix in *Stage 7* (4.1), it is known that D_k will have a profit of $\Pi_{D_k} = 225 - p_{ki} - 54 = 171 - p_{ki}$ if it is the only integrated firm on the market.

D_k is only able to choose a partner for the integration if at least one upstream firm has chosen to accept, $\{a\}$, the contract in *Stage 2*. As described above, a contract specifies the bid for the upstream assets and the set of side-payments. Thus, a contract is given by $C_{U_i}^{D_k}(p_{ki}, \{v_{kj}, h_{kl}\})$ if offered from D_k to U_i, and $C_{U_j}^{D_k}(p_{kj}, \{v_{ki}, h_{kl}\})$ if offered from D_k to U_j.

If U_i accepts $C_{U_i}^{D_k}$ and U_j rejects $C_{U_j}^{D_k}$, D_k signs an integration contract with the owner(s) of U_i to take over the assets. Even if both upstream firms accept, due to *Assumption 4.2*, D_k signs an integration contract with the owner(s) of U_i if $p_{ki} + v_{kj} + h_{kl} \leq p_{kj} + v_{ki} + h_{kl}$.

Stage 2: upstream units decide to integrate or not

In *Stage 2*, both upstream firms, U_i and U_j, have to choose simultaneously to accept or reject the contract offered to them.

From the discussions above it is clear that U_i will only accept the contract $C_{U_i}^{D_k}$ if p_{ki} is at least as high as either its profit from the market for the intermediate products when being the only separate upstream firm in a partially integrated market plus the side-payment which will by offered in *Stage 4*, or the counter-merger offer it expects from the remaining downstream firm in *Stage 5*. From *Lemma 4.1* it is known that the owner(s) of the upstream assets do not expect to receive an (adequate) offer for its assets in *Stage 5* if $v_{kj} + h_{kl} \geq 54$. Hence, the separated upstream firm gets a total profit of $\Pi_{U_j} = 54 + v_{kj}$ in *Stage 7*. Thus, the owner(s) of the upstream firms, e.g. of U_i, only accept a merger contract with D_k if the price for its assets is given by $p_{ki} \geq 54 + v_{kj}$.

This result is summarized in the following lemma.

Lemma 4.2 *The owner(s) of the assets of U_i accepts, $\{a\}$, a contract to sell the upstream assets to D_k if $p_{ki} \geq 54 + v_{kj}$. This holds if D_k offers a contract set of*

$$C_{U_i}^{D_k}\left(p_{ki} \geq 54 + v_{kj}, \{v_{kj}, h_{kl}\}\right), \text{ with } v_{kj} + h_{kl} \geq 54. \tag{4.3}$$

Proof The proof immediately follows from the discussion above and form *Lemma 4.1*. ■

Stage 1: contracts are offered

In *Stage 1*, D_k offers the contracts to the upstream firms.[72]

Lemma 4.2 gives the contract that ensures a market structure where only D_k is integrated. From contract set (4.3) it can be seen that any vertical side-payment $v_{kj} > 0$ increases the price D_k has to pay for the upstream assets. Thus, due to profit maximization it is obvious that D_k offers contracts which include horizontal side-payments only: D_k has to invest an amount of $p_{ki} + v_{kj} + h_{kl} = (54 + v_{kj}) + v_{kj} + (54 - v_{kj}) = 108 + v_{kj}$ to reach the position of the only integrated firm on the market. This investment reaches its minimum at $v_{kj} = 0$.

As a result D_k offers contracts of

$$C_{U_i}^{D_k}\left(p_{ki} = 54, \{v_{kj} = 0, h_{kl} = 54\}\right) \quad \text{to} \quad U_i, \tag{4.4}$$

and

$$C_{U_j}^{D_k}\left(p_{kj} = 54, \{v_{ki} = 0, h_{kl} = 54\}\right) \quad \text{to} \quad U_j. \tag{4.5}$$

Equilibrium payoffs

Plugging in the results above in the payoff matrix in *Stage 7* (4.1) gives the following equilibrium payoffs of the integration game:

$$
\begin{aligned}
U_i &= p_{ki} & & & &= 54 && \text{(4.6a)}\\
U_j &= 54 + v_{kj} & &= 54 + 0 & &= 54 && \text{(4.6b)}\\
D_k &= 225 - p_{ki} - (h_{kl} + v_{kj}) & &= 225 - 54 - (54 + 0) & &= 117 && \text{(4.6c)}\\
D_l &= 36 + h_{kl} & &= 36 + 54 & &= 90 && \text{(4.6d)}
\end{aligned}
$$

From payoff matrix (4.6) it can be seen that both downstream firms increase their profits due to the integration and both upstream firms are worse of compared to the

[72] Remember, if in *Stage 2* no upstream firm has chosen to accept the contract, this action would then belong to the other downstream firm, D_l.

outcomes under a separated market structure (see, *Table 4.1*).[73] Furthermore, the payoff of D_l is larger than the payoff of the separated downstream firm which receives the side-payments. Thus, there exists no *hold-out problem* of being the first downstream mover in the integration game.[74] *Figure 4.3* below illustrates an example for a resulting equilibrium market structure where D_1 and U_A are the integrated firms and D_2 and U_B remain separated.

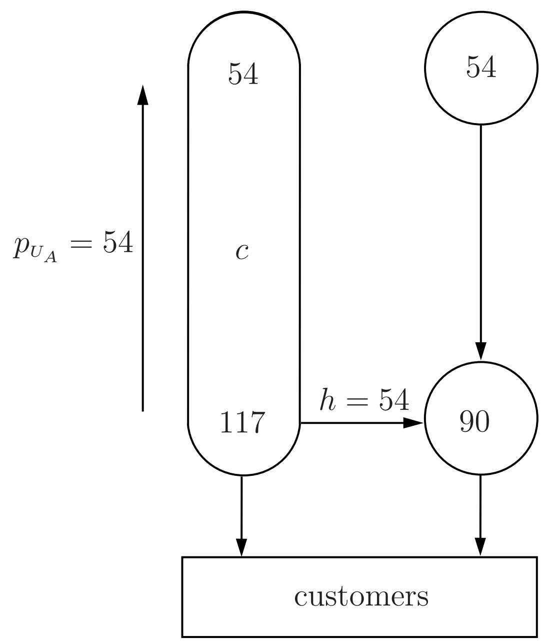

Figure 4.3: Equilibrium market outcome and market structure from partial integration if horizontal side-payments are payed

The following proposition summarizes the result:

Proposition 4.1 *If ex-post monopolization of the market is permitted by antitrust law and side-payments are allowed, then a partially integrated market structure in a* 2×2 *successive vertical Cournot market is an equilibrium. Due to profit maximization, the equilibrium is sustained by horizontal side-payments only.*

[73] That upstream firms are worse off and downstream firms increase their profits is due to the assumption of backward integration. However, this result will be discussed in *Section 4.5*.

[74] Otherwise, e.g. if due to the side-payments D_l needs to ensure to prevent the counter-merger, the profit of D_k would be higher than the profit of D_l, it could be an equilibrium that no firm would start the integration game.

Proof The proof follows immediately from the discussion above. ■

4.4 Welfare analysis, policy implications, and extensions

This section gives some policy implication of the equilibrium derived above. The welfare parameters of the market structures are compared and the antitrust policy with regard to side-payments will be discussed. Furthermore, the assumptions that side-payments are allowed in general and that ex-post monopolization of the market structure is prohibited is relaxed.

Proposition 4.1 states that an asymmetric vertical integrated market structure is possible if side-payments are allowed by antitrust law. In *Table 4.2* it can be seen that partial integration increases the total surplus (TS), the consumer surplus (CS), and the equilibrium profit of the integrated downstream unit (Π_{D_k}), while the producers surplus (PS, which is equal to to profit of the whole industry) decreases compared to the values under the initial fully separated market structure.[75]

Table 4.2: Comparison of a separated market structure (SP) and a market structure of partial (asymmetric) integration (PI)

	SP		PI
Π_{D_k}	64	$<$	117
PS	320	$>$	315
CS	128	$<$	220.5
TS	468	$<$	535.5

[75] All calculations can be found in *Mathematical appendix, A.2.1* and *A.2.2, (i)* and *(ii)*. Again, all values are normalized by $\frac{(a-c)^2}{1296b}$, thus e.g. 117 as the equilibrium profit of the integrated downstream unit, D_k, stands for 117 $\frac{(a-c)^2}{1296b}$.

4.4.1 The effect of a ban on side-payments

However, if side-payments were not allowed by antitrust law, it is easy to show that in a model as developed above the equilibrium of the game would be full integration (FI) where each downstream firm is integrated with on upstream unit:

With a ban on side-payments, D_k is neither able to offer D_l nor U_j a payment to prevent them from a counter-merger. Thus, since the outside option of each upstream firm which is not integrated under partial integration is equal to 54, one subgame perfect equilibrium is that D_k and D_l make take-it-or-leave-it offers amounting to $p_{ki} = 54$ and $p_{lj} = 54$ in *Stage 1* and *Stage 5* and upstream firms will accept these offers. Thus, *Table 4.1* and the *Mathematical appendix, A.2.1* give the equilibrium firm profits if side-payments are banned:

$$U_i = p_{ki} \quad = \quad 54 \tag{4.7a}$$

$$U_j = p_{lj} \quad = \quad 54 \tag{4.7b}$$

$$D_k = 144 - p_{ki} \quad = \quad 90 \tag{4.7c}$$

$$D_l = 144 - p_{lj} \quad = \quad 90 \tag{4.7d}$$

This equilibrium market structure (full integration) is the same as already described e.g. in Bühler and Schmutzler (2005) who analyze a 2×2 vertical Cournot market structure under linear quantity contracts, but without considering side-payments. In their paper, full integration is the only equilibrium market structure if the costs of integration are low (or equal to zero).[76]

Under full integration, the effect of *double marginalization* does not exist any longer. As a result, the consumer surplus and the total welfare increases under full integration at the costs of an even lower industry profit as under partial integration. *Table 4.3* gives the comparison in detail:[77]

[76]For other examples see, e.g., Gaudet and Long (1996), and Abiru et. al. (1998).
[77]All calculations can be found in *Mathematical appendix, A.2.1* and *A.2.2, (i), (ii)* and, *(iii)* and all values are normalized by $\frac{(a-c)^2}{1296b}$.

Table 4.3: Comparison of a separated market structure (SP), a market structure of partial (asymmetric) integration (PI), and a fully integrated market structure (FI)

	SP		PI		FI
Π_{D_k}	64	$<$	117	$>$	90
PS	320	$>$	315	$>$	288
CS	128	$<$	220.5	$<$	288
TS	468	$<$	535.5	$<$	576

Since the ban on side-payments results in full integration, the antitrust authorities should be cautious by allowing side-payments among firms, even if they increase the welfare and the consumer surplus compared to the initial separated market structure.

On the other hand, if no firm is willing to start the integration game, the authority should allow side-payments.[78] Independent of the question why no firm starts to integrate, if no firm is willing to integrate, then allowing for side-payments would increase the incentive to integrate since an integrated firm under partial integration (which come about side-payments) has a larger profit, i.e. $\Pi_{D_k} = 117$, from being integrated, whether the rival starts a counter-merger, i.e. $\Pi_{D_k} = 90$ (see the comparison of Π_{D_k} in *Table 4.3*). At the same time the welfare increases (see TS and CS in *Table 4.3*).

To take account of this argumentation the following conjecture is stated:

Conjecture 1 *If an antitrust authority observes that no downstream firm starts to*

[78]The circumstances why firms do not to start the integration game are not in the focus of this model. However, it would be interesting to investigate the reasons for this. For instance, following the model assumptions by Bühler and Schmutzler (2005) the resulting downstream profit of $\Pi_{D_k} = 90$ could be too low to compensate the downstream firm for its 'costs of integration'. One further reason could be that the total profit of the integration parters under full integration, i.e. $\Pi_{U_i} + \Pi_{D_k} = 54 + 90 = 144$, is lower then under separation (SP), i.e. $\Pi_{U_i} + \Pi_{D_k} = 96 + 64 = 160$ (see, *Table 4.1* and payoff matrix (4.7)). In the model developed above take-it-or-leave-it offers from the downstream firms are assumed. Therefore, the model concentrates on the incentives to integrate of the downstream firms only. Otherwise, if integration would require an increase in profits of both production units, firms have no incentive to integrate if full integration is the market structure in the end of the game.

integrate in a 2×2 successive Cournot market, the authority should allow for side-payments to increase the incentives of the firms to start the integration game.

4.4.2 The effect of lifting the ban on ex-post monopolization

So far ex-post monopolization of single tiers or of the whole market was assumed to be forbidden in line with literature on vertical integration. It can be shown, however, that if ex-post monopolization is feasible, downstream firms are able to achieve monopolization by the use of side-payments.

The argument for this is as follows: If ex-post monopolization is allowed by the antitrust authority, D_k has an incentive to pay D_l a side-payment, h_{kl}, to leave the market. Then, D_l will not compete with D_k in both: the final product market and during the integration game. If D_l leaves the market, a separated upstream unit can not expect to get any counter-merger offer in *Stage 5*. Since the integrated firm would not ask for intermediate products from the upstream market, a separated upstream firm thus gets a profit of $\Pi_{U_j} = 0$ when its rival integrates and one downstream firm leaves the market. Thus, the owner(s) of each upstream firm accept to integrate with D_k for price $p_{ki} = p_{lj} \geq 0$.

Since the equilibrium price for the assets of one upstream firm is equal to zero, the profit the downstream rival D_l can make by offering a counter-merger to U_j is given by $\Pi_{D_l} = 144 + p_{lj} = 144 + 0 = 144$. It turns out, to prevent a counter-merger D_k has to offer a contract to each upstream firm U_i:

$$C_{U_i}^{D_k}\big(p_{ki} = 0, \{v_{kj} = 0, h_{kl} = 144\}\big), \tag{4.8}$$

in *Stage 1* if ex-post monopolization is feasible.[79]

An integrated monopolistic downstream firm gets a profit from the final product market of $\Pi_{D_k} = 324$[80]. With regard to the discussion above, *Assumption 4.2*, and

[79]From the discussion in *Stage 1* it is obvious that D_k will not offer vertical side-payments to the upstream units, since this would rise the price for the upstream assets.

[80]See *Mathematical appendix, A.2.1 (iv)* and note again that the value is normalized by $\frac{(a-c)^2}{1296b}$.

profit maximization, D_k pays a price of $p_{ki} = 0$ to take over the assets of U_i and a horizontal side-payment of $h_{kl} = 144$. Allowing for such side-payments has the same effect as a horizontal merger in the downstream tier. The equilibrium market structure and the resulting payoffs for the firms are given in the following *Figure 4.4*.

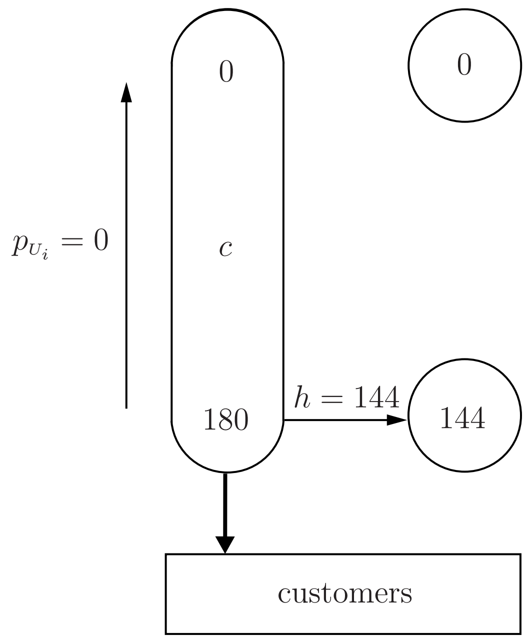

Figure 4.4: Equilibrium market outcome and market structure if ex-ante monopolization is feasible

Both upstream units will have a profit of zero since they have no other outside option. The two downstream firms share the monopoly profit. Thus, the integrated firm gets a profit of $\Pi_{D_k} = 324 - h_{kl} = 324 - 144 = 180$ and the separated downstream firm a profit of $\Pi_{D_l} = h_{kl} = 144$ since it has to leave the market when accepting h_{kl}.

The following table shows the values to compare the welfare results in a monopolistic market structure (M) with the market structures already discussed above.[81]

[81] Again, all calculations can be found in *Mathematical appendix, A.2.1* and *A.2.2 (i)* to *(iv)* and all values are normalized by $\frac{(a-c)^2}{1296b}$.

Table 4.4: Comparison of all market structures

	SP		M		PI		FI
Π_{D_k}	64	$<$	180	$>$	117	$>$	90
PS	320	$<$	324	$>$	315	$>$	288
CS	128	$<$	162	$<$	220.5	$<$	288
TS	468	$<$	486	$<$	535.5	$<$	576

From *Table 4.4* it can be seen that D_l has an incentive to monopolize the market structure since it would increase its profit compared to the SP, PI, or FI cases. Surprisingly, the antitrust authority would have no argument to forbid such side-payments since even a monopolistic market structure increases the consumer surplus and the total welfare compared to the initial separated market structure (SP). Compared to a partial integrated market (PI) the consumer surplus and the total welfare are lower under monopolization, however. *Conjecture 4.1* states that the antitrust authority should allow for side-payments if downstream firms have no incentives to start the integration game, however. The considerations in this section suggest that antitrust authorities should restrict such welfare increasing side-payments to trigger partial integration only since partial integration increases welfare by a larger amount as monopolization.

The reason is that integration reduces on the one hand *double marginalization* and on the other hand it fosters competition between a vertically integrated firm and the separated downstream competitor. As a result, this reduces the price in the final product market. If the separated competitor do not compete any more, however, the *double marginalization* is reduced, but competition is weakened as well. Interestingly, in market structure as assumed above, the effect of *double marginalization* is so strong that the welfare is affected positively compared to the market structure of full separation where two firms on each tier compete.

The following conjecture takes account of the observations above:

Conjecture 2 *An antitrust authority that expects no downstream firm to start the integration in a 2×2 successive Cournot market, should restrict side-payments to partial integration only.*

4.5 Discussion: backward integration

The developed model assumes backward integration only. Making assumptions about the bargaining structure to explain certain equilibrium market outcomes is established in the literature on vertical integration. The literature differs in the modality of the assumptions, however. For instance, Hart and Tirole (1990) give all the bargaining power to the upstream tier where firms with different marginal costs compete. In a similar spirit Jansen (2003) allows for forward integration only and thus gives all the bargaining power to the upstream firms as well, although there is competition of perfect symmetric firms on both tiers of the market. Contrary to them – as already mentioned above – Bühler and Schmutzler (2005) assume backward integration. Moreover, Fontenay and Gans (2005) assume a bargaining game about the rent allocation between the integrated units.

However, the assumption of backward integration is not crucial for the result that side-payments are important to sustain an asymmetric vertical integration in a successive 2×2 market structure where firms face Cournot competition under linear pricing. Changing this assumption into forward integration where upstream firms start to bid for the assets of downstream units in *Stage 1* and the following stages would be changed in the same way, only the allocation of the rents between the tiers and the firms would change: Under forward integration, the first moving upstream firm has the same incentives to pay side-payments to prevent a counter-merger of its rivals as well as the first moving downstream firm under backward integration. Moreover, just like the downstream firm before, the upstream firm will have no incentive to offer any vertical side-payment since offering a side-payment to the separated downstream firm would raise the price for the asset it needs.

Even assuming a bargaining game where the firms bargain the market structure and the distribution of the rents may result in an equilibrium of asymmetric integration sustained by side-payments: From *Table 4.1* it can be seen that an integrated firm in a partially integrated market structure has a profit of $\Pi_I^{PI} = 225$. Starting with full separation, an upstream firm will ask for at least its initial profit of $\Pi_{U_i}^{SP} = 96$. At the same time, a downstream firm will ask for at least a profit of $\Pi_{D_i}^{SP} = 64$. From the discussion above it is known that side-payments amounting to 54 have to be spend to prevent a counter-merger. Thus, an additional profit from bargaining of $\Delta = 225 - 96 - 64 - 54 = 11 > 0$ has to be shared between the three firms which are necessary to establish an equilibrium market structure of asymmetric vertical integration. It would be interesting to analyze the equilibrium outcome of the bargaining game. However, two main problems may arise from bargaining: First, the increasing profit from partial integration for the three *insider* firms comes at costs of one *outsider*. It is not clear which firm will be this *outsider*. However, it would be neither clear if the *outsider* is an upstream or a downstream firm. Second, the *hold-out problem*, as mentioned above, may arise since it could be more profitable in equilibrium to be the firm that receives the side-payment than to be the unit that is vertically integrated.

4.6 Conclusions

This essay shows how side-payments can be used to sustain asymmetric vertical integration in a successive duopoly market structure in an environment where firms sign linear contracts and compete with quantities. As a result, under the assumption of backward integration, a downstream firm prevents the counter-merger of its rivals by transferring side-payments to them. An integrated downstream firm will, however, never offer a vertical side-payment to the upstream tier since this would rise the price for the asset it needs to take over.

The welfare analysis reveals that antitrust authorities should allow for side-payments, since they increase the welfare compared to a market structure where all firms are separated. On the other hand, if firms are willing to integrate without side-payments, such payments should be banned since they can be used to prevent a market structure of full integration. A fully integrated market results in a higher welfare compared to a partially integrated market. Hence, a ban on side-payments would be welfare increasing. Even if the antitrust law allows for side-payments, an antitrust authority should restrict its use to pairwise integration only. The model shows that firms are able to use side-payments to establish a monopoly. Surprisingly, even a monopoly increases welfare compared to the initial market structure of a fully separated duopoly. Hence, the effect of a strong reduction of the *double marginalization* outweighs the effect of no competition in this model. Since partial integration leads to a higher welfare than the ex-post monopolization, however, side-payments should be restricted to trigger partial integration only.

Coming back to the initial example of the E.ON Ruhrgas merger on the German natural gas market: Following the argumentation of the model developed above, one can argue that it was a correct decision of the antitrust authority to allow for the side-payments. Without the out-of-court settlements of E.ON with is competitors it could be that no firm on the German natural gas market would be integrated by now. The competitors of E.ON feared a reduction of its profits resulting from the merger. This argument is in line with the model developed above. However, side-payments can compensate the competitors for their losses. In the end, the downstream firm which is integrated and the separated rival(s) which get the side-payments increase their profits. Even the consumers profit from the vertical integration due to the reduction of the *double marginalization* and the resulting lower price for the final product. All these positive results come at the cost of lower profits of the firms on the upstream tier of the market. The lower profits result from the assumed backward integration structure of the model. This allocation of the rents disappears if the model is changed to forward integration or extended to a bargaining game. However, it is again not clear how the bargaining power should be distributed among the firms and how the timing of the integration game should be assumed. Thus, the analysis of the bargaining game is left for future research.

Chapter 5

Concluding remarks

This chapter provides a few concluding remarks on the topics presented in this thesis.

The model presented in *Chapter 2* analyzes the effects of different antitrust policies when firms are not able to observe market outcomes directly. Several interesting results are derived. First, it is shown that charging a fine for collusive behavior allows firms in industries with a relative low probability of demand shocks to collude, even if the threat of punishment through a price war would be too weak to facilitate collusion. Thus, charging fines from collusive firms enables more industries to collude. If information about firms' pricing history is disclosed, e.g. by the antitrust authority, the number of colluding industries increases even further. Moreover, information makes punishment via price war periods unnecessary and unprofitable. That is why firms never choose price wars to sustain collusion now. Additionally, information increases collusion in industries with a low probability of demand shocks and allows industries with a high probability of demand shocks to collude. Since firms get information when blowing the whistle, the fine can be interpreted both as a punishment tool and as the price for information about the behavior of the rival. Thus, the effect of modifying the fine is ambiguous. On the one hand, increasing the fine provides a harder punishment and thus increases the number of colluding industries with a relative low probability of demand shocks. On the other hand, an increase of the fine is equivalent to an increase in the price of information, which reduces the sustainability of collusion in industries with a relative high probability of demand shocks. Therefore, leniency programs have ambiguous effects in general. If the probability of demand shocks is relatively low and fines are not too high, a leniency program reduces the number of colluding industries. If the fine is relatively high, a leniency program only increases the necessary frequency of whistleblowing. The number of industries which collude in an environment of a high probability of demand shocks is, however, increasing if a leniency program is implemented since it reduces the price of information for these firms.

The model has strong implications for antitrust policy especially with regard to leniency programs. Antitrust authorities should keep the adverse effects of leniency programs in combination with the information provided to the firms in mind. The more generous a leniency program is, the lower the expected costs of information that is useful for collusive agreements are. Moreover, leniency programs may lead to more cartel cases since the frequency of whistleblowing increase due to lower fines. Thus one might expect more information exchange between the authority and the firms. As this may facilitate collusion – especially in uncertain environments – and leniency programs render information less expensive, the antitrust authority should be extremely restrictive with the information given to firms under investigation.

The model presented in *Chapter 3* focuses on whether ringleaders of cartels should be given the possibility to apply for leniency. This is (again) strongly relevant in antitrust practice as the EU Competition Commission and the US Department of Justice take a different stance on conduct vis-à-vis ringleaders. The US law stipulates that ringleaders can not obtain a fine reduction through leniency. Contrarily, due to the reform of the EU leniency regulation in 2002 and 2006, ringleaders have the option to participate in the leniency program in the EU. The model identifies several parameters relevant for the question which regime is more favorable for an antitrust authority. It is shown that both legal approaches can in different situations be useful to reduce cartel activity. Giving ringleaders the opportunity to participate in the leniency program is preferred by the antitrust authority if the probability that industries are reviewed is relatively small. Then the additional information provided by ringleaders who undertake whistleblowing leads to a higher probability of conviction and thus makes it consequently harder to sustain collusion. If the antitrust authority commits to a relatively high probability of review, however, the exclusion of the ringleader from the program may be the better option for the antitrust authority. This is due to the fact that the ringleader faces a higher expected fine. The higher the fine for the ringleader the higher the compensation the ringleader demands from the ordinary cartel members in equilibrium. The resulting asymmetry between the firms reduces the sustainability of collusion. The probability of review by that the one or the other approach is superior depends on a number of parameters, e.g. the value by which a whistleblower increases the probability that the antitrust authority finds enough evidence to convict the cartel, the scope of the leniency program, the total amount of the fine, the probability that the antitrust authority finds enough evidence to convict the cartel without the help of a single firm, and the number of firms within the cartel.

As for policy implications, an antitrust authority should be aware that excluding the ringleader from leniency reduces the internal stability of a cartel since the ringleader asks for a larger share of the cartel profit. If the authority is able to ensure a high probability of review, an asymmetry in the industry could be more effective in fighting cartels than to target on the additional information provided by a whistleblowing ringleader. If the information from an additional whistleblower is very valuable, however, allowing the ringleader to participate in the leniency program may be more efficient in preventing cartel activity.

The model presented in *Chapter 4* analyzes the effect of side-payments on the equilibrium market structure in the context of vertical integration in a successive duopoly. The model derive the result that firms are able to prevent counter-mergers of its rivals by transferring a certain amount of its benefit from integration to one rival. This transfer is defined as a side-payment among firms. Furthermore, assuming backward integration it is shown that an integrated downstream firm will never offer vertical side-payments to the upstream tier since this would reduce the profit of the downstream firm due to the resulting rise of the price for the upstream assets.

Again, some implications for the economic design of antitrust policies can be derived from the model. The welfare analysis shows that side-payments should be allowed if they trigger the welfare increasing vertical integration of at least one pair of firms. On the other hand, if all firms on the market are willing (and able) to integrate pairwise, side-payments should not be allowed since they can be used to prevent full integration. Full integration would increase welfare compared to a partially integrated market even more. Moreover, if antitrust authorities allow side-payments, they should restrict to facilitate pairwise integration. The analysis shows that firms are able to establish a monopoly by the use of side-payments. Even such a monopoly increases welfare compared to a fully separated duopoly. However, partial integration leads to a higher welfare than ex-post monopolization. Hence, side-payments should be forbidden if firms try to establish a monopoly by the use of these side-payments.

Appendix A

Mathematical appendix

A.1 Chapter 2: Antitrust and imperfect monitoring

A.1.1 Proof of Lemma 2.4

Proof We start with proving condition (ii): As $\frac{\partial IC}{\partial \delta_d^{eff}} = -(1-2\alpha) \leq 0$ for $\alpha \leq \frac{1}{2}$ and $\frac{\partial IC}{\partial \delta_d^{eff}} > 0$ if $\alpha > \frac{1}{2}$, we will set $\delta_d^{eff} = \gamma\delta$ if $\alpha \leq \frac{1}{2}$ and $\delta_d^{eff} = \delta$ if $\alpha > \frac{1}{2}$ to calculate the minimal $\delta(\alpha, \phi)$ where the IC holds. To prove condition (ii) we have to analyze five cases depending on different parameter values of α and ϕ.

The simplest case is the proof for $\delta(\alpha, \phi = 0)$: If $\phi = 0$, firms can always choose $\gamma = 1$, thus the IC and the PC change to $IC_{\gamma=1}^{\phi=0} = 2\delta - 1 \geq 0$ and $PC_{\phi=0} = (1-\alpha) \geq 0$. This leads to $\delta(\alpha, \phi = 0) \geq \frac{1}{2}$ for all $\alpha \leq 1$.

The second case we have to prove is for $\delta\left(\alpha \leq \frac{1}{2}, \phi < 1\right)$: If $\alpha \leq \frac{1}{2}$, the PC always holds if $\phi < 1$ and thus $\gamma^{max} = 1$. Furthermore the IC changes to $IC^{\delta_d^{eff}=\gamma\delta} = (1-2\alpha)(\delta - \gamma\delta) + (\gamma\phi - 1)(1-(1-\gamma)\delta) + \frac{\gamma\delta}{1-\alpha}(2(1-\alpha) - \gamma\phi) \geq 0$. From $\frac{\partial IC^{\delta_d^{eff}=\gamma\delta}}{\partial \gamma} = (1-\delta)\phi + 2\alpha\delta - \frac{2\alpha\delta\gamma\phi}{1-\alpha}$ and $\frac{\partial^2 IC^{\delta_d^{eff}=\gamma\delta}}{\partial \gamma^2} = -\frac{2\alpha\delta\phi}{1-\alpha}$, it follows that the IC has its maximum at $\gamma^* = \frac{(1-\alpha)[(1-\delta)\phi + 2\alpha\delta]}{2\alpha\delta\phi}$. Since $\frac{\partial IC^{\delta_d^{eff}=\gamma\delta}}{\partial \delta} = \left(1 + \frac{\alpha\gamma}{1-\alpha}\right)(2(1-\alpha) - \gamma\phi) \geq 0$ if $\alpha \leq \frac{1}{2}$, $\phi < 1$, and $\gamma^{max} = 1$, the minimal $\delta(\alpha \leq \frac{1}{2}, \phi < 1)$ where $IC \geq 0$ holds is determined trough $\gamma = min[1, \gamma^*]$. Since $\frac{\partial \gamma^*}{\partial \alpha} = -\frac{(1-\delta)\phi + 2\alpha^2\delta}{2\alpha^2\delta\phi} < 0$, $\frac{\partial \gamma^*}{\partial \delta} = -\frac{1-\alpha}{2\alpha\delta^2} < 0$, and $\frac{\partial \gamma^*}{\partial \phi} =$

$-\frac{1-\alpha}{\phi^2}<0$, it is easy to show that for $\alpha \leq \frac{1}{2}$, $\delta \to \frac{1}{2}$, and $\phi \to 1 \Rightarrow \gamma^* > 1$. Thus we set $\gamma = 1$ and $IC^{\delta_d^{eff}=\gamma\delta}$ changes to $IC_{\gamma=1}^{\delta_d^{eff}=\gamma\delta} = (\phi-1)+\frac{\delta}{1-\alpha}(2(1-\alpha)-\phi) \geq 0$ which holds if $\delta(\alpha \leq \frac{1}{2}, \phi < 1) \geq \frac{(1-\alpha)(1-\phi)}{2(1-\alpha)-\phi}$.

Accordingly we have to prove the cases $\delta\left(\alpha > \frac{1}{2}, \phi < 1\right)$: If $\alpha > \frac{1}{2}$, the PC only holds if $\gamma \leq \frac{1-\alpha}{\alpha\phi} \equiv \gamma^{max}$ and the IC changes to $IC^{\delta_d^{eff}=\delta} = (\gamma\phi - 1)(1-(1-\gamma)\delta) + \frac{\gamma\delta}{1-\alpha}(2(1-\alpha)-\gamma\phi) \geq 0$. From $\frac{\partial IC^{\delta_d^{eff}=(1-\gamma)\delta}}{\partial\gamma} = (1-2\alpha)\delta+\phi(1-\delta)+\frac{\alpha\delta(2-2\alpha-\gamma\phi)}{1-\alpha}-\frac{\alpha\delta\gamma\phi}{1-\alpha}$, we get $\gamma^* = \frac{1-\alpha}{\alpha\phi}\frac{(1-\delta)\phi+\delta}{2\delta}$ with $\gamma^* \gtreqless \gamma^{max}$. Plugging γ^* into $IC^{\delta_d^{eff}=\delta}$ we get $IC_{\gamma=\gamma^*}^{\delta_d^{eff}=\delta} = \frac{1}{4\alpha\delta\phi}[((1-\alpha)(1-\delta)^2)\phi^2 + (2\delta(1-\delta)(1-3\alpha))\phi + (1-\alpha)\delta^2] \geq 0$. This condition holds if $\delta \geq \frac{\left((3\alpha-1)+(1-\alpha)\phi+2\sqrt{2\alpha^2-\alpha}\right)\phi}{[2(3\alpha-1)+(1-\alpha)\phi]\phi+(1-\alpha)} \equiv \delta_1$ and if $\delta \leq \frac{\left((3\alpha-1)+(1-\alpha)\phi-2\sqrt{2\alpha^2-\alpha}\right)\phi}{[2(3\alpha-1)+(1-\alpha)\phi]\phi+(1-\alpha)} \equiv \delta_2$. Plugging δ_1 into γ^* we get $\gamma^*_{\delta=\delta_1} = \frac{1-\alpha}{\alpha\phi}\frac{(1+\phi)\alpha+(1-\phi)\sqrt{2\alpha^2-\alpha}}{(3\alpha-1)+(1-\alpha)\phi+2\sqrt{2\alpha^2-\alpha}} \gtreqless 1$, where $\frac{\partial\gamma^*_{\delta=\delta_1}}{\partial\alpha} < 0$, $\frac{\partial\gamma^*_{\delta=\delta_1}}{\partial\phi} < 0$, and as a result $\gamma^*_{\delta=\delta_1} \leq \gamma^{max}$ holds. It can be shown that $\gamma^* \geq 1$ if $\alpha \leq \frac{1}{1+2\phi-\phi^2}$. Thus, if $\alpha < \frac{1}{1+2\phi-\phi^2}$, we set $\gamma = 1$ and $IC^{\delta_d^{eff}=\delta}$ changes to $IC_{\gamma=1}^{\delta_d^{eff}=\delta} = (\phi-1)+\frac{\delta}{1-\alpha}(2(1-\alpha)-\phi) \geq 0$ which holds if $\delta(\alpha < \frac{1}{1+2\phi-\phi^2}, \phi < 1) \geq \frac{(1-\alpha)(1-\phi)}{2(1-\alpha)-\phi}$. If $\alpha \geq \frac{1}{1+2\phi-\phi^2}$, we set $\gamma = \gamma^*$, $IC^{\delta_d^{eff}=\delta}$ changes to $IC_{\gamma=\gamma^*}^{\delta_d^{eff}=\delta} \geq 0$ which holds if $\delta(\alpha \geq \frac{1}{1+2\phi-\phi^2}, \phi < 1) \geq \delta_1$. Plugging δ_2 into γ^* we get $\gamma^*_{\delta=\delta_2} = \frac{1-\alpha}{\alpha\phi}\frac{(1+\phi)\alpha-(1-\phi)\sqrt{2\alpha^2-\alpha}}{(3\alpha-1)+(1-\alpha)\phi-2\sqrt{2\alpha^2-\alpha}}$. We can ignore this solutions, as with $\frac{\partial\gamma^*_{\delta=\delta_2}}{\partial\alpha} > 0$ and $\frac{\partial\gamma^*_{\delta=\delta_2}}{\partial\phi} < 0$ we get $\gamma^*_{\delta=\delta_2} > 1$, when going to the limits.

To prove the parameter cases for $\delta\left(\alpha \leq \frac{1}{2}, \phi \geq 1\right)$ is very simple again: If $\alpha \leq \frac{1}{2}$, it follows that the PC always holds if $\gamma \leq \frac{1-\alpha}{\alpha\phi} \equiv \gamma^{max} \leq 1$. Further, the IC always holds if $\gamma = \frac{1}{\phi} \leq \gamma^{max}$. If we set $\gamma = \frac{1}{\phi}$, $IC^{\delta_d^{eff}=\gamma\delta}$ changes to $IC_{\gamma=\frac{1}{\phi}}^{\delta_d^{eff}=\gamma\delta} = (1-2\alpha)\left(\delta - \frac{\delta}{\phi}\right) + \frac{(1-2\alpha)\delta}{(1-\alpha)\phi} \geq 0$ and the PC to $PC_{\gamma=\frac{1}{\phi}} = 1-2\alpha \geq 0$. Both conditions always hold if $\delta(\alpha \leq \frac{1}{2}, \phi \geq 1) \geq 0$.

After all we have to prove the cases for $\delta\left(\alpha > \frac{1}{2}, \phi \geq 1\right)$: Again, the PC holds if $\gamma \leq \frac{1-\alpha}{\alpha\phi} \equiv \gamma^{max}$. Since $\phi > 1$ it follows that $\gamma^{max} < 1$ for all $\alpha > \frac{1}{2}$. Furthermore the IC changes again to $IC^{\delta_d^{eff}=\delta} \geq 0$. Consequently, the following proof is similar to the proof of $\delta\left(\alpha > \frac{1}{2}, \phi < 1\right)$ above. Thus we get $IC_{\gamma=\gamma^*}^{\delta_d^{eff}=\delta} \geq 0$ holds if $\delta \geq \delta_1$ and if $\delta \leq \delta_2$. Plugging δ_1 into γ^* we get $\gamma^*_{\delta=\delta_1} = \frac{1-\alpha}{\alpha\phi}\frac{(1+\phi)\alpha+(1-\phi)\sqrt{2\alpha^2-\alpha}}{(3\alpha-1)+(1-\alpha)\phi+2\sqrt{2\alpha^2-\alpha}}$ with $\frac{\partial\gamma^*_{\delta=\delta_1}}{\partial\alpha} < 0$, $\frac{\partial\gamma^*_{\delta=\delta_1}}{\partial\phi} < 0$, and $\gamma^*_{\delta=\delta_1} \leq \gamma^{max} < 1$ for all $\alpha > \frac{1}{2}$. Thus we set $\gamma = \gamma^*$ and the $IC^{\delta_d^{eff}=\delta}$ changes to $IC_{\gamma=\gamma^*}^{\delta_d^{eff}=\delta} \geq 0$ which holds if $\delta(\alpha > \frac{1}{2}, \phi \geq 1) \geq \delta_1$. Again, we have to ignore

δ_2 as we get $\gamma^*_{\delta=\delta_2} = \frac{1-\alpha}{\alpha\phi}\frac{(1+\phi)\alpha-(1-\phi)\sqrt{2\alpha^2-\alpha}}{(3\alpha-1)+(1-\alpha)\phi-2\sqrt{2\alpha^2-\alpha}}$ with $\frac{\partial\gamma^*_{\delta=\delta_2}}{\partial\alpha} > 0$ and $\frac{\partial\gamma^*_{\delta=\delta_2}}{\partial\phi} < 0$. One can show that $\gamma^*_{\delta=\delta_2}$ is larger than γ^{max} even if we go to the limits with $\alpha \to \frac{1}{2}$ and $\phi \to 1$. The proof of condition (i) can be done in the same way as to the proof of condition (ii). ■

A.2 Chapter 4: Vertical integration and side-payments

A.2.1 Market outcomes

(i) Separation

The inverse linear demand function is given by the equation $t = a - b(q_{D_k} + q_{D_l})$. Each downstream firm D_k with $k \in \{1,2\}$ gets a price t when it sells the intermediate product to the final consumers. Its cost is the input price ω only, since marginal costs of the downstream firms are assumed to be zero. Following this, each downstream firm, D_k with $k \in \{1,2\}$, takes q_{D_l} as given and chooses q_{D_k} that solves

$$\max_{q_{D_k}} \Pi_{D_k} = (t-\omega)q_{D_k} = ([a - b(q_{D_k} + q_{D_l})] - \omega)q_{D_k}. \tag{A.1}$$

Since firms are symmetric if all downstream firms are separated, maximization yields the best-response functions of both downstream firms with

$$q_{D_k} = \frac{a-\omega}{2b} - \frac{q_{D_l}}{2}. \tag{A.2}$$

Solving the best-responce functions yields

$$q_{D_k} = \frac{a-\omega}{3b}. \tag{A.3}$$

Since the total downstream demand is given by $Q = 2q_{D_k} = q_{D_k} + q_{D_l}$ and – by assumption – one intermediate product q_{U_i} is transformed in one final product, q_{D_k}, the inverse demand function for two upstream firms is given by

$$\omega = a - \frac{3bQ}{2} = a - \frac{3b(q_{U_i} + q_{U_j})}{2}. \tag{A.4}$$

The upstream firms U_i with $i \in \{A, B\}$ have symmetric marginal costs of c. Thus, the symmetric profit function is given by $\Pi_{U_i} = (\omega - c)q_{U_i}$. The upstream firm U_i takes q_{U_j} as given and chooses q_{U_i} that solves

$$\max_{q_{U_i}} \Pi_{U_i} = (\omega - c)q_{U_i} = \left(\left[a - \frac{3b(q_{U_i} + q_{U_j})}{2}\right] - c\right) q_{U_i}. \tag{A.5}$$

The maximization yields in symmetric best-response functions of both upstream firms:

$$q_{U_i} = \frac{a-c}{3b} - \frac{q_{U_j}}{2}. \tag{A.6}$$

Solving this reveals that in equilibrium each upstream firm produces

$$q^*_{U_i} = \frac{2(a-c)}{9b} \tag{A.7}$$

units of the intermediate product, which has to be equal to the production and selling of the downstream firms, $q^*_{D_k}$. Thus, the total quantity of (intermediate and final) products is given by

$$Q^{SP} = \frac{4(a-c)}{9b}. \tag{A.8}$$

The equilibrium price for the intermediate product and for the final product is then given by

$$\omega^{SP} = \frac{a+2c}{3} \qquad \text{and} \qquad t^{SP} = \frac{5a+4c}{9}. \tag{A.9}$$

This results in a profit for each upstream firm U_i, with $i \in \{A, B\}$, of

$$\Pi^{SP}_{U_i} = \frac{2(a-c)^2}{27b} = 96\,\frac{(a-c)^2}{1269b} \tag{A.10}$$

and a profit for each downstream firm D_k, with $k \in \{1, 2\}$, of

$$\Pi_{D_k}^{SP} = \frac{4(a-c)^2}{81b} = 64\,\frac{(a-c)^2}{1269b}. \tag{A.11}$$

(ii) Partial integration

Under partial integration only one vertical pair of firms is vertically integrated to a new firm I. If only D_k integrates with U_i, the upstream unit of I, former upstream firm U_i, delivers its intermediate products to the former downstream unit D_k for marginal costs c. Note that the integrated upstream unit will make zero profits from the market by accepting to integrate, since in the setting assumed above the integrated firm withdraws from the market for intermediate products. Thus, the former downstream unit, D_k, has to pay a compensation – a merger fee – to have the ability to get the products by a price of c. This price is denoted by p_{ki} if D_k integrates with U_i. An non-integrated downstream firm, D_l, has to buy its intermediate products for a price of ω from the remaining (and now monopolistic) upstream firm U_j. The – now asymmetric – best-response functions of integrated firm and the remaining separated downstream firm D_l are then given by

$$q_I = \frac{a-c}{2b} - \frac{q_I}{2} \qquad \text{and} \qquad q_{D_l} = \frac{a-\omega}{2b} - \frac{q_{D_k}}{2}. \tag{A.12}$$

The remaining separated upstream firm U_j only opt for the demand for the remaining downstream firm D_l. Solving the best-response functions above yields a downstream demand of

$$q_{D_l} = \frac{a+c-2\omega}{3b}. \tag{A.13}$$

The inverse demand function of the separated upstream firms is then given by

$$\omega = \frac{a+c-3bq_{D_l}}{2} \tag{A.14}$$

The supply of upstream units, q_{U_j}, has to be equal to the demand of the remaining downstream market, q_{D_l}, in equilibrium. Thus, U_j chooses a supply of an intermediate product quantity that solves

$$\max_{q_{U_j}} \Pi_{U_j} = (\omega - c)q_{U_j} = \left(\left[\frac{a + c - 3bq_{U_j}}{2}\right] - c\right) q_{U_j}. \tag{A.15}$$

This yields to the equilibrium quantity of intermediate products on the market of

$$q^*_{U_j} = \frac{a-c}{6b} = q^*_{D_l}. \tag{A.16}$$

The market price for the intermediate product is then given by

$$\omega^{PI} = \frac{a+3c}{4}. \tag{A.17}$$

Due to the best-response functions above, the integrated firm sells a quantity of

$$q^*_I = \frac{a-c}{2b} - \frac{q^*_{D_l}}{2} = \frac{5(a-c)}{12b}. \tag{A.18}$$

Thus, the total quantity supplied on the final product market is qual to

$$Q^{PI} = q^*_I + q^*_{D_l} = \frac{7(a-c)}{12b}, \tag{A.19}$$

which gives a price for the final products of

$$t^{PI} = a - bQ^{PI} = \frac{5a+7c}{12}. \tag{A.20}$$

As a result, the equilibrium profit of the integrated firm is given by

$$\Pi^{PI}_I = \Pi^{PI}_{U_i} + \Pi^{PI}_{D_k} = p_{ki} + \left(\frac{25(a-c)^2}{144b} - p_{ki}\right) = 225\,\frac{(a-c)^2}{1296}. \tag{A.21}$$

The equilibrium profit of the separated downstream firm D_l results in

$$\Pi^{PI}_{D_l} = \frac{4(a-c)^2}{144b} = 36\,\frac{(a-c)^2}{1296b} \tag{A.22}$$

and the equilibrium profit of the separated monopolistic upstream firm U_j is

$$\Pi_{U_j}^{PI} = \frac{6(a-c)^2}{144b} = 54\,\frac{(a-c)^2}{1296b}. \tag{A.23}$$

(iii) Full integration

If all firms are vertically integrated no market for the intermediate product exists anymore. The former upstream firms U_i with $i \in \{A, B\}$, deliver now the intermediate products for marginal costs c to its integrated downstream units – the former downstream firms D_l with $k \in \{1, 2\}$. I_1 is denoted as the integrated firm consisting of U_i and D_k, and I_2 as the integrated firm consisting of U_j and D_l. Thus, best-response functions are symmetric and given by

$$q_{I_1} = \frac{a-c}{2b} - \frac{q_{I_2}}{2} \qquad \text{and} \qquad q_{I_2} = \frac{a-c}{2b} - \frac{q_{I_1}}{2}. \tag{A.24}$$

Solving the best-response functions yields

$$q_{I_1}^* = q_{I_2}^* = \frac{a-c}{3b}. \tag{A.25}$$

Thus, the total supply to the downstream market is given by

$$Q^{FI} = q_{I_1}^* + q_{I_2}^* = \frac{2(a-c)}{3b}, \tag{A.26}$$

which yields a price for the final consumers of

$$t^{FI} = \frac{a+2c}{3}. \tag{A.27}$$

The upstream units have to be compensated for making zero profits now. The corresponding acquisition fees is denoted by p_{ik} and p_{jl}. Thus the profit of the integrated firms is given by

$$\Pi_{I_k}^{FI} = \Pi_{U_i}^{FI} + \Pi_{D_k}^{FI} = p_{ik} + \left(\frac{(a-c)^2}{9b} - p_{ik}\right) = 144\,\frac{(a-c)^2}{1296b} \tag{A.28}$$

and

$$\Pi_{I_l}^{FI} = \Pi_{U_j}^{FI} + \Pi_{D_l}^{FI} = p_{jl} + \left(\frac{(a-c)^2}{9b} - p_{jl} \right) = 144\, \frac{(a-c)^2}{1296b}. \tag{A.29}$$

(iv) Monopolization

If the market is monopolized, the monopolist has to choose a quantity of final products that solves

$$\max_{q_M} \Pi_M = (t^M - c)q_M = ([a - bq_M] - c)q_M. \tag{A.30}$$

Solving this yields a quantity of

$$q^* = Q^M = \frac{a-c}{2b} \tag{A.31}$$

on the market for the final product and to a price of

$$t^M = \frac{a+c}{2}. \tag{A.32}$$

The profit of the monopolist is thus given by

$$\Pi^M = \frac{(a-c)^2}{4b} = 324\, \frac{(a-c)^2}{1296b} \tag{A.33}$$

A.2.2 Welfare analysis

In this section all parameters which are important to compare the welfare results of each market structure discussed in the paper are calculated: The total profit of the industry, which is equal to the producers surplus (PS), the consumer surplus (CS) and the total surplus (TS).

(i) Separation

$$PS^{SP} = \sum \Pi^{SP} = 320 \frac{(a-c)^2}{1296b} \tag{A.34}$$

$$CS^{SP} = \frac{\left(a - t^{SP}\right) Q^{SP}}{2} = 128 \frac{(a-c)^2}{1296b} \tag{A.35}$$

$$TS^{SP} = PS^{SP} + CS^{SP} = 448 \frac{(a-c)^2}{1296b} \tag{A.36}$$

(ii) Partial integration

$$PS^{PI} = \sum \Pi^{PI} = 315 \frac{(a-c)^2}{1296b} \tag{A.37}$$

$$CS^{PI} = \frac{\left(a - t^{PI}\right) Q^{PI}}{2} = 220.5 \frac{(a-c)^2}{1296b} \tag{A.38}$$

$$TS^{PI} = PS^{PI} + CS^{PI} = 535.5 \frac{(a-c)^2}{1296b} \tag{A.39}$$

(iii) Full integration

$$PS^{FI} = \sum \Pi^{FI} = 288 \frac{(a-c)^2}{1296b} \tag{A.40}$$

$$CS^{FI} = \frac{\left(a - t^{FI}\right) Q^{FI}}{2} = 288 \frac{(a-c)^2}{288b} \tag{A.41}$$

$$TS^{FI} = PS^{FI} + CS^{FI} = 576 \frac{(a-c)^2}{1296b} \tag{A.42}$$

(iv) Monopolization

$$PS^M = \Pi^M = 324\,\frac{(a-c)^2}{1296b} \tag{A.43}$$

$$CS^M = \frac{\left(a-t^M\right)Q^M}{2} = 162\,\frac{(a-c)^2}{288b} \tag{A.44}$$

$$TS^M = PS^M + CS^M = 486\,\frac{(a-c)^2}{1296b} \tag{A.45}$$

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