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## Once bitten, twice shy? Market size affects the effectiveness of a leniency program by (de-)activating hysteresis effects

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**Once bitten, twice shy?**  
**Market size affects the effectiveness of a leniency program**  
**by (de-)activating hysteresis effects.**

Eva Tebbe\*

October 2018

**Abstract**

This article presents results of a laboratory experiment testing whether the effectiveness of a moderate leniency program depends on market size. Against theory, the results indicate that a moderate leniency program is not preferable to a policy which only includes fines for detected cartels, either in duopolies or in quadropolies. Surprisingly, the leniency program is not even entirely to be preferred compared to a laissez-faire policy. Yet, the leniency program seems to work better in markets involving four firms, compared to markets with two firms, especially in terms of the prevention of hysteresis effects.

**JEL Classification:** C9; D3; D4; L1; L4

**Keywords:** Cartels; Corporate Leniency Program; Experiments; Hysteresis effect; Chat-hysteresis; Bertrand game

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## 1 Introduction

Since the US Congress passed the Sherman Act as a first federal statute of the US antitrust law in 1890, competition law has gained importance within the OECD. A broad range of institutions aiming at the prevention and deterrence of illegal cooperation has been established. One of the most prominent milestones in the history of competition law is the introduction of leniency programs in various legislations.<sup>1</sup> These programs aim at facilitating the antitrust authorities' investigatory procedure by granting fine-reductions or even fine-immunity, so as to incentivize firms or individuals to provide the authorities with valuable information about illegal cooperation. As it allows controlling for various influences, to test the counterfactual and to observe long-term effects, experimental research continues to investigate the functionality of such programs and analyzes forms of leniency programs in various games. This present research can be ranked among those papers and adds to the current state of research analyzing the influence of market size on cartelization and on post-cartelization behavior in a price-game and when a moderate leniency program<sup>2</sup> is present. I test the effectiveness of my moderate leniency program in the context of a Bertrand oligopoly laboratory experiment, comparing an institutional setting encompassing a leniency rule with alternative antitrust policies, among which is a setting which does not provide leniency, but only includes fines for exogenously detected cartels. To do so, I introduce market-price-dependent fines, in order to avoid bias due to revenue-based or fixed fines, and combine this setting with a leniency program which allows for public as well as private reports. This design implies that trust plays an important role for cartel (re-)establishment.

The results indicate that there are differences in the effectiveness of antitrust policies between different market sizes. For duopolies, there is a price-stabilizing effect of the moderate leniency program, increasing overall market prices significantly compared to a laissez-faire policy without any cartel prosecution. This finding does not hold for quadropolies, although in these markets, the leniency program is still less effective in reducing welfare-harming collusive prices than a traditional antitrust policy based on fines without leniency. Both fines-only and the moderate leniency program are far removed from reducing prices to the level yielded in a scenario where communication as a tool facilitating explicit coordination is impossible. I conclude that the tested leniency program is not preferable to a policy only encompassing fines when it comes to the prevention of explicit collusion as well as collusive market prices, and that the effectiveness of a leniency policy compared to a laissez-faire policy depends on market size. My data also provides new insights into the existence of hysteresis with regard to willingness to chat (WTC)<sup>3</sup> and prices in treatments based on fines only and treatments encompassing a leniency program: In duopolies, (1) previously higher prices as well as (2) previous communication reduce the effort to start a new cartel, indicating chat-hysteresis. Evoking price-hysteresis, (3) previous communication increases prices in periods without communication. In

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<sup>1</sup> E.g. in 1978 in the US and in 1996 in the EU.

<sup>2</sup> According to Spagnolo (2004) and Buccirrossi and Spagnolo (2006), a moderate leniency program is one in which the fine reduction does not exceed the fine, i.e. rewards are excluded.

<sup>3</sup> Abbreviations are used as follows: Incentive Compatibility Constraint (ICC); Participation Constraint (PC); Wilcoxon Rank Sum Test (WRS-test); Willingness To Chat (WTC).

quadropolies, effects (1) and (2) are reduced or negligible, compared to duopolies. The same holds for effect (3) if a leniency policy is implemented. Market size, hence, not only moderates the effectiveness of a leniency program in terms of its power to inhibit high market prices in collusive periods, but also the intensity of hysteresis effects.

The remainder of this paper is structured as follows. Section 2 gives an overview of the related literature. Section 3 presents the experimental design as well as the procedure. Based on this, in Section 4, hypotheses are formulated, and Section 5 presents the results. Finally, in Section 6, conclusions, limitations and directions for further research are considered.

## 2 Related literature

Since the start of the new millennium, research on antitrust issues has been growing. A considerable number of papers deal with the effectiveness of leniency programs. Starting with the seminal papers of Motta and Polo (2003) and Spagnolo (2004), the theoretical literature has repeatedly shown that if well designed and if the antitrust authorities' resources are restricted, a leniency program might at least not be harmful, and in the best case even an effective antitrust enforcement tool. In order to facilitate law enforcement, an effective leniency program should be generous towards the first reporter, so as to induce reporting, and should be combined with high fines as well as the opportunity to report even after investigation has started. However, if the leniency program is not properly designed, it might also reduce expected net-penalties (Motta and Polo 2003; Houba, Motchenkova, and Wen 2015), offer a credible enforcement tool for collusion (Buccirossi and Spagnolo 2006; Spagnolo 2000) and / or increase the caseload of the authorities and thereby reduce the threat of exogenous investigations for wrongdoers (Chang and Harrington 2008).

To evaluate whether the theoretical statements hold, empirical investigation is valuable. Focusing on field data, some studies indicate that the current leniency programs in the OECD in fact have positive effects (e.g. Borrell and Jiménez 2008; Borrell, Jiménez, and García 2014; Miller 2009; Klein 2011). These empirical results tend to support theoretical propositions, but also point to the importance of time horizons in assessing the efficiency of leniency programs (Brenner 2009; Miller 2009; De 2010; Zhou 2015). However, the results derived from documented investigations are by definition characterized by gaps. The use of field data is not plain sailing when it comes to evaluating the efficiency of leniency programs compared to alternative antitrust policies. First, it does not provide any data on the number of undetected cartels; second, it does not yield any conclusions with regard to comparing the status quo and the counterfactual. As Apesteguia, Dufwenberg, and Selten (2007) and Spagnolo (2004) point out, this is a sufficiently strong condition to use experimental data as reference for comparing the effectiveness of different antitrust policies.<sup>4</sup>

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<sup>4</sup> I restrict my review of experimental literature to studies based on Bertrand price games. Besides these, there is also a range of papers based on other concepts (e.g. prisoners' dilemmas, as in Hamaguchi, Kawagoe, and Shibata (2009)).

## 2.1 Experimental literature on the effectiveness of leniency programs in single-size markets

Being the first to analyze the effects of leniency programs in a laboratory experiment, Apesteguia, Dufwenberg, and Selten (2007) test a setting based on a discrete one-shot homogenous-goods Bertrand game introduced by Dufwenberg and Gneezy (2000). Apesteguia, Dufwenberg, and Selten analyze markets with three opponents in four different legal frameworks: (1) “IDEAL”, where no communication is possible and no antitrust prosecution is implemented; (2) “STANDARD”, where convicted firms face fines equivalent to 10% of their revenue (hence, no fines were imposed if the firm has no revenue) and where firms could report the cartel free of charge, but also without fine reductions; (3) “LENIENCY”, in which firms which have reported their participation in a cartel receive a fine reduction (if they have generated revenue and therefore face a positive fine), while fine reductions are split equally among all reporting parties; (4) “BONUS”, where reporting cartel members receive part of the fines paid by other firms as a reward. In the treatments with communication, participants are able to communicate for 10 minutes about whatever they wish (except identities). Their results suggest that LENIENCY is favorable to STANDARD and BONUS, with BONUS generating the highest market prices and the highest number of cartels. IDEAL leads to the lowest prices, but is not statistically different from LENIENCY. Moreover, LENIENCY yields the lowest percentage of formed cartels. Accordingly, the theoretical prediction that BONUS might be the most efficient antitrust tool cannot be supported by this study, while a moderate leniency program seems to perform well in reducing the number of price agreements as well as market prices.

Extending the setup of Apesteguia, Dufwenberg, and Selten, Hinloopen and Soeteven (2008) play a repeated version with at least 20 rounds of the previously outlined Bertrand game. Market opponents are fixed across all rounds. Moreover, in contrast to Apesteguia, Dufwenberg, and Selten, the communication phase lasts one minute and participants are only permitted to insert price ranges as communication strings. Hinloopen and Soeteven focus on a moderate leniency program and do not assess bonus programs, but take into account the order of reports, thus unleashing a “race to the courthouse”. The first reporter receives a 100% fine reduction, the second a 50% reduction and the third has to pay the full fine. Reporting is only possible after subjects learned the market prices and is not for free (as in Apesteguia, Dufwenberg, and Selten), incurring a small reporting fee. The authors construct four treatments which differ with regard to the option of nonbinding price-discussions before price decisions have to be taken: (1) “BENCHMARK”, where no price discussion is possible; (2) “COMMUNICATION”, where costless price matches are possible (the communication protocol is restricted); (3) “ANTITRUST”, where the exogenous detection-probability is 15% and where, when detected, the fine accounts for 10% of the period’s revenue (if the cartel has not been dissolved, fine liability carries over to the next period); and (4) “LENIENCY”, where participants can receive a fine reduction as described above. Based on this setting, the authors analyze the efficiency of leniency programs with regard to the question of whether the increase in detected cartels in the OECD is due to an increased quota of detected cartels or driven by a rising number of cartels. Their analysis indicates that under LENIENCY, there are fewer cartels, cartels have a shorter lifetime and it is harder to establish prices above

the Nash-equilibrium price due to more frequent undercutting of the agreed-upon price. These results confirm those found by Apesteguia, Dufwenberg, and Selten. It is noteworthy that the study also shows that price-defectors regularly use reports to avoid fines, suggesting that the line between positive and negative effects of leniency programs might be thin.

Bigoni et al. (2012) conduct a differentiated repeated price game to assess the effect of leniency programs on cartels in duopolies. They include four main treatments: (1) “L-FAIRE”, which allows free communication; (2) “FINE”, which includes a fixed fine with a detection-probability of 10% and an opportunity to report, but no fine reductions; (3) “LENIENCY”, resembling FINES, but with the adaptation that participants obtain a fine reduction of 100% if only one party reports and 50% if both report; and (4) “REWARD”, differing from LENIENCY in that a single reporting party receives as a bonus the full fine levied on the account of the other party.<sup>5</sup> Some features of this study are worth detailed explanation. First, and of importance for the study at hand, the design includes two opportunities to report under LENIENCY and REWARDS: The first before, the second after all players have observed price choices. This procedure allows subjects to apply for leniency confidentially (i.e. privately) in the first reporting stage if they want to leave the cartel or defect, thus capturing the “race to the courthouse” and “protection from fines” effects. The second reporting opportunity (i.e. public reporting) supports reports that are likely to be driven by the desire to punish price-defectors. In addition to this feature, the set-up also adopts a re-matching methodology, so that at the end of each stage game, there is an 85% probability of the match ending. The end of the supergame is uncertain with a termination probability of 15% after the 20<sup>th</sup> round. To simplify the resulting complex setting, fixed fines are introduced, so as to control subjects’ expectations on the level of the fines. Another simplification is the restricted communication protocol, similar to that adopted by Hinloopen and Soetevent (2008), which only allows inserting prices, but no free chats. Furthermore, a default price (= 0) is implemented for subjects who fail to insert a price within 30 seconds. The results of this study implicate that the opportunity to report stabilizes existing cartels and increases prices. On the other hand, cartel formation and re-establishing rates are reduced by the reporting opportunity, and more so in the LENIENCY than the FINES treatment. These two heterogeneous effects counterbalance each other, so that welfare does not significantly benefit from either of the two settings, compared to L-FAIRE. If positive bonuses are implemented (“REWARDS”), prices fall to the competitive level and welfare is enhanced. These results are not in line with those of Apesteguia, Dufwenberg, and Selten as well as Hinloopen and Soetevent. The controversy might be due to the fact that the setting of Bigoni et al. avoids the non-generic discontinuities of homogeneous-goods Bertrand games with revenue-based fines, where a deviation implies zero profits and zero fines as well as zero fine-reductions under moderate leniency (i.e. fines as well as reports do not influence net-payoff) for undercut parties.

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<sup>5</sup> In addition to these treatments, three others were run so as to investigate some hypotheses in more detail. I refer to the original paper for details.

## **2.2 Experimental literature on the influence of market-size on cartelization in absence of leniency programs**

The studies mentioned in Section 2.1 focus on the effects of various antitrust regulations in markets with a fixed number of firms. However, beyond the institutional setting, leniency programs cannot be fully evaluated independently of market conditions. Research indicates that the number of market participants seems to be important for the feasibility of illegal cooperation. Analyzing markets with two, four, six and eight firms in a repeated Bertrand oligopoly market game with homogenous goods, inelastic demand and constant marginal cost of production, Fonseca and Normann (2012) show that the profit gain of explicit communication is non-monotonic in the number of firms, with medium-sized markets realizing the biggest increase, compared to tacit collusion. In a follow-up study, Fonseca and Normann (2014) focus on markets with two and four firms and integrate fines into their design. Fines carry over to the next period if a cartel was not dissolved, up to a maximum of five periods. In this paper, the authors find that in four-firm industries, there are more individual attempts to establish cartels, and cartels are successfully formed more often than in duopolies, because the larger markets gain less from a hysteresis effect after cartel disruption.

## **2.3 Experimental literature on the accuracy of the Beckerian Proposition when leniency programs are implemented**

The papers reviewed above are based on fixed assumptions with regard to the probability of detection and the level of fines. According to Becker (1968), the level of fines and the detection-probability are substitutable as long as the expected fine remains constant, and in the absence of a positive detection-probability, law enforcement should not produce deterrence, no matter what the level of the fine. Under this so-called “Beckerian Proposition“, it would be optimal to increase fines rather than invest in detection (as long as the detection probability is strictly positive). Yet, this notion of rational utility maximization might mask possible non-normative effects. When it comes to leniency programs, aspects other than mere expected fines might be important. Therefore, the analysis of different levels of fines and detection-probabilities is of interest.

Dealing with this question, in a follow-up study to the one mentioned above, Bigoni et al. (2015) aim at differentiating the role of the probability of detection and the expected fine from distrust as another possible channel through which law enforcement instruments may deter collaborative crimes. To do so, based on the setting outlined above, the authors have constructed three fine treatments and three leniency treatments, which differ with regard to the detection-probability and the (fixed) level of fines. For both the fines and leniency treatments, two of the three have the same minimum expected fine. The generated data indicates that with leniency programs, the actual level of the fine which might be due is much more important for deterrence than the probability of exogenous detection, which has little to no effect. Parallel to this, the expected fine is of minor importance, compared to the absolute fine. This indicates that deterrence is mainly motivated by a lack of trust, or by strategic risk, that is, by the fear of partners deviating and reporting. Another noteworthy – because unexpected – result is that even when the probability of detection is zero, fines have a deterrence effect. By contrast, in the absence of leniency, both the probability of detection and the expected fine matter, which is more in line with the Beckerian Proposition.

In another study on the effect of the level of fines and the probability of detection, Chowdhury and Wandschneider (2016) experimentally survey markets with three parties in a repeated Bertrand game. Their design is based on that of Hinloopen and Soetevent, i.e. it includes a fixed matching scheme with a small but positive cost for reporting. However, in contrast to the benchmark study, the order of reports is disregarded. Besides a baseline treatment with zero detection-probabilities and zero fines, there are four treatments: two with leniency and two without, which vary in that one has a low probability of detection and a high fine and the other a low fine and a high probability of detection. The authors find that under antitrust policies without leniency programs, the Beckerian Proposition holds. If leniency programs are in place, fines matter more and the propensity to collude as well as the overall number of cartels are significantly lower than for a policy based on high probabilities of detection and low fines. These results are in line with those of Bigoni et al. (2015).

The results presented by Bigoni et al. (2015) and Chowdhury and Wandschneider (2016) might have implications for the influence of fines under leniency: if, due to the importance of trust, the absolute level of the fine matters so much under leniency compared to the probability of exogenous detection, the assessment basis of the fines should be important, too. In addition, the gap between results regarding the efficiency of moderate leniency in homogenous-goods games with revenue-based fines and those found in a game with differentiated goods and fixed fines suggests that the effect of the calculation of the fine might be substantial.

## 2.4 Derivation of the research question

Summarizing the current state of the literature, experimental research supports the theoretical result that leniency programs might help to prevent cartelization, but it also provides evidence indicating that if reports can be used as an efficient threat in repeated interactions, leniency programs might in fact stabilize existing cartels. The literature also shows that with a leniency program in place, the level of the fine matters, whereas the probability of detection seems to be of minor importance. Furthermore, there are substantial differences in the effectiveness of antitrust policies when it comes to different market sizes.

An open question in the literature is whether market-size effects also influence the effectiveness of leniency programs. Until now, to the best of my knowledge, there is no study analyzing the functionality of a moderate leniency program in Bertrand markets of different sizes. My work horse is an extended version of the model introduced by Fonseca and Normann (2014), including a unique feature compared to the previously outlined studies on the effectiveness of leniency programs: the fine is calculated according to the minimum market price, rather than individual revenue (as in Apesteguia, Dufwenberg, and Selten (2007); Hinloopen and Soetevent (2008)). In contrast to fines depending on revenue, calculating fines based on market prices enables the fining of participants in homogenous goods markets, even if they have been undercut by other players, which avoids biases. Even though fixed fines, as implemented by Bigoni et al. (2012, 2015), also control for such biases, they do not adapt to changes in the level of collusion, nor do they allow fines to be imposed on cartels relative to the cartel-damage. My work adopts the setup of Fonseca and Normann (2014) and extends it by a moderate leniency program, in order to test the effectiveness of leniency when the

calculation of fines depends on prices. The design of the current study thus allows the testing of moderate leniency in an environment encompassing an important and realistic aspect for decision-making processes: participants know that exogenous detection as well as reporting might be costly, not only when the collusive price is established successfully, but also if there are price defectors in the market. Accordingly, trust and signaling trustworthiness might play an important role in my setting. The resulting dynamics and the relative efficiency of moderate leniency programs compared to antitrust policies without leniency might differ from those found in homogenous-goods games with revenue-based fines, as well as from those derived from heterogeneous-goods games with fixed fines. Table 1 provides an overview of experiments testing collusion under Bertrand competition, and relates my work to previous papers.

Table 1: Overview of current research on collusion in Bertrand experiments.

	Apestegui, Dufwenberg & Selten (2007)	Hinloopen & Soeteven (2008)	Chowdhury & Wand- schneider (2013)	Bigoni et al. (2012, 2015)	Fonseca & Normann (2014)	This paper
<b>Basic Game Features</b>						
Repeated game	-	✓	✓	✓	✓	✓
No. of firms on a market	3	3	3	2	2 and 4	2 and 4
Homogenous vs. differenti- ated goods	Homogenous	Homogenous	Homogenous	Differenti- ated	Homogenous	Homogenous
Re-matching of subjects	-	-	-	✓	-	-
Default prices	-	-	-	✓	-	-
Indicator for cartelization	Communica- tion decision	Communica- tion decision	Simple agree- ment <sup>6</sup>	Communica- tion decision	Communica- tion decision	Communica- tion decision
<b>Treatment Features</b>						
<i>Communication</i>						
Communication?	✓	✓	-	✓	✓	✓
Communication protocol	Free	Restricted	-	Restricted	Free	Free
<i>Fines</i>						
Fines?	✓	✓	✓	✓	✓	✓
Fine calculation	Percentage of revenue	Percentage of revenue	Fixed Fines	Fixed Fines	Fines as mul- tiple prices	Fines as mul- tiple prices
Liability is independent of deception	-	-	-	-	✓	✓
<i>Leniency</i>						
Leniency?	✓	✓	✓	✓	-	✓
Bonuses?	✓	-	-	✓	-	-
Private or public reporting	Private	Private	Public	Both	-	Both
Direct cost for reporting	-	✓	✓	-	-	-
Leniency rule with multiple reporters	Fine-reduc- tion is split equally	Order of re- ports is con- sidered	Fine-reduc- tion is split equally	Fine-reduc- tion is split equally	-	Fine-reduc- tion is split equally
Reports yield fine reductions relative to welfare-harm, in- dependent of deception	-	-	-	-	-	✓

<sup>6</sup> In this paper, cartels are formed via a (nonbinding) agreement to set the highest possible collusive price.

### 3 Model specification

My experimental design is based on an infinitely repeated price-game introduced by Fonseca and Normann (2012, 2014). Consumer demand in a certain period  $t$  ( $t \in \mathbb{N}$ ) for the produced homogenous good is inelastic up to a market price  $p_t$  of 100, so that  $p_t \in [0; 1; \dots; 100]$ . The quantity demanded  $q$  is 300 units and there are  $N$  ( $N \in M$ ) firms in the non-monopolistic market (with  $M := \{x \in \mathbb{N} | x > 1\}$ ). There are no capacity constraints on firm- or market-level and firms have zero production costs. All  $N$  firms choose discrete prices  $\hat{p}_{it}$  simultaneously, where  $i$  denotes a unique firm identifier ( $i = 1; \dots; N$  so that  $i \in I$ , while  $I := \{x \in \mathbb{N} | x \leq N\}$ ). The  $\Gamma_t$  firms (with  $\Gamma_t := |\mathcal{K}_t|$  and  $\mathcal{K}_t \subset I$ , so that  $\mathcal{K}_t := \{i \in I | \hat{p}_{it} = p_t\}$ ) with the lowest price  $p_t$  in period  $t$  share the demand equally and thus generate a profit  $\Pi_{it}$  of  $\frac{p_t \cdot q}{\Gamma_t}$ , so that the following proposition holds.

$$(1) \quad \forall i \in \mathcal{K}_t: \Pi_{it} = \frac{p_t \cdot q}{\Gamma_t}$$

The remaining  $L_t$  firms (with  $L_t := |\overline{\mathcal{K}}_t|$  and  $\overline{\mathcal{K}}_t = I \setminus \mathcal{K}_t$ , so that  $L_t := \{i \in I | \hat{p}_{it} > p_t\}$ ) with prices  $\hat{p}_{it}$  that exceed the minimum market price  $p_t$  earn nothing. Firms follow Grimm-trigger strategies if and only if they are able to explicitly coordinate a collusive price via communication beforehand and competitive solutions otherwise. That is, I assume that active communication is a necessary condition for explicit collusion. The one-shot static Nash-equilibrium requires all individually chosen prices not to exceed marginal costs ( $\forall i \in I: \hat{p}_{it} = p_t^o = 0$ ), implying that the Nash-profit  $\Pi_{it}^o$  is zero for all firms.

#### 3.1 Model implications without any antitrust measures

In the infinitely repeated model without fines or other antitrust measures (model *FC*), once a cartel has been established via communication, per-period collusive solutions with prices  $p_t^c$  ( $p_t^c \in [1; \dots; 100]$ ) and profits  $\Pi_{FC,it}^c$  exceeding the competitive solution will be realized as long as no firm deviates, i.e. as long as each firm chooses a price  $\hat{p}_{it}$  that is equal to the jointly coordinated price  $p_t^c$ . Given a certain collusive agreement  $p_t^c$  that exceeds 1, a firm  $i$  deviating from this agreement choosing a price  $\hat{p}_{it}^D$  with  $\hat{p}_{it}^D = p_t^c - 1$  earns a deviation profit  $\Pi_{FC,it}^D$  of  $(p_t^c - 1) \cdot q$ . Once this happens in period  $t$ , the other firm(s) earn nothing in this specific round and choose the static Nash pricing at marginal cost for the remainder of the game, i.e. they choose a price  $p_t^o$  of 0, which leads to competitive profits  $\Pi_{FC,i\tau}^o$  of 0, for all  $\tau \in [t + 1; \infty)$  and all  $i \in I$ . This also implies that either all  $N$  firms on a market agree on a specific cartel price  $p_t^c$ , so that  $N$  equals  $\Gamma_t$ , or the competitive solution will be played. Partial cartels, thus, are not stable in my model. In other words,  $N = \Gamma_t$  is a necessary condition for cartels to be stable.

In this setting, the participation constraint (PC) for firm  $i$  to join the cartel in period  $\varphi$  ( $\varphi \in \mathbb{N}$ ) is that the expected profit  $\Pi_{FC,i\varphi}^c$  at a fix collusive price  $p^c$  ( $\forall t: p_t^c = p_\varphi^c = p^c$ ) exceeds the competitive profit  $\Pi_{FC,i\varphi}^o$ , i.e. that relation (2) holds.

$$(2) \quad PC_{FC}: \quad \frac{p^c \cdot q}{N} \geq 0$$

The incentive compatibility constraint (ICC) evoking that firms repeatedly stick to the collusive agreement rather than deviate from it in period  $\varphi$  is that the expected profit from repeated collusion  $\Pi_{FC,i}^c$  ( $\Pi_{FC,i}^c =$

$\sum_{t=\varphi}^{\infty} \Pi_{FC,it}^C = \frac{p^C \cdot q}{(1-\delta) \cdot N}$ , with  $\forall t: p_t^C = p^C$  and discount factor  $\delta \in [0; 1]$ , is higher than the profit from deviating  $\Pi_{FC,i}^D$  ( $\Pi_{FC,i}^D = \Pi_{FC,i\varphi}^D + \sum_{t=\varphi+1}^{\infty} \Pi_{FC,it}^D = (p^C - 1) \cdot q$ ). With a fixed collusive price the following relation (3) holds.

$$(3) \quad ICC_{FC}: \quad \frac{p^C \cdot q}{(1-\delta) \cdot N} \geq (p^C - 1) \cdot q$$

Based on these simple arguments involving no regulatory measures to avoid cartelization, I add the opportunity to get fined (3.2) and to report illegal cooperation (3.3).

### 3.2 Model implications with fines

Analogous to Apesteguia, Dufwenberg, and Selten (2007), Hinloopen and Soeteven (2008) and Fonseca and Normann (2014), I include a fine for communication which is due with a probability of 15% (model *F*). Following Fonseca and Normann (2014), the stage-game fine  $SGF_{it}$  is calculated as  $100 \cdot \frac{p_t}{N}$  for all  $i \in I$ . In the supgame, liability for fines is passed on and the fines accumulate, up to a maximum of five periods, so that the total fine  $F_{it}$  is  $\sum_{r=\theta}^t \frac{100}{N} \cdot p_r$  with  $\theta = \max\{t - 4; t_0\}$ , where  $t_0$  is the first round with communication since the start of the experiment, or since the last cartel disruption. Under these conditions, the per-period expected profit for positive cartel-prices  $\Pi_{F,it}^C$  is  $\frac{p_t^C \cdot q}{N} - 0.15 \cdot 100 \cdot \frac{p_t^C}{N}$ . Even though this calculation of the fine causes stage-game-specific net-payoffs for a company with positive sales to be nonnegative, if fines for several periods add up, per-period payoffs can be outreached. If  $p_t^C$  exceeds 1, a firm  $i$  deviating from this agreement choosing a price  $p_{it}^D = p_t^C - 1$  earns a profit  $\Pi_{F,it}^D$  of  $(p_t^C - 1) \cdot q - 0.15 \cdot 100 \cdot \frac{p_t^C - 1}{N}$ . As in the model without fines, deviations lead to competitive pricing in all following periods, with  $p_{it}^D = 0$  and  $\Pi_{F,it}^D = 0$ , for all  $t \in [t + 1; \infty)$  and all  $i \in I$ .

In terms of the PC, the profit from collusion in period  $\varphi$  needs to exceed the profit from competition in the very same period.

$$(4) \quad PC_F: \quad \frac{p^C \cdot q}{N} - 15 \cdot \frac{p^C}{N} \geq 0$$

In the supgame involving fines, the expected profit from repeated collusion  $\Pi_{F,i}^C$  at a fixed collusive price  $p^C$  from period  $\varphi$  onwards and with  $\delta$  as discount factor is  $\sum_{t=\varphi}^{\infty} \Pi_{F,it}^C = \frac{1}{1-\delta} \left( \frac{p^C \cdot q}{N} - 15 \cdot \frac{p^C}{N} \right)$ , while the profit from deviating  $\Pi_{F,i}^D$  in period  $\varphi$  is  $\Pi_{F,i\varphi}^D + \sum_{t=\varphi+1}^{\infty} \Pi_{F,it}^D = (p^C - 1) \cdot q - 15 \cdot \frac{p^C - 1}{N}$ , with  $\varphi \in \mathbb{N}$ . Relation (5) presents the ICC valid for my model with fines.

$$(5) \quad ICC_F: \quad \frac{1}{1-\delta} \left( \frac{p^C \cdot q}{N} - 15 \cdot \frac{p^C}{N} \right) \geq (p^C - 1) \cdot q - 15 \cdot \frac{p^C - 1}{N}$$

### 3.3 Model implications with the opportunity to report and to receive fine reductions

The third model specification (model *L*) encompasses the opportunity to report in exchange for fine reductions when communicating in order to agree on a collusive solution, i.e. it involves a leniency program. As in Bigoni et al. (2015), I include two opportunities to report: one is private (directly after prices are set), and one is public (after market prices and quantities are known). The second reporting opportunity only is provided if the first, private one has not been used by any market participant. I focus on a moderate leniency program, in which a single reporting party receives full fine reductions. If several firms report in the same

reporting stage, fine reductions are shared equally among all reporting parties (as in Bigoni et al. (2015)). The per-period fine under leniency after reporting  $SGF_{wt}^R$ , thus, is  $100 \cdot \frac{p^c}{N} \cdot \left(1 - \frac{1}{Y_t}\right)$ , where  $Y_t$  denotes the number of firms applying for leniency in period  $t$ , and  $w$  ( $w \in W_t$ ) uniquely identifies a reporting firm, with  $W_t := \{x \in N | x \leq Y_t\}$ . Firms that did not report in period  $t$  have to pay the full fine as in model  $F$ . Given these parameters, the per-period profit from collusion as well as the competitive profit are equal to those derived from the model with fines only. Therefore, the PC under leniency resembles the one under fines.

$$(6) \quad PC_L: \quad \frac{p^c \cdot q}{N} - 15 \cdot \frac{p^c}{N} \geq 0$$

Also, the profit from repeated collusion  $\Pi_{L,i}^c$  from period  $\varphi$  onwards resembles the one under fines, i.e. it is  $\sum_{t=\varphi}^{\infty} \Pi_{F,it}^c = \frac{1}{1-\delta} \left( \frac{p^c \cdot q}{N} - 15 \cdot \frac{p^c}{N} \right)$ . In terms of deviation strategies, however, under leniency, it is always optimal to report privately when deviating in period  $\varphi$ , so that the fine after reporting  $F_{w\varphi}^R$  is 0 and the corresponding deviation profit  $\Pi_{L,w\varphi}^D$  is  $(p^c - 1) \cdot q$  as long as there is no other deviator. The ICC for my third model specification is as follows.

$$(7) \quad ICC_L: \quad \frac{1}{1-\delta} \left( \frac{p^c \cdot q}{N} - 15 \cdot \frac{p^c}{N} \right) \geq (p^c - 1) \cdot q$$

Without deviations, reporting jointly after each collusive round would imply that the profit from collusion  $\Pi_{L,i}^{c,R}$  is  $\sum_{t=\varphi}^{\infty} \Pi_{L,it}^{c,R} = \frac{1}{1-\delta} \left( \frac{p^c \cdot q}{N} - 100 \cdot \frac{p^c}{N} \cdot \left(1 - \frac{1}{N}\right) \right)$ . As the collusive profit under leniency  $\Pi_{L,i}^c$  always exceeds  $\Pi_{L,i}^{c,R}$  for all  $N > 1$ , the leniency program is non-exploitable.<sup>1</sup>

## 4 Experimental design and procedure

Table 2: Policies tested in markets with  $N=2$  and  $N=4$ .

Treatment variable	Treatment policy			
	(1) BENCHMARK	(2) FREE COMMUNICATION	(3) FINES	(4) LENIENCY
Chatting is possible	-	✓	✓	✓
Fines might be due	-	-	✓	✓
Reports are possible	-	-	-	✓

The market game is based on the model outlined above. In this framework, I test both duopolies and quadropolies ( $N = 2; 4$ ), so as to compare small markets with larger ones. The supergame lasts at least 25 rounds. Participants were informed that after the 25<sup>th</sup> round the continuation probability is 1/6 (random termination rule), and they were randomly matched in pairs (or groups of four). Matches were kept the same until the end of the experiment. Based on the standard game, four treatments are tested: (1) “BENCHMARK”, in which communication is not possible; (2) “FREE COMMUNICATION”, in which participants are allowed to communicate freely; (3) “FINES”, in which communication can be fined and (4) “LENIENCY”, in which participants can receive fine reductions if they report a cartel. Table 2 summarizes the differences between the four tested antitrust policies. In treatments with the possibility to communicate, the design allows for free communication via typed messages. Chats were open for 45 seconds.<sup>2</sup> In order to communicate, participants

<sup>1</sup> Exploitable leniency programs might render illegal cooperation less costly due to the lower fines expected under leniency, which might lead to a higher expected benefit of cartel formation and reporting, compared to cartel formation without reporting (see Spagnolo (2004); Hinloopen and Soetevent (2008)).

<sup>2</sup> This is a duration somewhere between that in Fonseca and Normann (2014), which was 30 seconds, and in Fonseca and Normann (2012), which was 1 minute.

have to consciously and actively agree to communicate by pressing a button. Partial cartels are not possible, i.e. all subjects have to agree to communicate. Following the model described in Chapter 3, in the FINES and LENIENCY treatments, communication is exogenously detected with a probability of 15%. Once this happens, each firm on the market must pay a fine. In LENIENCY, however, firms might also actively apply for leniency, which qualifies them for fine reductions. Reporting decisions have to be made deliberately and actively, i.e. subjects are forced to explicitly press a report or a non-report button (as advised by Hinloopen and Soetevent (2008)). As described in Section 3.3, there are two reporting options, a private and a public one. Each stage-game consists of several steps, which are described in Table 3.

Table 3: Steps of the laboratory experiment.

Step	BENCH-MARK	FREE COMMUNICATION	FINES	LENIENCY
1. Communication decision: Each subject has to decide on whether he / she wants to communicate with the other firms. This decision is not taken when communication has already been active in the previous round and the cartel has not been dissolved. Afterwards, subjects are informed how many market participants agreed to communicate.	-	✓	✓	✓
2. Communication phase: Subjects are able to chat for 45 seconds via a chat window if all subjects agreed to communicate or if communication is still active from the previous round (i.e. the cartel has not been dissolved). Communication is open, i.e. not structured.	-	✓	✓	✓
3. Market phase: Each subject chooses his / her price in the range between 0 and 100 taler.	✓	✓	✓	✓
4. First reporting phase (private): Subjects are now able to report communication (reporting is free). Participants have to actively make a decision by pushing either the report or the non-report button. Up to now, no information about price choices or quantities sold or about reporting decisions of the other participants is provided.	-	-	-	✓
5. First information phase: Subjects are informed about the price choices of all firms and the resulting profits.	✓	✓	✓	✓
6. Second information phase: The number of reports made in the first reporting phase is displayed.	-	-	-	✓
7. Second reporting phase (public): If no market participant took the opportunity to report in the first step, a second report opportunity is provided.	-	-	-	✓
8. Third information phase: The number of reports in the second reporting phase is displayed.	-	-	-	✓
9. Prosecution phase: The cartel is detected with a probability of 15%. In LENIENCY, the exogenous detection is only relevant if no market participant has decided to report.	-	-	✓	✓
10. Fourth information phase: All relevant information about the stage-game are presented (prices, profits, total earnings of all firms, and – depending on treatment – fines, fine reductions).	✓	✓	✓	✓

The experiment was conducted at the University of Applied Sciences Ostwestfalen-Lippe in Germany and run with z-Tree (Fischbacher 2007). 326 student participants were invited by online invitation. Participants were allocated randomly to treatments and groups and were only allowed to participate once.<sup>3</sup> Identities were kept anonymous throughout the experiment. Participants received a fixed starting premium (€4) as well as a variable premium according to accumulated earnings in the experiment. Following Fonseca and Normann (2014), the exchange rate of the experimental currency “taler” to euro was 30,000:1 in the duopolies and 15,000:1 in the quadropolies, and the average payment across all treatments was €12. The sessions lasted between 1 and 1.5 hours. At the beginning of each session, the participants were randomly assigned

<sup>3</sup> Accordingly, this setting is designed for between-subject comparison as in Fonseca and Normann (2014) and Bigoni et al. (2008), but does not allow within-subject comparisons, as in Fonseca and Normann (2012).

to isolated computers. Once all participants had taken their seats, they were asked to read written instructions for the experiment, after which the experimental sessions started. After the market game, a short questionnaire had to be completed. Participants were paid individually at the end of the session. For all treatments, I collected data for at least 12 markets. Table 4 contains an overview of the numbers of observations per treatment.

Table 4: Number of observations and sample characteristics.

	No. of subjects	No. of markets	Age (av.)	Gender (male,%)
<b>N=2 markets</b>				
(1) BENCHMARK	24	12	23	0.71
(2) FREE COMMUNICATION	24	12	24	0.63
(3) FINES	34	17	24	0.71
(4) LENIENCY	24	12	25	0.71
<b>N=4 markets</b>				
(1) BENCHMARK	48	12	24	0.69
(2) FREE COMMUNICATION	48	12	23	0.71
(3) FINES	72	18	24	0.60
(4) LENIENCY	52	13	24	0.60
<b>All</b>	326	108	24	0.66

## 5 Hypotheses

Based on the model outlined in Chapter 3, I can reformulate the PCs and ICCs for my treatments as in Table 5 in order to derive hypotheses. As the model per se, the formal analyses are restricted to markets with at least two participants.

Table 5: Conditions, limit value analyses and between-treatment comparisons of profits and discount factors necessary in order to fulfill the participation constraints and incentive compatibility constraints.

		$\lim_{N \rightarrow \infty}$	$\lim_{p^c \rightarrow \infty}$
<b>PARTICIPATION CONSTRAINT</b>			
$\pi_{FC}^{PC}$	$\pi_{FC}^{PC} \geq 0$	$\lim_{N \rightarrow \infty} \pi_{FC}^{PC} = 0$	$\lim_{p^c \rightarrow \infty} \pi_{FC}^{PC} = \infty$
$\pi_{F,L}^{PC}$	$\pi_{F,L}^{PC} \geq 0$	$\lim_{N \rightarrow \infty} \pi_{F,L}^{PC} = 0$	$\lim_{p^c \rightarrow \infty} \pi_{F,L}^{PC} = \infty$
$\Delta \pi_{(FC F,L)}^{PC}$	$\Delta \pi_{(FC F,L)}^{PC} = \frac{15p^c}{N}$	$\lim_{N \rightarrow \infty} \Delta \pi_{(FC F,L)}^{PC} = 0$	$\lim_{p^c \rightarrow \infty} \Delta \pi_{(FC F,L)}^{PC} = \infty$
$\Delta \pi_{(F L)}^{PC}$	$\Delta \pi_{(F L)}^{PC} = 0$	$\lim_{N \rightarrow \infty} \Delta \pi_{(F L)}^{PC} = 0$	$\lim_{p^c \rightarrow \infty} \Delta \pi_{(F L)}^{PC} = 0$
<b>INCENTIVE COMPATIBILITY CONSTRAINT</b>			
$\delta_{FC}$	$\delta_{FC}^{ICC} = 1 - \frac{p^c}{N(p^c - 1)}$	$\lim_{N \rightarrow \infty} \delta_{FC}^{ICC} = 1$	$\lim_{p^c \rightarrow \infty} \delta_{FC}^{ICC} = 1 - \frac{1}{N}$
$\delta_F$	$\delta_F^{ICC} = 1 - \frac{p^c(q - 15)}{(qN - 15)(p^c - 1)}$	$\lim_{N \rightarrow \infty} \delta_F^{ICC} = 1$	$\lim_{p^c \rightarrow \infty} \delta_F^{ICC} = 1 - \frac{q - 15}{qN - 15}$
$\delta_L$	$\delta_L^{ICC} = 1 - \frac{p^c(q - 15)}{qN(p^c - 1)}$	$\lim_{N \rightarrow \infty} \delta_L^{ICC} = 1$	$\lim_{p^c \rightarrow \infty} \delta_L^{ICC} = 1 - \frac{q - 15}{qN}$
$\Delta \delta_{(FC F)}^{ICC}$	$\Delta \delta_{(FC F)}^{ICC} = -\frac{15p^c(N - 1)}{N(qN - 15)(p^c - 1)}$	$\lim_{N \rightarrow \infty} \Delta \delta_{(FC F)}^{ICC} = 0$	$\lim_{p^c \rightarrow \infty} \Delta \delta_{(FC F)}^{ICC} = -\frac{15(N - 1)}{N(qN - 15)}$
$\Delta \delta_{(FC L)}^{ICC}$	$\Delta \delta_{(FC L)}^{ICC} = -\frac{15p^c}{qN(p^c - 1)}$	$\lim_{N \rightarrow \infty} \Delta \delta_{(FC L)}^{ICC} = 0$	$\lim_{p^c \rightarrow \infty} \Delta \delta_{(FC L)}^{ICC} = -\frac{15}{qN}$
$\Delta \delta_{(F L)}^{ICC}$	$\Delta \delta_{(F L)}^{ICC} = -\frac{15p^c(q - 15)}{qN(p^c - 1)(qN - 15)}$	$\lim_{N \rightarrow \infty} \Delta \delta_{(F L)}^{ICC} = 0$	$\lim_{p^c \rightarrow \infty} \Delta \delta_{(F L)}^{ICC} = -\frac{15(q - 15)}{qN(qN - 15)}$

$p^c$  := Collusive price,  $p^c \in \mathbb{N}^+$  for the PC conditions;  $p^c \in \mathbb{N}$ ,  $p^c > 1$  for the ICC conditions;

$q$  := Demand (= 300 for my design);

$N$  := Number of firms, with  $N \in \mathbb{N}$  and  $N \geq 2$ ;

$\pi_X^{PC}$  := Profit under policy  $X$  ( $X \in \{FC; F; L\}$  and  $FC = \text{Free Communication}$ ,  $F = \text{Fines}$ ,  $L = \text{Leniency}$ );

$\Delta \pi_{X|Y}^{PC}$  := Difference between profit of policy  $X$  and policy  $Y$  ( $X, Y \in \{FC; F; L\}$ ) at given  $p^c, q, N$ ;

$\delta_X^{ICC}$  := Minimum discount factor necessary for the ICC to hold under policy  $X$ ,  $\delta \in [0; 1]$ ;

$\Delta \delta_{X|Y}^{ICC}$  := Difference between minimum discount factors necessary for the ICC to hold of policy  $X$  and policy  $Y$ .

This paper focusses on the question whether the relative effectiveness of LENIENCY, compared to FREE COMMUNICATION, FINES and BENCHMARK, is equal for  $N=2$  and  $N=4$  markets. As I base my study on previous results on policies other than leniency programs, indicating that there are differences between markets of different sizes, I start the analyses by asking whether there are any general differences between the  $N=2$  and  $N=4$  markets also in my data. The first two entries in column three of Table 5 depict that for all policies with communication, the more firms there are on a market, the more the collusive profit converges towards the competitive level, i.e. the smaller the benefit from collusion. However, as long as the profit is positive, collusion remains optimal for both  $N=2$  and  $N=4$  markets. This implies that participants should always decide to collude as long as no one deviated before, independent of market size. Yet, in contrast to this theoretic statement, in their FINES-treatment, Fonseca and Normann (2014) find that the quadropolies formed almost twice as many cartels as the duopolies, even though they need more attempts to do so. I am interested in whether I am able to reproduce their theory-contradicting findings with regard to differences between  $N=2$  and  $N=4$  markets in my FINES and FREE COMMUNICATION treatments, and whether they are also valid for my newly introduced LENIENCY treatment. I therefore formulate my first alternative hypotheses as follows.

**Hypothesis 1:** The number of instances in which a subject wants to establish a new cartel and the number of successfully established cartels is higher for  $N=4$  markets than for  $N=2$  markets.

For the ICC to hold, unilateral deviation with punishment must not yield higher profits than sticking to collusion. Entries five, six and seven in the third column of Table 5 show that, independently of the policy, with an increasing number of firms on a market, the discount factor necessary in order to keep collusion preferable compared to deviation rises. The ICC becomes stricter with more firms, and the incentive to deviate is always higher with more firms on a market, so that deviations might occur more regularly. Thus, prices in periods with communication might be lower in  $N=4$  markets, compared to  $N=2$  markets. Fonseca and Normann (2014) find evidence for this, and confirm the conventional wisdom that duopolies generally have higher average prices than the quadropolies, even without communication. I formulate the following hypothesis accordingly.

**Hypothesis 2:** Prices are higher for  $N=2$  markets than for  $N=4$  markets.

Regarding the relative effectiveness of the antitrust policies tested in my treatments with explicit collusion, I turn to the third and fourth entry in the second column of Table 5, comparing differences between the profits associated with a given positive price and a given number of firms between policies. The expected profit from collusion in contrast to competition is equal for the FINES and LENIENCY treatments, but higher for the FREE COMMUNICATION treatment, in which collusion is not prosecuted. Thus, the PC is more stringent for the LENIENCY as well as the FINES treatment, compared to FREE COMMUNICATION. With regard to differences in the willingness to chat (WTC) and the number of cartels between policies, I do however restrict my analysis to comparing LENIENCY and FINES, as in the FREE COMMUNICATION treatment, no antitrust tool meant to trigger disruption and prevention is established. As the PC does not vary

between these two treatments, I test against the null-hypothesis that, independent of market size, LENIENCY and FINES should not differ in terms of the number of cartels established as well as in terms of WTC. In absence of any previous experimental evidence corresponding to a model comparable to mine providing hints on the direction of potential effects, I formulate an open hypothesis as follows, contradicting the theoretic proposition of absence of differences between FINES and LENIENCY.

**Hypothesis 3:** The number of instances in which a subject wants to establish a new cartel and the number of successfully established cartels per market is not equal for LENIENCY and FINES.

In terms of the ICC, per stage-game, my LENIENCY policy has the tightest ICC, as with LENIENCY, there are stronger incentives to deviate, compared to FINES and FREE COMMUNICATION. Such deviation reduces the expected fine, and private reports reduce fines even more. The second tightest ICC comes along with FINES, followed by FREE COMMUNICATION. This is also evident when comparing the policy-specific minimum discount factors necessary in order to make collusion preferable compared to deviation in the lower part of the second column of Table 5. The minimum discount factor under LENIENCY exceeds the ones under FINES as well as under FREE COMMUNICATION, so that the requirement for sticking to collusion is stricter with the former policy than with the latter ones. Likewise, as  $\delta_F^{ICC}$  exceeds  $\delta_C^{ICC}$ , the incentive to deviate is higher under FINES compared to FREE COMMUNICATION. I can apply this reasoning to market prices and formulate Hypothesis 4<sup>4</sup>. As a reference, I take the BENCHMARK treatment, which resembles a situation in which explicit collusion is impossible, so that prices should be close to the competitive level.

**Hypothesis 4:** Market prices are lowest in BENCHMARK, followed in order of increasing magnitude by LENIENCY, FINES and FREE COMMUNICATION.

The hypothesis should hold independent of market size, even though differences between policies might be smaller with more firms, as prices are generally squeezed towards zero in bigger markets. The corresponding entries in column three of Table 5 show that differences in terms of the ICC are smaller the more firms there are in the market. The relative benefit from sticking to the collusive agreement under FREE COMMUNICATION compared to FINES as well as LENIENCY, and under FINES compared to LENIENCY becomes smaller the more firms there are in a market. This is directly connected to the previously outlined proposition that with more firms, per-firm-profits should be lower.

In addition to differences between treatments regarding the overall number of established cartels and market prices, I am also interested in the dynamics resulting from previous cartels. Theoretically, building on the understanding that collusion is only feasible as long as firms communicate, I would expect post-cartel prices to fall to the competitive level immediately. However, as outlined in Section 2, Fonseca and Normann (2014) find evidence of hysteresis effects, indicating that post-cartel prices remain relatively high, even though they

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<sup>4</sup> As hypothesis 2, this hypothesis also refers to overall market prices. As theory suggests market prices in non-cartel periods to be zero, independently of the policy and market size tested, average market prices over all periods should follow the ordinal scale of market prices in cartel periods suggested by theory. Below, I nonetheless discuss market prices in cartel periods and non-cartel periods separately, in addition to overall market prices.

are lower than in periods with communication. The authors also find that four-firm industries gain less from this hysteresis effect after cartel disruption than duopolies (i.e. tacit collusion is less pronounced in the larger markets). I formulate two further hypotheses to test post-cartelization behavior in the FINES and LENIENCY treatment. In order to do so, I build on a broad understanding of hysteresis, defining it as periods of tacit collusion following a period of explicit collusion. That is, after disruption and being fined, participants might hesitate to establish new explicit cartels, and rather try to sustain high prices without communicating. Under this assumption, I expect two phenomena to occur: (1) chat-hysteresis, i.e. previous cartels decrease the odds to establish a new chat, and (2) price-hysteresis, i.e. previous cartels increase current prices.

**Hypothesis 5:** Chat-hysteresis is stronger for  $N=2$  markets than for  $N=4$  markets.

**Hypothesis 6:** Price-hysteresis is stronger for  $N=2$  markets than for  $N=4$  markets.

Besides analyzing differences in terms of post-cartel dynamics between markets of different sizes for each antitrust policy individually, I am interested in the way these two factors interact. Until now, it remains an open question in what way market size interacts with the effect of a leniency program, and whether this interaction influences post-cartelization behavior.<sup>5</sup> While the former aspect is covered by the hypotheses outlined above, I formulate an exploratory research question in order to tackle the latter.

**Exploratory research question:** Is the relative effectiveness of LENIENCY, compared to FREE COMMUNICATION, FINES and BENCHMARK, in terms of the prevention of tacit collusion equal for  $N=2$  and  $N=4$  markets?

## 6 Results

In order to analyze cartel activity, both (I) active communication as well as (II) the establishment of high market prices will be analyzed. I first focus on (I) communication via chats, which represents explicit collusion in my experiment.

### 6.1 Treatment-effects on communication

Table 6: Average number of newly established cartels and average number of instances in which subjects were willing to chat per market.

	#Obs.	Number of cartels		WTC	
		AV	SD	AV	SD
FREE COMMUNICATION ( $N=2$ )	12	0.92	0.29	1.83	1.89
FREE COMMUNICATION ( $N=4$ )	12	1.00	0.00	2.94	1.66
FINES ( $N=2$ )	17	1.65	1.41	4.59	3.86
FINES ( $N=4$ )	18	2.22	1.40	8.24	4.92
LENIENCY ( $N=2$ )	12	3.00	2.80	4.79	4.50
LENIENCY ( $N=4$ )	13	4.15	4.98	10.46	7.34

Number of cartels: The number of instances in which a new chat was successfully established on a market, per market.

WTC: The average number of instances in which a subject of a certain market wanted to establish a new chat, per subject.

AV: Average value over all rounds.

SD: Standard deviation.

<sup>5</sup> Chowdhury and Crede (2015) show that tacit collusion after periods of cartelization occurs irrespective of the specific antitrust policy. Yet, they do not test for differences between smaller and larger markets.

Table 6 shows average values (AV) as well as standard deviations (SD) of two variables. “Number of cartels” indicates how often participants successfully established a new phase of communication during the whole game, i.e. it represents the number of cartels formed per market in the supergame<sup>6</sup>. “WTC” captures how often individual players on a market wanted to start a new chat in the course of the supergame. On average, new chats are established more frequently in the quadropolies than in the duopolies in all three policies with a chatting-option. Likewise, participants are on average willing to chat more often in the four-firm markets. Yet, only the latter difference is statistically significant across all three treatments with communication, i.e. in FREE COMMUNICATION, FINES and LENIENCY (two-sided Wilcoxon rank sum test (WRS-test)<sup>7</sup> for differences in WTC between N=2 and N=4 markets per policy; all p-values <0.05; WRS-test for differences in the number of cartels between N=2 and N=4 markets per policy; all p-values >0.11).<sup>8</sup> Accordingly, and in line with the experimental finding of Fonseca and Normann (2014), there are generally more attempts to form cartels in the larger markets. Consequently, I can confirm my Hypotheses 1 with regard to WTC.

**Result 1:** There are significantly more attempts to form cartels in N=4 than in N=2 markets in all treatments.

Differences between the LENIENCY and the FINES treatments in terms of the number of cartels and WTC are not statistically significant (WRS-test for differences in WTC and the number of cartels between FINES and LENIENCY per market size; N=2: p-value>0.1; N=4: p-value>0.5). Hence, based on these distribution tests, I cannot support the alternative Hypothesis 3 and the notion that the opportunity to report significantly influences the number of cartels. My results, thus, are rather in line with the theoretic proposition derived from my model saying that there are no differences between FINES and LENIENCY in terms of the number of cartels and WTC.

In order to analyze post-cartelization effects on WTC in the FINES and LENIENCY treatments, I estimate a random effects probit regression related to that of Fonseca and Normann (2014) as follows.

$$(8) \quad WTC_{i,t} = I\{(\beta_0 + \beta_1 Quad_j + \beta_2 Leniency_j + \beta_3 Quad_j \times Leniency_j + \beta_4 CartelB4_{j,t} + \beta_5 CartelB4_{j,t} \times Quad + \beta_6 CartelB4_{j,t} \times Leniency_j + \beta_7 SellingPrice_{j,t-1} + \beta_8 SellingPrice_{j,t-1} \times Quad + \beta_9 SellingPrice_{j,t-1} \times Leniency_j + \beta_{10} Period_t + v_j + \epsilon_{j,t}) > 0\}$$

The endogenous dummy variable  $WTC_{i,t}$  equals one if individual  $i$  who is active on market  $j$  is willing to chat in period  $t$ , conditional on a cartel not being carried over from the previous period. Table 7 presents the results. I first estimate a simple version of the model (version (a)) in order to verify the effects described above with regard to market size and policy differences. The significance and direction of the coefficient aligning  $Quad_j$  in model (a) and model (b) supports Result 1, indicating that there is a market size effect with

<sup>6</sup> Unless indicated otherwise, analyses cover 25 periods.

<sup>7</sup> For all hypotheses-tests reported in this paper, the unit of observation is the average value of the variable of interest over all participants of a certain market and over all rounds. As has been noted by a careful reader (thanks for that), with subject-period-combinations as independent observations, results would be biased as within-market-observations might correlate.

<sup>8</sup> This also implies that the success rate to form cartels is higher in the smaller markets.

regard to WTC. As in the distribution tests, differences between FINES and LENIENCY are insignificant. Estimating the full model (version (c)), a higher price in the previous period ( $SellingPrice_{j,t-1}$ ) as well as previously existing cartels ( $CartelB4_{j,t}$ ) significantly reduce the likelihood of being willing to chat. These findings indicate chat-hysteresis; that is, previous explicit communication and higher former prices reduce the desire to communicate, which is probably due to subjects' anticipation of implicitly sticking to the collusive agreement (i.e. to collude tacitly). The positive and significant influences of the interaction terms ( $SellingPrice_{j,t-1} \times Quad_j$  and  $CartelB4 \times Quad_j$ ) indicate that the chat-hysteresis is less strong for the N=4 markets. Accordingly, I can support my Hypothesis 5 and the notion that chat-hysteresis is weaker for four-firm industries, as found by Fonseca and Normann (2014). In model (c), the difference between N=2 and N=4 markets is still significant. Yet, in contrast to the distribution tests and models (a) and (b), the direction of the effect is reversed, so that, prima facie, the likelihood of being willing to chat and the likelihood of successful cartelization seem to be lower in the larger markets. In combination with the interaction terms indicating differences in terms of chat-hysteresis between duopolies and quadropolies, I can conclude that the difference in WTC between N=2 and N=4 markets indicated by the distribution tests and models (a) and (b) is mainly driven by the subdued chat-hysteresis.

**Result 2:** Explicit communication and higher prices in previous rounds inhibit the likelihood of being willing to chat, indicating chat-hysteresis. A larger market size reduces the scope of these effects.

Table 7: RE Probit models of the likelihood of being willing to start a cartel (WTC); per subject for FINES and LENIENCY.

	(a)	(b)	(c)
<b>Quad</b>	1.127*** (0.215)	0.867*** (0.245)	-0.997** (0.452)
<b>Leniency</b>	0.094 (0.272)	0.102 (0.307)	0.815 (0.518)
<b>Quad <math>\times</math> Leniency</b>	0.044 (0.331)	0.055 (0.376)	-0.439 (0.405)
<b>CartelB4</b>	--	-0.079 (0.200)	-0.747** (0.341)
<b>CartelB4 <math>\times</math> Quad</b>	--	--	1.078*** (0.351)
<b>CartelB4 <math>\times</math> Leniency</b>	--	--	-0.337 (0.381)
<b>SellingPrice<sub>t-1</sub></b>	--	-0.012*** (0.002)	-0.027*** (0.004)
<b>SellingPrice<sub>t-1</sub> <math>\times</math> Quad</b>	--	--	0.018*** (0.004)
<b>SellingPrice<sub>t-1</sub> <math>\times</math> Leniency</b>	--	--	-0.001 (0.003)
<b>Period<sub>t</sub></b>	-0.047*** (0.008)	-0.034*** (0.008)	-0.032*** (0.008)
<b>Constant</b>	-0.246 (0.190)	0.464* (0.269)	1.892*** (0.428)
<b>Observations (Groups)</b>	2992 (182)	2810 (178)	2810 (178)
<b>Wald Chi-square</b>	87.17 <sup>a</sup>	127.02 <sup>a</sup>	237.04 <sup>a</sup>
<b>Log Pseudolikelihood</b>	-1424.475	-1185.123	-1148.222

Robust standard errors (clustered by markets) are reported in parenthesis.

\*\*\*=0.01, \*\*=0.05, \*=0.1 significance levels; <sup>a</sup> 0.01 significance level.

### 6.3 Treatment effects on market prices

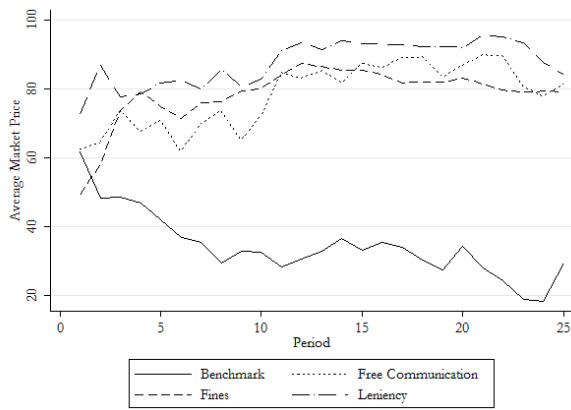


Figure 1: Average market prices per round in duopolies.

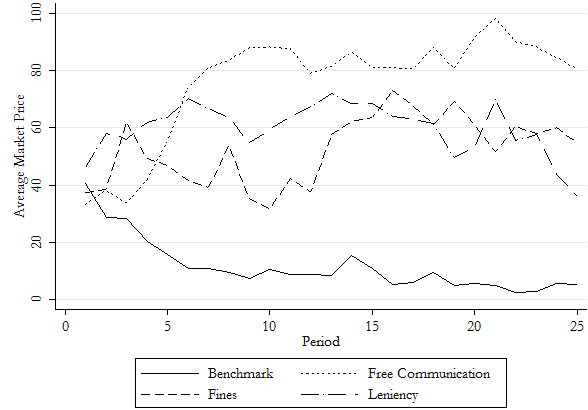


Figure 2: Average market prices per round in quadropolies.

With regard to market prices as the second indicator of collusion (II), Figure 1 (Figure 2) depicts the development of market prices for the duopolies (quadropolies) in the course of the experiment. In general, for both market sizes, BENCHMARK yields the lowest market prices consistently over all rounds. With regard to the other policies, there is no unique hierarchy across all rounds in either the N=2 or the N=4 markets, even though in general, prices in the N=4 markets seem to be more volatile than in the N=2 markets for the policies with communication.

Table 8: Average values and standard deviations of prices per market.

	BENCHMARK		FREE COMMUNICATION		FINES		LENIENCY	
	N=2	N=4	N=2	N=4	N=2	N=4	N=2	N=4
<b>Market prices over all periods</b>								
#Obs.	12	12	12	12	17	18	12	13
Av.	34.27	11.44	78.41	75.91	78.40	52.63	87.69	59.81
Sd.	15.88	7.95	16.65	20.94	28.63	29.64	18.65	33.74
<b>Market prices over all cartel periods</b>								
#Obs.	--	--	11	12	15	15	12	13
Av.	--	--	85.40	84.23	84.96	74.52	89.71	81.77
Sd.	--	--	10.77	22.16	24.76	21.01	16.65	29.24
<b>Market prices in the first cartel period</b>								
#Obs.	--	--	11	12	15	15	12	13
Av.	--	--	70.18	64.67	73.27	62.00	88.08	86.46
Sd.	--	--	18.63	40.51	35.79	34.83	19.26	27.69
<b>Market prices in non-cartel periods</b>								
#Obs.	12	12	6	11	17	17	12	13
Av.	34.27	11.44	43.61	21.94	74.95	35.91	80.35	35.29
Sd.	15.88	7.95	18.97	16.83	29.98	34.04	22.47	33.33
<b>Market prices in non-cartel periods w/o previous communication</b>								
#Obs.	12	12	6	11	13	13	7	11
Av.	34.27	11.44	43.61	21.94	36.72	24.98	55.57	29.04
Sd.	15.88	7.95	18.97	16.83	25.58	19.22	11.87	18.33
<b>Market prices in non-cartel-periods w/ previous communication</b>								
#Obs.	--	--	--	--	14	13	12	13
Av.	--	--	--	--	86.51	41.21	80.92	34.49
Sd.	--	--	--	--	30.10	39.79	22.99	35.45
<b>Subject prices after another market participant deviated</b>								
#Obs.	--	--	9	9	7	15	8	10
Av.	--	--	68.62	84.12	77.98	77.5	68.74	47.86
Sd.	--	--	18.16	12.97	28.97	19.89	22.64	27.96
<b>Subject prices after another market participant reported</b>								
#Obs.	--	--	--	--	--	--	8	11
Av.	--	--	--	--	--	--	78.9	57.2
Sd.	--	--	--	--	--	--	19.07	28.14

Subject prices after another market participant deviated & reported								
#Obs.	--	--	--	--	--	--	7	10
Av.	--	--	--	--	--	--	75.89	53.66
Sd.	--	--	--	--	--	--	18.42	25.93
Percentage of markets which formed a cartel at least once								
--	--	91.67	100	88.24	83.33	100	100	
Cumulative relative frequencies of market-price levels in the first cartel period								
= 0	--	--	0.00	8.33	0.00	6.67	0.00	0.00
< 25	--	--	0.00	16.67	20.00	13.33	0.00	7.69
< 50	--	--	9.09	41.67	26.67	26.67	8.33	7.69
< 75	--	--	54.55	41.67	40.00	53.33	16.67	23.08
< 100	--	--	90.91	50.00	46.67	86.67	50.00	38.46

Av.: Average values over market averages.

Sd.: Standard deviation.

Table 8 reports average values of situation-specific market prices. For all policies, average market prices over all periods are higher in the duopolies than in the quadropolies, and these differences are also significant for all treatments, except FREE COMMUNICATION (WRS-test for differences between N=2 and N=4 in BENCHMARK, FINES, LENIENCY: all p-values <0.04; WRS-test for differences between N=2 and N=4 in FREE COMMUNICATION: p-value >0.90). Consequently, I cannot fully support Hypothesis 2, as the existence of differences between market sizes in terms of prices is not entirely consistent for all policies. The difference between duopolies and quadropolies in LENIENCY is no longer significant as soon as only cartel-periods are considered, so that the bigger markets appear to be just as effective in establishing collusive prices as duopolies under LENIENCY when they are able to communicate actively (WRS-test for differences between N=2 and N=4 in FINES: p-value <0.03; WRS-test for differences between N=2 and N=4 in FREE COMMUNICATION and LENIENCY: p-values >0.65). In periods without communication, prices are significantly lower in the N=4 markets compared to the N=2 markets for all four policies (WRS-test for differences between N=2 and N=4 in BENCHMARK, FREE COMMUNICATION, FINES, LENIENCY: all p-values <0.03), so that I can support the corresponding finding of Fonseca and Normann (2014). The data clearly indicates that duopolies are better at colluding tacitly in periods without active communication.

**Result 3:** Prices over all period are significantly higher in N=2 markets than in N=4 markets in all treatments, except FREE COMMUNICATION. This difference is mainly driven by higher market prices in duopolies in periods without active communication. In periods with communication, only the FINES treatment yields significantly higher prices for duopolies than for quadropolies.

With regard to differences between antitrust policies, market and subject-specific prices in BENCHMARK are significantly lower than in all other policies, both for the duopolies and the quadropolies (WRS-test for differences between BENCHMARK and the other policies by market size: all p-values <0.002). Besides this, in the N=2 markets, market prices over all periods are significantly higher in LENIENCY than in FREE COMMUNICATION (WRS-test for differences between LENIENCY and FREE COMMUNICATION in N=2 markets: p-value <0.05). This significant difference disappears as soon as only those periods with active communication are considered (“Market prices over cartel periods”). In these periods, prices do not differ significantly between the policies with the opportunity to collude explicitly in N=2 markets (WRS-test for differences between treatments with the opportunity to communicate in N=2 markets: all p-values >0.2).

Regarding prices in periods without communication, FINES and LENIENCY yield significantly higher prices than FREE COMMUNICATION (WRS-test for differences between LENIENCY/FINES and FREE COMMUNICATION in N=2 markets: p-values <0.04). This difference, however, might be driven substantially by high prices in periods after cartel disruption in FINES and LENIENCY, as the corresponding analyses including only those prices in periods without current or previous communication do not yield significant differences (WRS-test for differences between LENIENCY/FINES and FREE COMMUNICATION in N=2 markets: p-values >0.15).

In the N=4 markets, there are no significant differences in non-cartel periods between any of the policies providing the opportunity to communicate (WRS-test for differences between FREE COMMUNICATION, LENIENCY and FINES in N=4 markets: p-values >0.50). Yet, considering those periods in which the opportunity to chat was provided, FREE COMMUNICATION and LENIENCY yield significantly higher prices compared to FINES (WRS-test for differences between FREE COMMUNICATION/LENIENCY and FINES in N=4 markets: p-value <0.08). Aggregating over all periods (“Market prices over all periods”), FREE COMMUNICATION still generates significantly higher prices than FINES (WRS-test for differences between FREE COMMUNICATION and FINES in N=4 markets: p-value<0.04).

All other pairwise comparisons between policies per market size are insignificant. Therefore, I cannot support Hypothesis 4, either for the duopolies or for the quadropolies. Rather, the data indicates that LENIENCY is not preferable to FINES when it comes to the reduction of high market prices. Unexpectedly, LENIENCY does not even seem to be more effective in this regard compared to FREE COMMUNICATION, at least in duopolies.

**Result 4:** BENCHMARK yields significantly lower prices compared to FREE COMMUNICATION, FINES and LENIENCY, both in N=2 and in N=4 markets. LENIENCY does not yield significantly lower prices compared to FINES and FREE COMMUNICATION, either in quadropolies, or in duopolies. In the smaller markets, LENIENCY even performs worse than FREE COMMUNICATION.

Parallel to the analysis of chat establishment via the RE Probit model, I estimate a RE regression model with market prices as the endogenous variable and variables capturing whether a cartel is active as well as the cartelization history as regressors as follows:

$$(9) \quad Price_{j,t} = \beta_0 + \beta_1 Quad_j + \beta_2 ActiveCartel_{j,t} + \beta_3 DetectedCartelB4_{j,t} + \beta_4 Quad_j \times ActiveCartel_{j,t} + \beta_5 Quad_j \times DetectedCartelB4_{j,t} + Period_t + v_j + \epsilon_{j,t}$$

There are two dummies included (besides  $Quad_j$ ) which capture effects based on the state as well as the history of collusion on a certain market  $j$  in period  $t$ .  $ActiveCartel_{j,t}$  takes a value of one if a cartel is active in period  $t$  (i.e. if the opportunity to chat is active) and  $DetectedCartelB4_{j,t}$  shows that there has been a cartel in past periods, but that there is no active cartel in period  $t$ . The regression results are provided in Table 9. Generally, cartels increase market prices. This effect is significantly stronger for larger markets than for

smaller ones under FREE COMMUNICATION. Previously detected and disrupted cartels also positively influence market prices under FINES and LENIENCY, indicating price-hysteresis. However, under LENIENCY, price-hysteresis is smaller or even overcompensated in quadropolies (Wald test on differences between  $\beta_3$  and  $\beta_5$  in the LENIENCY model:  $p > 0.7$ ).<sup>9</sup> I can thus confirm Hypothesis 6 for the LENIENCY setting.<sup>10</sup> I can further answer my exploratory research question, summarizing that there are indeed market-size dependent differences between LENIENCY and FINES in terms of price-hysteresis.

**Table 9: RE regression results. Market price as dependent variable.**

	FREE COMMUNICATION	FINES	LENIENCY
<b>Quad</b>	-30.58*** (8.91)	-23.08** (9.88)	-26.19*** (8.42)
<b>ActiveCartel</b>	31.93*** (7.29)	38.71*** (12.93)	27.66*** (8.19)
<b>ActiveCartel x Quad</b>	30.34*** (9.03)	6.03 (14.97)	15.24 (10.50)
<b>DetectedCartelB4</b>	--	36.79** (14.63)	19.98** (9.99)
<b>DetectedCartelB4 x Quad</b>	--	-19.45 (17.83)	-22.59* (13.03)
<b>Period</b>	0.52* (0.28)	0.36 (0.30)	0.40 (0.33)
<b>Constant</b>	44.92*** (7.12)	43.68*** (8.33)	60.21*** (5.62)
<b>Observations</b>	600	875	625
<b>Groups</b>	24	35	25
<b>R<sup>2</sup></b>	0.3452	0.3885	0.4164

Robust standard errors (clustered by markets) are reported in parenthesis.

\*\*\*=0.01, \*\*=0.05, \*=0.1 significance levels.

**Result 5:** Active cartels increase market prices in all treatments with explicit communication. Likewise, previously active, but disrupted cartels increase current prices in treatments where disruption is possible, the latter effect indicating price-hysteresis. This price-hysteresis effect is smaller or even overcompensated in larger markets under LENIENCY.

## 6.4 Discussion

I now want to discuss the market-size specific differences between policies in terms of cartel prices. In conformity with expectations, all treatments providing the opportunity to communicate trigger higher market prices than the BENCHMARK treatment. Contrary to expectations, LENIENCY does not yield lower cartel prices than FINES and FREE COMMUNICATION. In the duopolies, FINES also fails to reduce market prices in cartel periods significantly compared to the other policies with the opportunity to collude, while it is more effective in the quadropolies. In the context of previous literature on the effectiveness of leniency programs, my findings are more in line with those found by Bigoni et al. (2012) than with those of Apesteguia, Dufwenberg, and Selten (2007) as well as Hinloopen and Soetevent (2008). Following Bigoni et al. (2012), there could be three reasons for the ineffectiveness of LENIENCY in both N=2 and N=4 markets in terms of the reduction of market prices in cartel periods. First, selection effects could inhibit cartel re-establishment after

<sup>9</sup> Differences between periods without any current or previous cartelization and those without current, but with previous cartelization are insignificant for N=4 markets, both under FINES and under LENIENCY. In N=2 markets, these differences are significant for both treatments (WRS-test for these differences in N=2 markets: p-values <0.02; in N=4 markets: p-values >0.6).

<sup>10</sup> This finding partly contradicts the result found by Chowdhury and Crede (2015), indicating that tacit collusion after periods of cartelization occurs irrespective of the specific antitrust policy. Yet, their setup is very different from mine. I refer to the original paper for details.

deception, so that only those cartels with high prices remain.<sup>11</sup> This would imply lower average market prices in first cartel periods than in the entire section of cartel periods in all markets, as imperfect cartels are deterred or at least not re-established. This effect is not only reasonable in LENIENCY, but also in FINES, so that it could explain why these two treatments are not strictly more effective in preventing high market prices under explicit collusion compared to FREE COMMUNICATION in duopolies. Second, the implicit cost of communication represented by the risk of being fined might motivate participants to coordinate effectively under LENIENCY and under FINES. The existence of coordination effects would imply that cartel prices are higher in LENIENCY and FINES than in FREE COMMUNICATION. Contrary to the expectations raised by potential selection effects, this pattern should occur even in the very first cartel period. Third, enforcement effects driven by the fear of public reports as punishment might have led subjects to refrain from deviating in my LENIENCY setting. In this case, prices below 100 should occur only rarely when there is an opportunity to report.

In order to discuss these potential explanations, Table 8 shows (1) the percentage of markets which formed a cartel at least once, (2) average market prices in periods in which market participants successfully established a chat for the first time, (3) average market prices over all cartel periods, and (4) cumulative percentage shares of market-price levels in the first cartel period. Below, I assess explanations of the market price patterns across policies for different market sizes individually, starting with the duopolies. What drives the high market prices in LENIENCY in the smaller markets? Concerning selection effects, Table 8 indicates that, in general, average market prices in the very first cartel period are lower than average market prices over all cartel periods for all treatments, which might suggest selection effects. This pattern, however, occurs independently of the policy tested and is not significant in the FINES and LENIENCY treatments<sup>12</sup>, so that it does not serve as evidence of selection effects driving the differences between policies. Furthermore, FREE COMMUNICATION yields a lower average market price than FINES and LENIENCY from the start, while LENIENCY yields the highest average market price already in the very first period of cartelization. In the same vein, for the duopolies, the percentage share of markets establishing the highest collusive market price (i.e. 100) in the first period with active communication is 53.33% and 50% for FINES and LENIENCY respectively, while it only accounts for roughly 9% in the duopolies under FREE COMMUNICATION. These findings suggest that the unexpectedly high price levels under LENIENCY in the course of all cartel periods are not fueled by self-selection of well-working cartels. The same holds for prices under FINES.

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<sup>11</sup> When being deceived, the expected cartel profit  $\Pi_{F/L,i}^C$  for an undercut party  $i$  is  $\frac{-15p^C}{N}$ , which is not preferable compared to the competitive profit  $\Pi_{F/L,i}^O = 0$ . If  $i$  modifies its assumptions in terms of realizable cartel prices according to previous experiences and plays a Grimm-trigger strategy, then there is no incentive to agree to communicate again as soon as another party deviates.

<sup>12</sup> The difference between market prices in the first cartel period and market prices in all cartel periods is insignificant for all policies with communication in  $N=2$  markets, except FREE COMMUNICATION (WRS-test FREE COMMUNICATION  $p < 0.04$ , FINES/LENIENCY  $p > 0.70$ ).

Contrary to selection effects, the existence of coordination effects driven by the expected cost of communication in FINES and LENIENCY would imply that cartel prices are high in LENIENCY and FINES from the very first period of communication onwards. This is in line with the pattern shown in Table 8 concerning the level of market prices in the first cartel period. The numbers indicate that there is reason to suspect that coordination effects contribute to the high prices in communication periods under FINES and LENIENCY, so that they do not significantly differ from FREE COMMUNICATION, even though the incentive to deviate is higher in the former treatments.

Effective coordination might not be the only driver of the high price levels under LENIENCY. If enforcement effects play a role, deviations should not occur regularly under LENIENCY. Table 10 displays deviation variables for the three policies with communication. Comparing the average percentage share of instances in which the participants deviated per policy for N=2 markets reveals that participants deviated more frequently in FREE COMMUNICATION than in FINES and LENIENCY (approx. 40% versus approx. 24% of cartel periods, “All deviations”).<sup>13</sup>

Table 10: Deviations per policy in percent.

Market size		N=2			N=4		
Policy		FREE COMMUNICATION	FINES	LENIENCY	FREE COMMUNICATION	FINES	LENIENCY
#Obs.		11	15	12	12	15	13
All deviations	AV	39.63	23.88	24.35	20.77	35.56	16.64
( $\exists i \in j: \hat{p}_{i\omega} < 100$ )	SD	(27.96)	(34.91)	(33.74)	(23.14)	(26.58)	(18.22)
Deviations while all other market partners stick to 100	AV	4.04	2.37	6.60	4.39	6.65	4.65
( $\exists i \in j: \hat{p}_{i\omega} < 100$ )	SD	(4.48)	(4.68)	(10.01)	(6.62)	(4.96)	(7.06)
All market partners deviate	AV	35.59	21.51	17.75	6.25	23.00	2.91
( $\forall i \in j: \hat{p}_{i\omega} < 100$ )	SD	(26.22)	(33.78)	(29.95)	(10.86)	(25.02)	(6.18)
Lower-level collusion	AV	10.13	4.63	5.59	0.00	2.11	0.77
( $\forall i \in j: \hat{p}_{i\omega} < 100$ $\wedge \forall i: \hat{p}_{i\omega} = p_{\omega}^c$ )	SD	(14.19)	(9.31)	(8.82)	(0.00)	(3.93)	(2.77)

AV: Average value over all subjects (and cartel rounds when referring to “all cartel periods”).

SD: Standard deviation.

$p_{\omega}^c$  := Collusive market price in cartel period  $\omega$ .

$\hat{p}_{i\omega}$  := Price set by player  $i$  in cartel period  $\omega$ .

Values are calculated as follows:  $\left( \frac{\sum_{i=1}^N \sum_{\omega=1}^{\Omega} d_i^{\omega}}{\Omega \cdot N} \right)$ ;

$\Omega$  := Number of periods with active communication ( $\Omega \in [1; 2; \dots; 25]$ ;  $\omega \in [1; 2; \dots; \Omega]$ );

$d_i^{\omega}$  := Dummy indicating that subject  $i$  deviated from collusive agreement in cartel period ( $d \in \{0; 1\}$ ;  $i \in [1; 2; \dots; N]$ );

In a considerable number of these deviation cases, all market participants deviate simultaneously (i.e. in the same period, 36% of cartel periods in FREE COMMUNICATION versus 18-22% in FINES and LENIENCY, “All market participants deviate”). Yet, only a relatively small share of these simultaneous deviations represents some (intentional or unintentional) lower-level collusion (10% versus 5-6% of cartel periods). Equivalently, the relative share of single player deviations is low in all duopoly treatments, accounting for 4% of cartel periods in FREE COMMUNICATION, roughly 2% in FINES and roughly 7% in LENIENCY. The infrequency of deviations under LENIENCY in the N=2 markets even though incentives to deviate are generally high could be taken as evidence for the notion of enforcement effects driven by the fear of public reports

<sup>13</sup> The difference between FINES and FREE COMMUNICATION is significant, so that FINES yields significantly fewer deviations than FREE COMMUNICATION (WRS-test: p-value < 0.07).

as punishment. For FINES, deterrence is exogenous, so that punishments via reports are not possible, and direct enforcement effects implausible. Yet, the infrequency of deviations under FINES nonetheless requires some explanation, and could constitute strategic signaling. When considering deviations, participants know that undercut participants could decide to reject cartel re-establishment after deterrence, as they align their expectations on the potential cartel profit according to their previous experiences. This is more likely to happen under FINES and LENIENCY compared to FREE COMMUNICATION. While in FREE COMMUNICATION, the incentive to (re-)establish a cartel after deterrence is always non-negative, even if the expected profit is zero, this does not hold for FINES and LENIENCY. Here, the PC does not hold as soon as a participant expects his/her own profit to be zero.<sup>14</sup> Thus, undercut parties have an incentive to disagree to communicate again after deterrence if they expect their market partners to deviate from any collusive agreement. If subjects fear this kind of punishment, they might refrain from deviating in order to signal trustworthiness. The infrequency of deviations not only under LENIENCY, but also under FINES suggests that such strategic signaling might influence the results substantially. Furthermore, the high importance of trust in my setting as described in Chapter 2.4 substantiates the plausibility of this effect.

After discussing possible explanations of the findings for the duopolies, I turn to the quadropolies. What drives the high cartel prices in LENIENCY in the quadropolies? Concerning selection effects, average market prices are again lower in the first period of cartelization than in all cartel periods under FREE COMMUNICATION and FINES, but not with LENIENCY (Table 8).<sup>15</sup> In a similar vein, the share of cartels coordinating at the highest price in the first cartel period is largest under LENIENCY. This implies that prices are high under LENIENCY even at the very beginning of cartelization, so that, again, coordination effects, rather than selection effects, seem to drive the ineffectiveness of LENIENCY with regard to the reduction of market prices in the quadropolies. Likewise, enforcement effects remain powerful, as deviations occur only rarely under LENIENCY in the quadropolies (approx.. 17% of cartel periods, Table 10). Under FINES, by contrast, the average number of deviations is higher in the quadropolies than in the duopolies, so that signaling effects seem to be weaker with more market participants in this setting.<sup>16</sup> The latter finding might be driven by an increased risk of being undercut with more market participants, so that market prices might be low anyway, and punishments in terms of refused re-establishment might occur independently of one's own behavior. This raises the cost of signaling trustworthiness and reduces the opportunity costs of sticking to the collusive agreement when deviating from it, which offsets the benefit of signaling trustworthiness suspected in the context of duopolies.<sup>17</sup>

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<sup>14</sup> See Footnote 18.

<sup>15</sup> The difference between market prices in the first cartel period and those in all cartel periods is insignificant for all policies in N=4 markets (WRS test: p-values for FREE COMMUNICATION, FINES, LENIENCY >0.19).

<sup>16</sup> WRS test for differences in the number of deviations between N=2 markets and N=4 markets under FINES: p-value <0.07; under LENIENCY: p-value >0.9. WRS test for differences in the number of deviation between FINES and LENIENCY in the N=4 markets: p-value <0.03.

<sup>17</sup> The underlying logic might be related to the notion that "groups are trusted less", which is discussed in literature dealing with the "interindividual-intergroup-discontinuity effect" (see publications by Chester and Schopler). I pursue analyzing the role of this effect for the effectiveness of leniency programs in ongoing research.

Summarizing the discussion of potential explanations of the ineffectiveness of LENIENCY (in both  $N=2$  and  $N=4$  markets) and FINES (in  $N=2$  markets) with regard to the reduction of market prices in periods with explicit communication, I find that, in general, selection effects do not seem to drive high prices in LENIENCY as well as FINES. The existence of coordination effects in FINES and in LENIENCY is plausible, given that talk is costly if fines and reports enter the game. Additionally, enforcement effects driven by the fear of public reports seem to enhance cartel prices even more under LENIENCY. As a third driver of my unexpected findings concerning the effectiveness of the tested policies, strategic signaling appears to motivate participants to refrain from deviating in order to signal trustworthiness in the duopolies. As this effect is not present in the larger markets, cartel prices under FINES decrease significantly, compared to FREE COMMUNICATION and LENIENCY. Under LENIENCY, enforcement seems to be strong enough to attenuate this tendency.

Besides prices in cartel periods, I find differences in prices in non-cartel periods. First, duopolies seem to be able to coordinate tacitly, realizing higher prices than quadropolies in periods without communication. Accordingly, hysteresis effects are particularly pronounced in smaller markets, so that the gain from previous communication is larger for these markets and the need to re-establish new cartels is reduced, compared to larger markets.<sup>18</sup> In duopolies under LENIENCY, the level of tacit collusion after disruption is high enough to raise the overall price-level above that realized under FREE COMMUNICATION. In quadropolies under LENIENCY, markets do not benefit from higher prices after cartel disruption, so that LENIENCY generally does not perform worse than FREE COMMUNICATION in  $N=4$  markets.

An explanation of the decreased hysteresis under LENIENCY for  $N=4$  markets might be that in an environment in which being subject to defection does not necessarily imply zero fines after reporting, submitting lower prices in periods after being deceived could be preferred to punishing defectors via (costly) reports. Furthermore, in a situation of report-induced detection, market participants might punish reporting counterparts implicitly by submitting lower prices in the following round, thus reducing post-cartel market prices. The reason why these effects are pronounced in larger markets could be that re-establishing new explicit cartels is more difficult with more market participants and the loss incurred from defection and reporting is perceived as particularly severe, while the incentive to deviate from any cartel agreement is higher with more firms on a market. Hence, by offering prices significantly lower than the agreed-upon collusive price in periods after disruption, participants might try to play off other deceived market participants, who tactically set lower prices than the price defector. The descriptive results presented in Table 8 support this reasoning. Subject prices after being undercut are lower under LENIENCY compared to FREE COMMUNICATION and FINES in  $N=4$  markets (and this difference is also significant, WRS-test: FREE COMMUNICATION/FINES vs. LENIENCY  $p$ -values  $<0.01$ ), indicating that deviation is punished more harshly under LENIENCY in

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<sup>18</sup> Relaxing the assumption that communication is a necessary condition for cartels to be stable, a possible explanation for these market-size differences in hysteresis effects might simply be a higher incentive to deviate without communication. The discount-factor could be extended by a risk premium due to the lack of information on the state of mind of the other market participants.

quadropolies. In addition, undercutting seems to be punished more severely than reporting, as prices after reports are not as low as those after deception in the quadropolies. Metaphorically speaking, rather than being shy after being bitten, participants appear to bite back. Consequently, subjects also need to heal their wounds fast, as with declining prices, the desire to communicate and to agree on a common price grows. These dynamics may not be present in duopolies, where each player has to make assumptions concerning the decision of only one other player, the price-setting behavior of whom he might be able to anticipate due to strategic signals. Here, subjects can indeed afford to be shy after being bitten. This leads to relatively high market prices in non-cartel periods under LENIENCY in duopolies.

**Table 11: Reporting behavior, punishment and protection (in percent of 25 rounds).**

	Private reporting		Protection		Public reporting		Punishment		Unused reporting chances		All reporting chances exploited		All reporting chances	
	AV	SD	AV	SD	AV	SD	AV	SD	AV	SD	AV	SD	AV	SD
<b>N=2</b>	6.17	7.11	4.25	4.71	1.00	1.04	0.75	1.04	26.33	32.21	7.17	7.51	36.33	30.05
<b>N=4</b>	6.31	8.39	3.90	5.20	1.62	3.82	1.60	2.76	35.62	33.14	7.92	9.91	50.15	29.60

All values: average percentage share of 25 rounds.

AV: Average value over all subjects and rounds.

SD: Standard deviation.

Protection: Frequency of private reporting after deviating.

Punishment: Relative frequency of public reporting after being deceived.

The reasoning that reports are not used extensively as a punishment tool is supported further by the descriptive results of the reporting variables (Table 11), indicating that private reports have been used more often than public reports (on average), although both are only used rarely. Furthermore, Table 11 shows that if deceived, the average percentage frequency of subjects reporting publicly is only 1% in the duopolies and <2% in the quadropolies, representing very low rates of explicit punishment. In a similar vein, only roughly 6% of subjects use private reports after having undercut in the duopolies as well as in the quadropolies, so that protection effects are also a rare phenomenon. Reports are not used regularly as a punishment tool (which would imply public reporting), and neither in order to benefit from a race to the courtroom or to avoid being punished (which would suggest private reporting). However, reports (private and public) are generally used only rarely, which indicates that the opportunity to report might predominantly be used as an effective threat in order to stabilize collusive agreements.<sup>19</sup>

## 7 Conclusion

In summary, my data indicates that the effectiveness of leniency programs is indeed influenced by market size, as it is more effective in N=4 markets, compared to N=2 markets in terms of reducing price-hysteresis. However, independent of market size, the tested moderate leniency program with fine reductions for all

<sup>19</sup> With regard to differences in reporting behavior between smaller and larger markets, there are no significant differences between the N=4 markets and the N=2 markets (WRS-test for differences between N=2 and N=4 markets in terms of the reporting variables displayed in Table 11: all p-values > 0.2). This is in line with the suggestion that the differences in WTC between smaller and larger markets are due to the decreased benefit from hysteresis, rather than due to an increased number of opportunities to establish a new chat driven by an increased incidence of report-induced disruptions.

reporting parties does not perform well in terms of the deterrence and prevention of explicit collusion. A fines-only policy seems to work better in markets with four firms.

I also find evidence of hysteresis effects with regard to the willingness to establish a new cartel and prices, both with a policy based on fines-only and one based on a leniency program. These effects are generally stronger for smaller markets, as the need to establish a new explicit cartel is less pronounced in these markets. In line with these main findings, I support the notion that there are not more cartels the fewer the firms, but that smaller markets are generally able to establish higher market prices.

For future research, it would be useful to investigate whether the stronger incentives to deviate induced by a bonus system (i.e. positive rewards) would counterbalance the effects of my leniency program.<sup>20</sup> Additionally, an important and until now insufficiently answered question is how the results would change if participants were only provided with incomplete information on the decisions of other market participants or if the probability of detection<sup>21</sup> were not exogenously given.

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<sup>20</sup> As derived by Spagnolo (2005).

<sup>21</sup> For a discussion of these settings, see Chen and Harrington (2007); Harrington (2008).

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## Appendix

### A.1 Experimental Instructions for duopolies (translated from the original German)

*[All Treatments]*

Welcome to my experiment! Please read the instructions very carefully.

This experiment is expected to last about 1.5 hours. You will remain anonymous during and after the experiment for all other participants. The experimental data will not be saved along with your name, or with any other data that is clearly assignable to you. From now on (until the end of the experiment), I ask you to remain silent and to follow the instructions. Please do not talk to the other participants. If you have a question in the course of the experiment, please raise your hand and I will come to you.

In this experiment, you will have to make decisions repeatedly, and you can earn taler, depending on your decisions, as well as on the decisions of another participant taking part in the experiment. These taler will be exchanged for euro (in cash) immediately after the experiment. The exchange rate is

**30.000 taler = 1 euro.**

You will receive 120.000 taler (= 4 euro) as a starting budget. When you come to collect your earnings, please return all the documents you received. All participants get the same instructions.

**In summary, you are facing the following situation: You and another participant each represent a firm and produce and sell the same good on a market. The consumers will buy from the firm which sets the lowest price. The firm which sets the higher price cannot sell anything. If both firms set the same price, consumers will split their purchases evenly between both firms.**

*[Treatments FREE COMMUNICATION, FINES, LENIENCY]*

**It is possible for you to communicate with the other firm in the market before price decisions are made.**

*[Treatments FINES, LENIENCY]*

**However, with a probability of 15%, you have to make a payment (P) if you communicate.**

*[Treatment LENIENCY]*

**In addition, firms can report the communication to an authority, implying that the payment (P) is definitely due (100% probability), but reporting firms only have to pay a reduced payment (P).**

*[All Treatments]*

### **Firms and markets**

During this experiment, you are representing a firm, and there is also another firm (represented by another participant in this room) active in your market. Throughout the whole experiment you will operate with the same firm (i.e. participant) in your market. The firms have to set a price for a product. All firms in the market produce an identical good with no production costs.

The market includes **300 identical consumers**, each one of whom wants to buy one product unit at the lowest price. Each consumer is willing to pay a maximum of 100 taler for one unit of the product. Therefore, each firm can set a **price between 0 and 100 taler** (including 0 and 100, in whole numbers).

The profit earned by your firm depends on the prices of both active firms in the market. The firm setting the lowest price sells its products to all 300 consumers (i.e., this firm's price is the market price). The other firm will not sell any products and thus obtains zero profit. If both firms set the same price, consumers will be split equally between both firms, meaning that each firm sells 150 products. The profit earned by the firm you represent determines your personal profit in this experiment.

### Examples

1. Firm A sets a price of 95 and firm B of 90 taler. Firm B has set the lowest price and therefore sells all 300 units. The profit is  $90 \cdot 300 = 27,000$  taler. Firm A will not sell anything and will earn nothing.
2. Both firms A and B have set a price of 75 taler. Therefore, both firms sell 150 units at a price of 75 taler. The profit for both firms is  $75 \cdot 150 = 11,250$  taler.

*[All Treatments]*

### **Periods and earnings**

The experiment lasts **at least 25 rounds**. A new round begins as soon as all participants taking part in the experiment have made their decisions. After the 25<sup>th</sup> round, the computer will throw a virtual dice, which determines whether another round will be played. The experiment will be over if a six is thrown, otherwise another round will be played. This procedure is repeated after each successive round. Hence, the exact duration of the experiment is unknown, but I will end the experiment if it lasts more than 2.5 hours.

*[Treatments FREE COMMUNICATION, FINES, LENIENCY]*

### **Communication**

At the beginning of the first round, **both firms will be asked whether they want to communicate (=to chat) with each other, before price decisions are made.** If one of the firms decides against communication, there will be no communication in this round and the firms will be asked again at the start of the following round whether they wish to communicate. If both firms decide to communicate, a chat box will appear on your screen for 45 seconds before you can set prices. You may communicate through this chat box freely about anything you want, with just two restrictions: you are not allowed to identify yourself (e.g. reveal your name) or use offensive language. You will not receive any money if you violate these restrictions.

*[Treatment FREE COMMUNICATION]*

If both firms decide to communicate, you do not have to decide again whether you want to communicate. Communication remains enabled until the experiment ends.

*[Treatments FINES, LENIENCY]*

If both firms decide to communicate, communication remains enabled as long as you do not have to make a payment (P) (see next section). If a payment (P) has been due, the firms can decide again whether or not they want to communicate.

*[Treatments FINES, LENIENCY]*

### **Payment for communication**

If firms decide to communicate, they will have to make a payment (P) with a **15%** probability, while no payment (P) is due with an **85%** probability. A computer will decide randomly whether a payment (P) has to be made.

If not all firms decide to communicate with each other, no payment (P) will have to be made.

The payment (P) is determined by the **market prices charged in your market up to five rounds back.**

If the communication started less than five rounds back, only the rounds since the start of communication will be charged. The market prices from five rounds back will be aggregated and multiplied by 50:

**$P = 50 \times \text{the sum of the market prices since the start of communication, but not more than for the last 5 rounds, with a 15\% probability.}$**

### Examples

1. If, in Example 1, firms decided to communicate before setting the prices and if the payment (P) has to be made according to the random draw, the payment (P) will be equal to  $P=50 \times 90=4,500$  for each firm. Firm A would make a loss of 4,500 taler and firm B's payoff would be 27,000 minus 4,500 = 22,500. If the communication has been enabled for more rounds, the payment (P) is correspondingly larger.

2. In Example 2, both firms have chosen a price of 75. If the firms have decided in favor of communication, the payment (P) to be made after the random draw would be  $P=50*75=3,750$  taler for each firm. Both would earn  $11,250-3,750=7,500$  taler.

If communication has been enabled at this price of 75 for five rounds already, the payment (P) is  $P=5*50*75=18,750$  taler and neither firm will receive any earnings, but in fact incur a loss of  $11,250-18,750=-7,500$  taler in the specific round in which the payment (P) is due.

3. Let's stay with Example 2 and assume that no payment (P) has to be made according the random computer draw. The earnings for both firms will then remain at  $75*150=11,250$  taler.

Note once again that you do not necessarily have to make a payment (P) in every round. The probability is 15%. Consider also, that if no payment (P) is due in a specific round, communication as well as the risk of a payment (P) remains active in the next rounds, until you eventually have to make a payment (P). Therefore, it may be that you have to make a payment (P) in a round in which you did not actively use the chat box. That would be because all firms agreed to communicate in a previous round and no payment (P) has been due up to the current round. If a payment (P) has to be made, there is no more risk of further payments (P), unless all firms again agree to communicate.

[Treatment LENIENCY]

### Reporting

The firms have two opportunities to report the communication before the random computer draw decides whether a payment (P) has to be made. The first opportunity is directly after prices have been set, and the second is after all participants have been informed about the price of the other firm in the market. This latter report option is only available if the first option has not been taken up by any market participant. Reporting implies that the payment (P) is definitely due (100% probability). Yet, reporting firms receive a reduction of the payment (P):

- If only one of the two firms uses the report option, the reporting firm receives a 100% reduction of the payment (P) and the other firm has to make the full payment (P).
- If both firms decide to report, both will have to pay 50% of the payment (P).

If you report, you will therefore not have to make a payment (P) at all or 50% of the original payment (P), whereas in the case of no reporting, there is a 15% probability of making a payment (P), and an 85% probability of no payment (P), respectively.

*[All Treatments]*

### **Practice rounds**

Before the actual experiment starts, there are two practice rounds which do not influence final payoffs and which are independent of the main experiment. In the practice rounds, you do not necessarily interact with the same participant as in the main experiment.

### **Market outcomes and decisions**

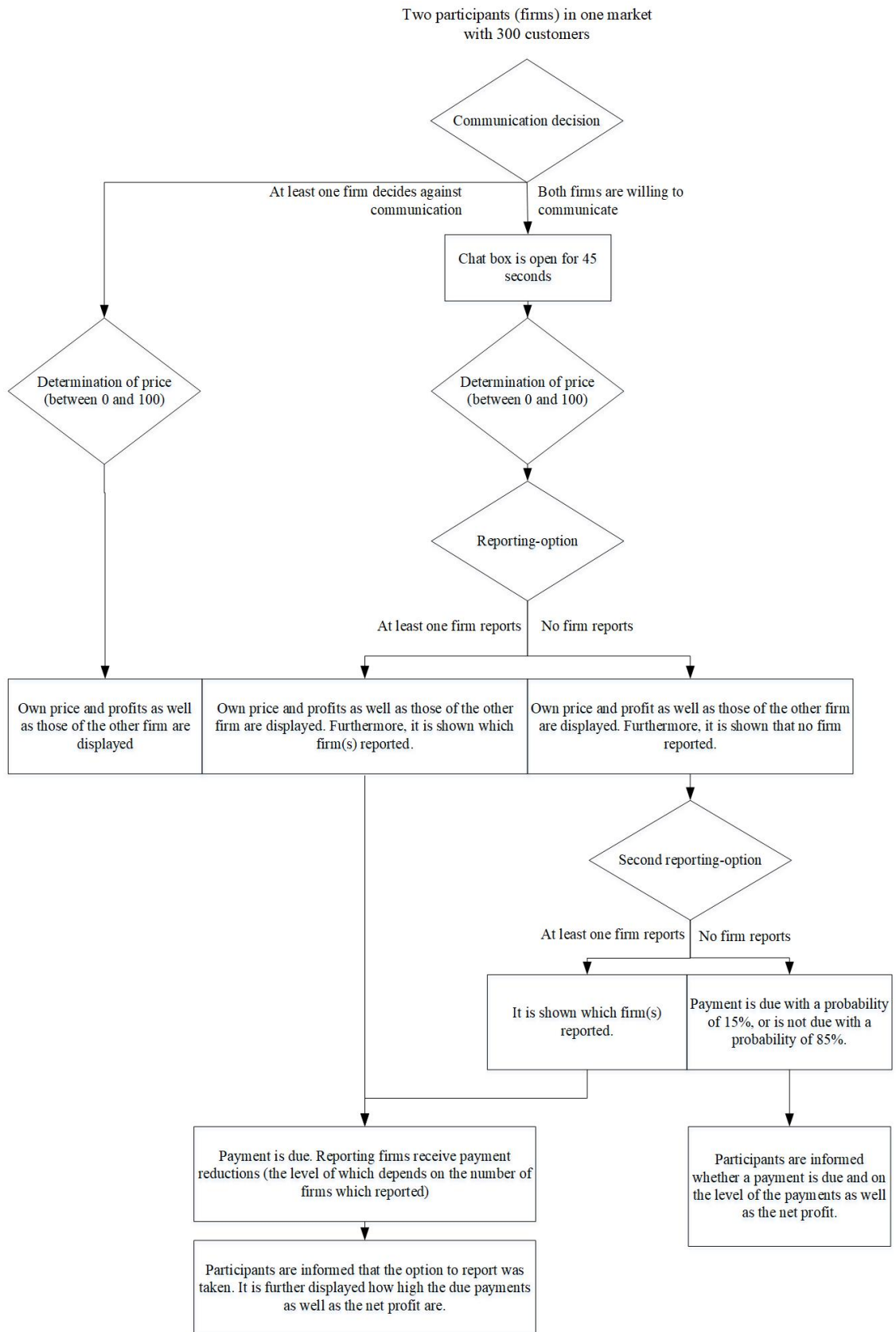
*[Treatment-abbreviations are used as follows: B=BENCHMARK; FC=FREE COMMUNICATION; F=FINES; L=LENIENCY]*

Each round runs as followed:

- 1 *[FC, F, L]* All firms decide if they wish to communicate or not.
  - 1.1 *[FC, F, L]* If all firms agree to communicate, a chat box appears for 45 seconds.
  - 1.2 *[FC, F, L]* If at least one firm did not agree to communicate, a screen will display how many firms did not want to communicate. No chat box appears.
- 2 *[B, FC, F, L]* You (and the other firm) set a price.
- 3 *[L]* If both firms agreed to communicate, the next step is the possibility to report the agreement.
- 4 *[B, FC, F, L]* The computer will calculate your selling quantity and profit. You will see the following information on your screen: the price chosen by your firm, the price set by the other firm and the profit for the current round of all firms. Profits are stated in taler. At the end of the experiment, you will be paid the total profit. Your total profit is calculated as the sum of all per-round profits plus your starting budget of 120,000 taler (= 4 euro).
- 5 *[B]* The accumulated profit since the first round will be shown. Afterwards, that round is over (a new round starts with step 2).
- 6 *[FC, F, L]* If the firms decided not to communicate, the accumulated profit since the first round will be shown. Afterwards, that round is over (go to step 9).
- 7 *[L]* If the firms decided to communicate, the screen will show whether, and if so, which firm reported the cartel. The following procedure differs according to whether or not the reporting option was used.
  - 7.1 *[L]* If at least one firm reported the cartel, a summary of the payment (P) and the net profits (gross-profit minus the payment (P)) will be displayed. Also, the accumulated profit since the first round will be shown. Afterwards, that round is over (go to step 9).
  - 7.2 *[L]* If no firm decided to use the reporting option, you will have a second chance to report after the prices and profits have been displayed.
    - 7.2.1 *[L]* If again no firm decides to use the reporting option, step 8 follows.
    - 7.2.2 *[L]* If at least one firm reported the cartel, a summary of the payment (P) and the net profits will be displayed. Furthermore, the accumulated profits since the first round will be shown. Subsequently, that round is over (go to step 9).

- 8 [F, L] If the firms decided to communicate, a payment (P) with a probability of 15% has to be made. The computer will show if any payments (P) have to be made and the level of the net profits. Afterwards, that round is over (go to step 9).
- 9 [FC, F, L] If, in the previous round, no communication took place, or if a random payment (P) was due, or if a report was made, the new round will start again with the question of whether or not to communicate. If you already decided to communicate, but no payment (P) was due and no reports were made, the chat box will appear immediately.

*[The following figure varied according to the specific treatment. This one is for LENIENCY]*



**Thank you for participating in my experiment and good luck!**