DISCUSSION PAPER SERIES

No. 9002

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INDUSTRIAL ORGANIZATION and PUBLIC POLICY

Centre for Economic Policy Research

www.cepr.org

Available online at: www.cepr.org/pubs/dps/DP9002.asp

ISSN 0265-8003

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Discussion Paper No. 9002

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CEPR Discussion Paper No. 9002

ABSTRACT

Trust and Deterrence*

This paper presents results from a laboratory experiment on the channels through which different law enforcement strategies deter cartel formation. With leniency policies offering immunity to the first reporting party a high fine is the main determinant of deterrence, having a strong effect even when the probability of exogenous detection is zero. Deterrence appears then mainly driven by 'distrust', the fear of partners deviating and reporting. Absent leniency, the probability of detection and the expected fine matter the most, and low fines are exploited to punish defections. The results appear relevant to several other crimes sharing cartels' strategic features, including corruption and financial fraud.

JEL Classification: C92, D03, K21, K42 and L41
Keywords: antitrust, betrayal, cartels, collusion, distrust, fines, leniency and whistleblowers

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* Many thanks to Tore Ellingsen, Dirk Engelmann, Joe Harrington, Benedikt Herrmann, Magnus Johannesson, Dorothea Kübler, Massimo Motta, Hans-Theo Normann, Henrik Orzen Nicola Persico and Georg Weizsaker for discussions and advice related to this project, and to audiences in Amsterdam (ACLE Conference, 2010), Berlin (WZB/RNIC Conference, 2008), Bologna, Gothenburg (Second Nordic Workshop in Behavioral and Experimental Economics, 2007), Mannheim (MaCCI Inaugural Conference 2012), Milan (EEA/ESEM Meeting, 2008), Mölle (SNEE, 2010), Princeton (ALEA Meeting, 2010), Rome (World ESA Meeting 2007, IAREP/SABE World Meeting 2008), Stockholm (EARIE 2011 and Konkurrensverket), Tilburg, and Vancouver (IIOC Meeting, 2010). We also gratefully acknowledge research funding from Konkurrensverket (the Swedish Competition Authority) that made this research possible.

Submitted 25 May 2012

1 Introduction

Cartels, like most other forms of organized economic crime (corruption, fraud, smuggling...), require effective cooperation between multiple wrongdoers. Being profitable in expectation is therefore not sufficient for them to be viable. Because illegal contracts cannot be enforced, the cooperative agreement must also be sustainable in equilibrium: each wrongdoer must prefer to respect the agreement rather than unilaterally deviate from it by 'running away with the money' (Stigler 1964). Beyond this, the wrongdoers must also coordinate on the cooperative equilibrium and trust that their partners, for the whole period of collaboration as well as after it, will not defect, e.g. by reporting to law enforcers.[1] A further peculiarity of these crimes is that there are always 'witnesses': cooperating wrongdoers typically end up having information on each other that could be elicited through suitably designed incentives to report.

These features imply that deterrence can be achieved through additional channels. While individual crime must be deterred by large enough expected sanctions (Becker 1968) – so that the individual Participation Constraint (PC) is violated – crimes like cartels can also be deterred:

- by ensuring that at least one co-offender's Incentive Compatibility Constraint (ICC) is violated, so that the crime – although profitable in expectation – is not an equilibrium; or
- by worsening the 'Trust Problem' (TP), i.e. each wrongdoer's fear that his partners will not stick to the illegal agreement, even if it is an equilibrium.

This paper reports results from a laboratory experiment investigating the deterrence properties of different law enforcement instruments against cartels. One of its purposes is to shed light on which of these multiple deterrence channels is more relevant under different law enforcement regimes.

We simulate a cartel formation game in the laboratory in which subjects play a repeated duopoly with uncertain end, and can choose whether or not to communicate illegally to fix prices. If players choose to communicate, they are considered as having formed an illegal conspiracy and fall liable to fines. Within this basic environment analogous to that in Bigoni, Fridolfsson, Le Coq, and Spagnolo (forth.) we run several treatments that differ in

[1] That criminal organizations require a lot of trust to function and pursue their illegal endeavors has been noted by a number of legal scholars in the past (see e.g. Leslie 2004, Von Lampe and Johansen 2004, and references therein).

the presence and size of the fine (F), in the probability (α) of detection by the competition authority, in the possibility of betraying partners by reporting information to the authority, and in the possibility of obtaining a lenient treatment by doing so.

In line with previous experimental work, we find that schemes granting leniency to the first wrongdoer that spontaneously 'turns in' his partners strongly increases deterrence. The novel and crucial finding of this work is that leniency appears to alter the main mechanism through which deterrence works.

Under standard law enforcement policies, i.e. absent leniency, deterrence increases more with *the expected fine* (αF), as predicted by classic 'Beckerian' law enforcement theory (crime becomes less profitable in expectation and the PC is tightened). With leniency, instead, *the actual fine* F becomes the main law enforcement component influencing behavior. Then wrongdoers react much less to changes in the probability of detection α. Most strikingly, we observe a very strong deterrence effect of F *even when* α *equals zero*.[2] These findings suggest that when leniency policies are present, the worsening of the Trust Problem – the increased fear and cost of being betrayed – tends to dominate other considerations.

We also find that in the absence of leniency, low fines and the possibility to report to law enforcers are used as a costly punishment to discipline cartel deviations, so that for sufficiently low fines deterrence falls with the fine even if the expected fine does not.

To the extent that these results are confirmed in future studies and apply outside the laboratory, they have important policy implications. They suggest that leniency policies limited to the first party that spontaneously reports, as in the US before the 1993 reform, can dramatically increase the efficiency of law enforcement if they are coupled with sufficiently robust sanctions. The results clearly point to the primary importance of complementing leniency-based revelation schemes with sufficiently severe sanctions rather than with a high probability of detection. The concern that the numerous recent leniency applications could undermine cartel deterrence by keeping competition authorities too busy to undertake independent audits (reducing α, see Riley 2007 and Chang and Harrington 2010) may in turn be less worrisome if sanctions are sufficiently robust and/or can be further strengthened. Our results also suggest that the risk that the legal system is strategically exploited to punish deviations and stabilize - rather than deter - cartels and similar crimes should be taken seriously in jurisdictions where sanctions are relatively low.

Our work contributes to a recent experimental literature evaluating the hard-to-measure

[2]A similar effect, although much smaller in size, is present even in the absence of leniency, provided self-reports are possible.

deterrence effects of differently designed leniency policies against cartels, which includes Apesteguia et al. (2007), Hamaguchi et al. (2007), Hinloopen and Soetevent (2008), Krajčová and Ortmann (2008), Bigoni et al. (forth.), and Hamaguchi et al. (2009) among others.[3] These studies are in turn based on the theoretical literature on leniency policies in antitrust, which extend to multi-agent conspiracies Kaplow and Shavell (1994)'s seminal analysis of self-reporting for individual crimes.[4] To our knowledge, ours is the first experiment considering different levels of fines and probabilities of apprehension together with leniency policies, and trying to disentangle the role of distrust from other possible channels through which law enforcement instruments may deter collaborative crimes.

Our work also relates to the large experimental literature on trust, recently surveyed in Fehr (2009). This literature suggests that trust is determined by various factors, including social preferences, fairness, guilt aversion and beliefs on others' trustworthiness.[5] The concept has typically a positive connotation since the focus of most studies is on pro-social forms of cooperation (see Gambetta 2000, and Knack and Zak 2003). In our context, trust is instead costly for society, and its most relevant component is probably 'trust as beliefs' (Fehr 2009; Sapienza, Toldra, and Zingales 2008), in that it defines the perceived likelihood that a partner wrongdoer sticks to the criminal plan rather than betraying the conspiracy.

The remainder of the paper proceeds as follows: The experimental design and procedures are described in Section 2. Section 3 derives theoretical predictions that form the benchmark for our tests. Section 4 reports the results and Section 5 concludes, discussing policy implications and avenues for further research. An appendix complements the paper, in particular with instructions for the leniency treatment.

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[3]Our work is also related to experiments on collusion and oligopoly like Huck et al. (1999), Offerman et al. (2002), Huck et al. (2004), Engelmann and Müller (2011) and Potters (2009).

[4]See Spagnolo (2004) for a theoretical study close to our experimental set-up. This literature, initiated by Motta and Polo (2003), highlights several possible reasons behind the apparent success of such policies but also some potential counterproductive effects, generating a number of hard-to-answer empirical questions. See Rey (2003) and Spagnolo (2008) for surveys. Brenner (2009) and Miller (2009) attempt to empirically identify the deterrence effects of leniency policies by looking at changes in the rate of detected cartels after the introduction of such policies. See also Chang and Harrington (2010), who introduce an alternative methodology based on observed changes in duration of detected cartels.

[5]See e.g. Berg et al. (1995), Fehr and List (2004), Kosfeld et al. (2005), Charness and Dufwenberg (2006), Falk and Kosfeld (2006) and Guiso et al. (2008) among others.

2 Experimental Design

Subjects played repeated duopoly games in anonymous two-person groups, participating in a single treatment only - a *between subjects* design. In every stage game, the subjects had to take three types of decisions. First, subjects had to choose whether or not they wanted to communicate and discuss prices, thereby forming an illegal price-fixing conspiracy (cartel). Second, they had to choose a price in a discrete Bertrand game with differentiated goods summarized in payoff Table 1. In the unique Bertrand equilibrium, both firms charge a price equal to 3 yielding per firm profits of 100 and the joint profit maximizing price is 9, yielding profits of 180. Subjects were provided with the table only and were not informed about the details of the game.[6] Third, the subjects could choose to self-report their cartel to a competition authority.

Whenever two subjects formed a cartel, a competition authority could detect it and convict its members for price fixing. Detection/conviction could happen in two ways. First, in every period, the competition authority detected and convicted cartels with an exogenous probability, α. If this happened, both cartel members had to pay an exogenous fine, F. Second, cartel members could self-report, in which case they were convicted for price fixing with certainty. If this happened, the size of the fine depended on the details of the law enforcement institution, our first treatment variable. The Fine treatments correspond to traditional antitrust laws without any leniency program: if a cartel was reported, both cartel members (including the reporting one) had to pay the full fine F. The Leniency treatments correspond to antitrust laws with a leniency program: if the cartel was reported by one of the cartel members only, the reporting member paid no fine while the other paid the full fine, F; if instead both cartel members reported the cartel simultaneously, both paid a reduced fine equal to $F/2$.

The second treatment variable is the mix between the per-period probability of detection (α) and the size of the actual fine (F). For each policy, Fine and Leniency, we implemented two treatments with an expected fine (αF) of 20: one with a high probability of detection ($\alpha = 0.10$) and a low fine ($F = 200$), the second with a low probability of detection ($\alpha = 0.02$) and a high fine ($F = 1000$). We also ran a treatment with a zero probability of detection (and thus a zero expected fine) but with a high fine ($F = 1000$) in case of a report. Finally, our baseline treatment L-Faire corresponds to a laissez faire regime where forming a cartel by discussing prices is legal ($\alpha = F = 0$).[7] The differences

[6] Appendix A presents the Bertrand game in more detail.

[7] To simplify the instructions and to eliminate irrelevant alternatives, subjects were not allowed to report

		your competitor's price												
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
your price	**0**	0	0	0	0	0	0	0	0	0	0	0	0	0
	1	29	38	47	56	64	68	68	68	68	68	68	68	68
	2	36	53	71	89	107	124	128	128	128	128	128	128	128
	3	20	47	73	100	127	153	180	180	180	180	180	180	180
	4	0	18	53	89	124	160	196	224	224	224	224	224	224
	5	0	0	11	56	100	144	189	233	260	260	260	260	260
	6	0	0	0	0	53	107	160	213	267	288	288	288	288
	7	0	0	0	0	0	47	109	171	233	296	308	308	308
	8	0	0	0	0	0	0	36	107	178	249	320	320	320
	9	0	0	0	0	0	0	0	20	100	180	260	324	324
	10	0	0	0	0	0	0	0	0	0	89	178	267	320
	11	0	0	0	0	0	0	0	0	0	0	73	171	269
	12	0	0	0	0	0	0	0	0	0	0	0	53	160

Table 1: **Profits in the Bertrand game**

between the treatments are summarized in table 2.

Treatment	fine (F)	probability of detection (α)	report	report's effects
	200	0.10		
Fine	1000	0.02	Yes	pay the full fine
	1000	0		
	200	0.10		no fine
Leniency	1000	0.02	Yes	(half the fine
	1000	0		if both report)
L-Faire	0	0	No	–

Table 2: **Treatments**

2.1 Experiment's timing and rematching procedure

At the end of each period, subjects were re-matched with the same competitor with a probability of 85%. With the remaining probability of 15%, all subjects were randomly matched into new pairs. If so, cartels formed in the previous match could no longer be fined. The experiment lasted at least 20 rounds. From round 20 on, the experiment ended with a termination probability of 15% and the re-matching probability equaled 0. To pin down expectations on very long realizations, subjects were also informed that the game would end after 2 hours and 30 minutes. This possibility was unlikely and never occurred. This re-matching procedure minimized problems with end game effects and allowed us to observe the subjects' behavior in several repeated games.

2.2 The timing of the stage game

With the exception of L-Faire, a stage game consisted of 7 steps. In L-Faire, steps 4, 5 and 6 were skipped.

Step 1: Communication decision. Each subject was asked whether or not he wished to communicate with his competitor. If both subjects pushed the yes button within 15 seconds, the game proceeded to step 2. Otherwise the two subjects had to wait for 30

cartels in L-Faire. In all other treatments cartel members were allowed to report cartels in which they participated.

seconds before pricing decisions were taken in Step 3. In all periods, subjects were also informed whether or not a re-match had taken place.

Step 2: Communication. If both subjects decided to communicate in step 1, the program prompted them to state simultaneously a minimum acceptable price in the range $\{0, ..., 12\}$. When both had chosen a price, they entered a second round of price negotiations, in which they could choose a price from the new range $\{p_{min}, ..., 12\}$, where p_{min} equaled the minimum of the two previously chosen prices. This procedure went on for 30 seconds. The resulting minimum price was referred to as the agreed upon price.[8]

Step 3: Pricing. Each subject had to choose his price from the choice set $\{0, ..., 12\}$. Price agreements in step 2 were non-binding. The subjects were informed that if they failed to choose a price within 30 seconds, then their default price would be so high that their profits became 0.

Step 4: Secret Reports. If communication took place in the current period or in one of the previous periods and had not yet been detected, subjects had a first opportunity to report the cartel. Reports in this step are referred to as 'secret'.

Step 5: Market prices and public reports. Subjects learned the competitor's price choice. If communication took place in the current period or in one of the previous periods without being detected and no one reported it in step 4, subjects had a new opportunity to report the cartel. The crucial difference between this 'public' report and the secret one is that subjects knew the price chosen by their competitor. In addition, the subjects were informed about their own profits and the profits of their competitor, gross of the possible fine.

Step 6: Detection. If communication took place in the current period or in one of the previous periods without being discovered or reported before (in steps 4 and 5), the cartel was detected with probability α.

Step 7: Summary of the current period. At the end of each period, all the relevant information about the stage game was displayed: the agreed upon price (if any), prices chosen by the two players, possible fines and net profits. When players were fined, they were also told how many players reported.

Note that subjects had two opportunities to report the cartel, before and after being informed about the price chosen by their opponent. Reports could thus serve two purposes: deviating subjects could report to protect themselves against prosecution; and cheated

[8]This iterative procedure helped the subjects to agree on a minimum acceptable price in a reasonably short lapse of time.

upon subjects could report to punish their opponents, if they had deviated but not reported earlier.

2.3 Experimental procedure

Our experiment took place in May 2007 at Tor Vergata University (Rome, Italy).[9] Sessions lasted on average 2 hours, including instructions and payment. We ran seven sessions (one per treatment), with 32 subjects per session. The experiment involved 224 subjects in all.[10] The average payment in the main game was €23.60, with a minimum (maximum) of €11 (€34) and a variance of €13.60.

The experiment was programmed and conducted with the software z-Tree (Fischbacher 2007). At the beginning of each session, subjects were welcomed in the lab and seated, each in front of a computer. When all subjects were ready, a printed version of the instructions and the profit table were distributed to them. Instructions were read aloud to ensure common knowledge of the rules of the game. The subjects were then asked to read the instructions on their own and ask questions, which were answered privately. When everybody had read the instructions and there were no more questions (always after about fifteen minutes), subject were randomly matched into pairs for five practice rounds; they were informed that profits realized during these rounds would not affect their earnings. After the practice rounds, participants had a final opportunity to ask questions and again were answered individually. Then they were randomly rematched into new pairs and the real game started.

At the end of each session, subjects were paid in private in cash. Subjects started with an initial endowment of 1000 points in order to reduce the likelihood of bankruptcy. At the end of the experiment, subjects were paid an amount equal to their cumulated earnings (including the initial endowment) plus a show up fee of €7. The conversion rate was 200 points for €1.

3 Theoretical predictions and Hypothesis

Our design ensures that forming a cartel by communicating on prices is an equilibrium in all treatments (see Appendix C.1). No hypotheses can thus be stated on the ground

[9] Fine with $\alpha = 0$ and $F = 1000$ was run in an additional session, taking place at Tor Vergata University in December 2007. The students who participated in previous sessions were not admitted.

[10] Table 2 in Appendix B reports more detailed information on the 9 experimental sessions.

that collusive outcomes do not constitute an equilibrium in some of the treatments. The strictness of the participation and of the incentive constraints for collusive equilibria change under different reporting regimes, as does the cost of being betrayed by a trusted partner.

Standard Equilibrium Conditions and Deterrence The participation constraint (PC) and incentive compatibility constraint (ICC), two necessary conditions for the existence of a collusive equilibrium, provide valuable insights on possible effects of law enforcement institutions. All else equal, the PCs in Fine and Leniency treatments are identically tighter than in L-Faire due to the expected fine payment. Moreover the ICCs are tighter in Leniency than in Fine or in L-Faire, since a deviation in Leniency is optimally combined with a secret report providing protection against the fine.[11] Under the standard assumption that stricter equilibrium conditions make it harder to sustain the equilibrium, deterrence should be stronger in treatments where the PC and ICC are tighter.

The ICCs presume that agents are perfectly able to coordinate on the collusive equilibrium. Even if cooperation constitutes an equilibrium, agents could however be discouraged from forming a cartel by the fear of miscoordination, and even more by the fear of being 'cheated upon' by the opponent. Recent theoretical and experimental work has shown that the fear of being cheated upon and receiving the 'sucker's payoff' constitutes a crucial determinant of subjects' decisions to cooperate (Bohnet et al. 2008; Blonski et al. 2011; Dal Bó and Fréchette 2011). We therefore provide a simple formal analysis of the demand for trust required to enter an illegal price-fixing conspiracy in the spirit of (Spagnolo 2004) and we show how this demand varies across treatments/law enforcement regimes.

Demand for Trust and Deterrence To assess the potential impact of trust on deterrence, we first define the *minimum level of trust* in the opponent that is necessary to make profitable the choice of joining a price-fixing conspiracy. Assume that a subject believes that following communication on the collusive price, his opponent will undercut the agreed upon price with some probability $(1-\beta)$. The complementary probability β can then be viewed as the agent's 'belief component of trust' in a partner conspirator (see e.g., Fehr 2009, Sapienza et al. 2008). The *minimum level of trust*, β_K, required to make price-fixing collusion profitable and sustainable in treatment $K \in \{L-Faire, Fine, Len\}$ can then

[11] Appendix C.1 provides a formal analysis underlying these claims. See also Spagnolo (2004) for an in-depth discussion.

be viewed as a measure of the 'demand for trust' in this treatment. Collusion is then sustainable if $\beta \geq \beta_K$.

Let V_K^{ss} (V_K^{ds}) denote the values of sticking to (deviating from) the collusive agreement in treatment K, assuming the opponent is trustworthy (i.e., sticks to the agreement). Similarly, let V_K^{sd} and V_K^{dd} denote these values, assuming instead that the opponent is not trustworthy (i.e., undercuts the agreed upon price). Then β_K is defined by the equality $\beta_K V_K^{ss} + (1-\beta_K)\, V_K^{sd} = \beta_K V_K^{ds} + (1-\beta_K)\, V_K^{dd}$, or equivalently

$$\beta_K = \frac{\left(V_K^{dd} - V_K^{sd}\right)}{\left(V_K^{dd} - V_K^{sd}\right) + \left(V_K^{ss} - V_K^{ds}\right)}. \tag{1}$$

β_K is thus determined by two components, $V_K^{ss} - V_K^{ds}$ and $V_K^{dd} - V_K^{sd}$. This measure, reminiscent of the 'basin of attraction' or 'resistance' of the cooperative strategy as defined in evolutionary game theory (see Myerson 1991, sect. 7.11) and of Blonski et al. 2011's selection criterion have been used in recent experiments to measure the importance of the sucker's payoff in a prisoner's dilemma (see Dal Bó and Fréchette 2011.). Presumably subjects are less willing to form cartels when the demand for trust increases. A reasonable conjecture is thus that deterrence increases as β_K increases (as the basin of attraction shrinks).

Appendix C.2 provides a formal expression for β_K and characterizes for each treatment the minimum level of trust, showing that $\beta_{L-Faire} = \beta_{Fine} < \beta_{Len}$. The amount of trust required by the price-fixing conspiracy is thus higher in LENIENCY (but not in FINE) than in L-FAIRE. The reason is twofold. First, an optimal deviation is combined with a simultaneous report under LENIENCY, which increases the cost of trusting a deviating partner. Second, in case the opponent cheats (i.e. undercuts and simultaneously reports), a player avoids paying half the fine by also undercutting and reporting. By contrast, the decision whether to undercut does not affect the expected fine payment absent leniency.

Hypotheses Under the assumptions that tighter PCs and ICCs as well as a higher demand for trust increase deterrence, the above analysis leads to the following hypotheses.

Hypothesis 1 (policy effects) Given α and F, deterrence is lowest in L-FAIRE, followed in order of magnitude by FINE and LENIENCY.

The deterrence effect of FINE relative to L-FAIRE is driven only by different PCs. Both the ICC and the minimum level of trust drive the higher deterrence effect of LENIENCY relative to FINE.

To disentangle the effects of the ICCs and the minimum level of trust, we now turn to the deterrence effects of changes in α and F, taking the policy as given. An increase in the *per period expected fine* αF increases the *discounted expected fine payment* EF and thereby tightens the PC for all policy treatments. The effect on the ICC and on β_K, however, depends on whether the policy includes leniency. Absent leniency, the change has no effect, neither on the ICC, nor on β_{Fine} since the expected fine payment EF is the same under FINE whether one, two or no cartel member undercut the agreed upon price. By contrast, the ICC is tightened under LENIENCY, since a deviation combined with a secret report protects against the increased expected fine payment, EF. For the same reason, β_{Len} also increases. These observations are discussed formally in Appendix C.3 and lead to our second hypothesis.

Hypothesis 2 (increased expected fine) An increase in the per period expected fine increases deterrence both under FINE and under LENIENCY.

It is not clear under which policy the deterrence effect following an increase in αF is strongest. The change tightens only the PC under FINE whereas under LENIENCY it also tightens the ICC and increases β_{Len}. This suggests that the effect should be stronger under LENIENCY. On the other hand, the starting pool of cartels may be larger under FINE than under LENIENCY (especially so if Hypothesis 1 is true) which may strengthen the deterrence effect under FINE.

Consider now an increase in F compensated by a fall in α so as to keep αF constant. Such a change tightens the PC in all policy treatments, but also tightens the ICC in LENIENCY and increases β_{Len}. The effect on β_{Len} is further magnified as the increase in F *per se* increases the cost of being betrayed, lowering the sucker's payoff (since a defecting subject also reports the cartel, which increases $V^{dd}_{Len} - V^{sd}_{Len}$). These observations are given a more formal treatment in Appendix C.4 and lead to our third hypothesis.

Hypothesis 3 (constant expected fine) An increase in F compensated by a fall in α so as to keep the per period expected fine constant increases deterrence both under FINE and LENIENCY.

The deterrence effect under FINE is driven solely by an increase in the expected fine payment, EF, which tightens the PC. This increase may be viewed as subtle; it is difficult to calculate and not very intuitive as EF increases despite the fact that the per period expected fine αF is constant. One may conjecture therefore that subjects are unable to compute EF accurately, in the lab and in reality. By contrast, the increased deterrence effect under Leniency is driven also by the increase in F, which worsens the sucker's payoff, increasing the demand for trust. This line of reasoning suggests that an increase in F compensated by a fall in α so as to keep αF constant will primarily increase deterrence under Leniency. Still one cannot fully rule out that the effect is stronger under Fine as Hypothesis 1 suggests that the starting pool of cartels may be larger.

The distinction between EF and αF is redundant when $\alpha = 0$ (but $F > 0$). Then $EF = \alpha F = 0$ and according to the PC and the ICC, Fine and Leniency should have no deterrence effect relative to L-Faire. The fact that the sucker's payoff is much worse under Leniency than under Fine and L-Faire motivates our last hypothesis, however (see also Appendix C.5).

Hypothesis 4 (zero expected fine) With a zero probability of detection, a positive fine generates deterrence under Leniency but not under Antitrust.

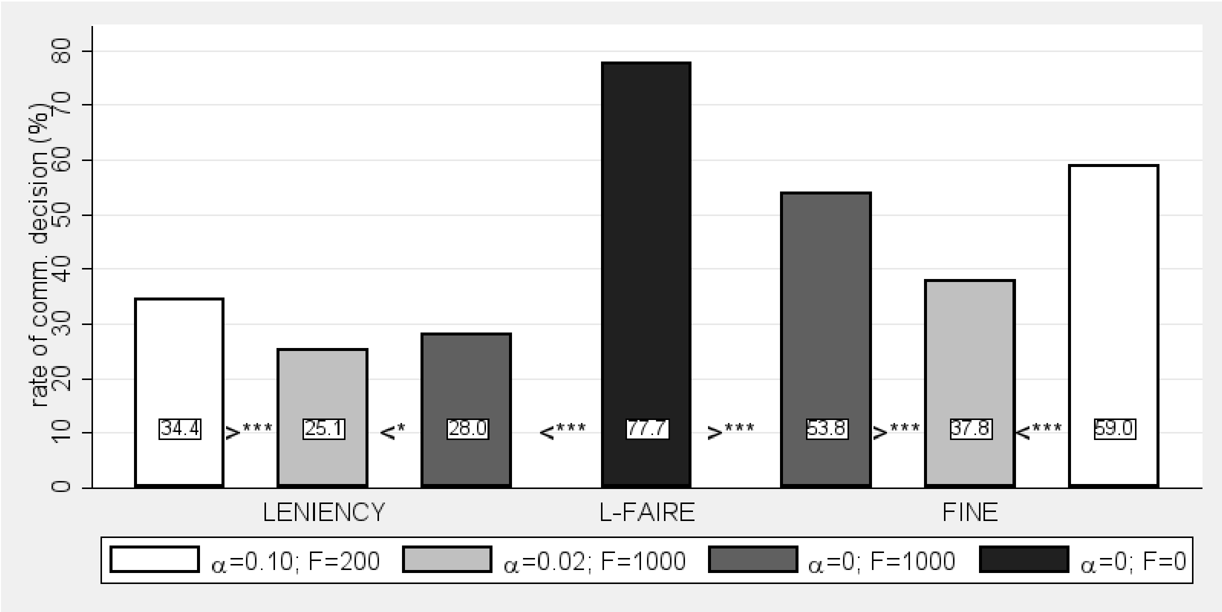
4 Results

Figure 1 provides an overview of how the legal framework affected the subjects' decisions of forming a cartel. Its most striking feature is probably that the introduction of a positive and substantial fine ($F = 1000$) induced deterrence even with a probability of detection α equal to 0, particularly when a leniency program was in place. In addition an introduction of a positive but small probability of detection ($\alpha = 0.02$) increased deterrence primarily in the Fine treatment; and a reduction in the fine ($F = 200$), compensated by an increase in the probability of detection so as to keep the expected fine constant ($\alpha F = 20$), decreased deterrence both with and without leniency.

The figure also reports statistical tests on the differences in the rates of communication decisions across treatments. These tests are based on *logit* regressions with 3-level random effects, to account for potential correlations among observations from the same subject and from the same duopoly.[12]

[12] Each regression compares pairs of treatments to assess the size and significance of the impact that a change in the size of the actual and expected fine has on deterrence, with and without leniency programs. In all these regressions, the dependent variable is the binary decision whether to communicate or not when subjects would not otherwise be liable for collusion. The main independent variable is a dummy taking value one for the treatment of interest, and zero for the reference treatment. Standard errors are robust for heteroskedasticity. See Appendix D for further details.

Figure 1: rates of communication decision



Note: The symbols ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively. See Appendix E.1 for the full regressions' results.

We will return to Figure 1 throughout the discussion of our results. Before doing so, we note that in line with our assumption in Section 3 and consistently with the large experimental literature on communication and coordination (see e.g., Crawford 1998), actual communication was critical for sustaining high prices in all treatments. On average, prices were equal to 3.5 when no communication took place, and 5.6 when it did. The difference was even bigger in the Fine (3.5 vs. 6.3) and the Leniency (3.6 vs. 6.7) treatments. See Table E.2.1 in Appendix E.2 for more details on prices.

We now turn to an in-depth discussion of our data, presenting first the results from the Leniency treatments.

4.1 Distrust and deterrence under Leniency

Standard theories of law enforcement do not predict that leniency programs will deter cartel formation due to the fear of being reported. The reporting behavior in the Leniency treatments suggests that these theories thereby may fail to capture an important deterrence channel; the majority of subjects undercutting the agreed upon price in the Leniency treatments did indeed simultaneously report the cartel (see Table E.3.1 in Appendix E.3). Our main result further corroborates the failure of the standard theories in explaining our experimental data:

Result 1. *A positive fine substantially increases deterrence under* Leniency *even if the probability of detection* α *equals 0.*

Result 1 reflects the large drop in the rate of communication decisions when we compare the Leniency treatment where $\alpha = 0$ and $F = 1000$ with L-Faire; the rate of communication decisions decreases by nearly 50 percentage points and the effect is highly significant (see Figure 1 and Table E.1.1a in Appendix E.1). The finding is consistent with Hypothesis 4 and suggests that the threat of being reported in the Leniency treatment severely undermines trust among potential criminal partners, reducing their willingness to form cartels.

The potentially important policy implication is that leniency programs may have a non trivial deterrence effect even when no resources are devoted to crime detection. It could even be optimal to divert all enforcement resources to other tasks than crime detection (for example to the prosecution of reported cartels), particularly so if non distorting fines are more efficient in deterring crime than costly audits and dawn raids. To shed some light on this issue, we now investigate the effects of changes in both the probability of detection and the fine on the subjects' propensity to form cartels.

Result 2. *Under* Leniency *a reduction in the probability* α *of detection, compensated by an increase in the fine* F *so as to keep the expected fine* αF *constant, significantly increases deterrence.*

Result 2 reflects differences in the rates of communication decisions across our three Leniency treatments. The comparison between the Leniency treatments with the same large fine ($F = 1000$) but different probabilities of detection ($\alpha = 0$ and $\alpha = 0.02$) indicates that an increase in the expected fine through an increase in the probability of detection only marginally increases deterrence; the rate of communication attempts falls by 2.9 percentage points and the effect is significant at the 10% level only. (see Figure 1 and Table E.1.1b in Appendix E.1) The relatively small deterrence effect induced by an increase in the probability of detection suggests that the tightening of the PC and the ICC plays a minor role when leniency programs are in place. The worsening of the trust problem linked to a large fine F appears instead the most important channel through which leniency generates deterrence.

The comparison between the Leniency treatments with the same expected fine but different mixes of α and F (i.e. the treatments where $(\alpha, F) = (0.02, 1000)$ and $(\alpha, F) =$

$(0.1, 200)$) corroborates this interpretation. The large reduction in the fine from 1000 to 200 substantially reduces deterrence despite the simultaneous increase in the probability of detection; the rate of communication attempts increases by 9.3 percentage points and the effect is significant at the 1% level (see Figure 1 and Table E.1.1c in Appendix E.1). The fine thus appears to be the most efficient tool in terms of deterrence, a finding which further points to the trust problem as the main deterrence channel under leniency.

4.2 Deterrence mechanisms under traditional law enforcement

This section focuses on the Fine treatments. The purpose is to identify channels through which deterrence works absent leniency and to contrast these channels with those at work under leniency. Our first finding suggests that low fines may have perverse effects.

Result 3. *A reduction in the fine F, compensated by an increase in the probability of detection α so as to keep the expected fine αF constant, substantially reduces deterrence even absent leniency.*

Result 3 reflects the sharp increase in the rate of communication decisions when we compare the Fine treatment where $\alpha = 0.1$ and $F = 200$ with the treatment where $\alpha = 0.02$ and $F = 1000$; the rate of communication decisions increases by 21.2 percentage points and the effect is highly significant (see Figure 1 and Table E.1.1a in Appendix E.1).

The strong reduction in deterrence is puzzling: according to Hypothesis 3, the change should at most have a marginal effect. However, the subjects may have perceived the use of costly reports as a credible threat against deviations when the fine was moderate. A first piece of evidence consistent with this explanation is that in the Fine treatment with the low fine, reports were used to punish cheating opponents in 19.7% of the instances it was possible to do so whereas costly reports were used in only 2.7% of those instances when $\alpha = 0.02$ and $F = 1000$. To further investigate this potential explanation, we ran the additional NoReport treatment, a Fine treatment without the possibility of reporting where $\alpha = 0.1$ and $F = 200$. The data reveal that removing the possibility to report substantially increases deterrence; the average drop is highly significant (see Table E.1.1a in Appendix E.1). This suggests that the possibility to report was perceived as an additional credible costly punishment tool against defections when the fine was low enough and thereby reduced deterrence.

Our final result sheds light on the role of the expected fine in law enforcement environments without leniency.

Result 4. *An increase in the expected fine αF through an increase in the probability of detection α increases deterrence significantly absent leniency.*

Result 4 reflects the substantial decrease in the rate of communication decisions when we compare the Fine treatment where $\alpha = 0.02$ and $F = 1000$ with the treatment where $\alpha = 0$ and $F = 1000$; the rate of communication decisions decreases by 16 percentage points and the effect is highly significant (see Figure 1 and Table E.1.1a in Appendix E.1). Under traditional law enforcement policies without leniency, deterrence thus increases with *the expected fine αF* as predicted by classic law enforcement theory (crime becomes less profitable in expectation and the PC is tightened).

Although an increase in the expected fine αF also induces some deterrence when a leniency program is in place, the effect is then significantly smaller. Instead it is the size of the fine F per se, and its potential to worsen the trust problem, which appears to explain the bulk of the deterrence effect associated with leniency programs. This further underscores that deterrence works very differently with and without leniency. Insofar the fine has any role in the Fine treatments other than affecting the expected fine, it appears to enforce cartel discipline (provided it is not too large) and thereby reduce deterrence.

For the sake of completeness, we finally compare the Fine treatment where $\alpha = 0$ and $F = 1000$ with L-Faire. At first sight, this comparison may suggest that after all the fine per se may have a deterrence effect even absent leniency, although the effect is now much smaller. The introduction of the fine indeed reduced the rate of communication decisions by 23.9 percentage points and the effect is highly significant (see Figure 1 and Table E.1.1a in Appendix E.1). In our view, this effect ought to be at least partly artificial as it is likely to reflect a framing effect. The description of the reporting possibility in the instructions of Fine may indeed have rendered the possibility of a mistaken report too salient to subjects relative to what is likely in real world enforcement absent leniency.

5 Conclusion

Our laboratory experiment explores the relative strength of several deterrence channels that may dissuade the formation of cartels and analogous crimes. Prisoner's Dilemma-like leniency policies, restricted to the first party that spontaneously reports, appear to produce a strong cartel deterrence effect mainly through 'induced distrust'. By increasing the likelihood and the cost of being betrayed by a partner, leniency generates a higher demand for trust among criminals, hence less crime for any given level of trust. Then a high absolute level of the fine is the most important determinant of deterrence, effective even if there is no risk of being detected by the law enforcement agency without a report.[13]

More traditional deterrence channels appear more important in the absence of leniency policies, as the probability of detection and the expected fines have a stronger influence on deterrence. Still, low fines are not advisable, as they are used strategically as punishments to stabilize rather than deter cartels.

To the extent that these results apply to real world settings they have important policy implications. They suggest that the benefits of tough sanctions may have been underestimated in the case of cartels and similar crimes. When reporting is an option, tough sanctions have a direct effect on deterrence independent of their well known effect on the level of the 'Beckerian' expected sanction. This effect is particularly strong when well designed leniency policies make betrayal and self-reporting highly attractive and likely. Our results suggest that recent concerns that too many leniency applications undermine cartel deterrence by keeping competition authorities too busy to run industry audits should be addressed with higher fines. They also point at the possibility that an enforcement regime with too low fines might actually harm welfare.

Interesting avenues for future research include in our view robustness checks, like changes in the parametrization and the framing of the experiment (although recent work by Krajčová and Ortmann 2008 suggests that our results should be robust); and studying whether the structure of criminal organizations reacts and adapts to the introduction of novel law enforcement methods, a possibility suggested by recent theoretical work (e.g. Garoupa 2007, and Baccara and Bar-Isaac 2008). It would also be interesting to try to identify and quantify experimentally the possible role played by 'betrayal aversion' (Bohnet et al. (2008)). An additional perceived cost of being betrayed by a peer relative to that of being discovered and fined by a more neutral 'law enforcement agency' may indeed have contributed to the strong deterrence effect of leniency in our experiment.

[13]It is worth noting that these findings are consistent with Blonski et al. (2011), who in a more abstract set up characterize and experimentally document the crucial role played by the cost of miscoordination as a determinant of subjects' ability to sustain cooperation.

A The Bertrand game

Consider the following standard linear Bertrand duopoly game in differentiated goods. The demand function for each firm i is given by:

$$q_i(p_i, p_j) = \frac{a}{1+\gamma} - \frac{1}{1-\gamma^2}p_i + \frac{\gamma}{1-\gamma^2}p_j$$

where p_i (p_j) is the price chosen by firm i (firm j), a is a parameter accounting for the market size and $\gamma \in [0, 1)$ denotes the degree of substitutability between the two firms' products. Each firm faces a constant marginal cost, c, and has no fixed costs. The profit function, $\pi_i(p_i, p_j)$ is thus given by $\pi_i(p_i, p_j) = (p_i - c)q_i(p_i, p_j)$. In the experiment, we chose $a = 36$, $c = 0$ and $\gamma = 4/5$ and subjects' price choice set was restricted to $\{0, 2, ..., 22, 24\}$. To simplify the table, prices were divided by 2 and payoffs rounded to the closest integer. These parameters yield payoff Table 1, distributed to each subject. In the unique Bertrand equilibrium, both firms charge a price equal to 3 yielding per firm profits of 100. The monopoly price (charged by both firms) is 9, yielding profits of 180. Note also that a firm would earn 296 by unilaterally and optimally undercutting the monopoly price, i.e., by charging a price of 7. In this case the other (cheated upon) firm earns a profit of only 20. Similarly, there are (lower) gains from deviating unilaterally from prices in the range of $\{4, ..., 8\}$, and associated (lower) losses for the cheated upon firm.

B Experimental Sessions

The table below provides additional details about each session: when and where they were conducted, the number of subjects in each session, and the number of periods and matches.

Treatment	**date**	**n. of subjects**	**n. of periods**	**n. of matches**
Fine	31/05/2007	32	26	6
	04/06/2007	32	27	2
	14/12/2007	32	25	3
Leniency	04/06/2007	32	25	2
	05/06/2007	32	26	3
	08/06/2007	32	22	3
L-Faire	30/05/2007	32	23	4

Table B.0.3: **Treatments**

C Appendix to the theoretical predictions

C.1 Existence of collusive equilibria

Our experimental design implements a discounted repeated (uncertain horizon) price game embedded in different antitrust law enforcement institutions. Experimental evidence shows that communication helps subjects coordinating on cooperation (see Crawford 1998). In line with these findings, the simple analysis below presumes communication (i.e., cartel formation) to be a prerequisite for successful cooperation (collusion). Its purpose is to reach sensible testable hypotheses, not to derive the whole equilibrium set.

For simplicity we assume throughout this section that the subjects must communicate once to establish successful collusion, but are able to collude tacitly following a detection by the competition authority.[14] Cartel members thus risk to be fined once on the collusive path. Given a per period probability of detection α, a fine F and a discount factor δ (the probability of being re-matched with the same competitor in the next period), the per period expected fine is given by αF and the expected fine payment by $EF = \alpha F + (1-\alpha)\,\delta EF$, or equivalently

$$EF = \frac{\alpha F}{1-(1-\alpha)\,\delta}. \tag{EFine}$$

The Participation Constraint (PC) The PC states that the gains from collusion should be larger than the expected cost. Assuming that across periods and treatments, cartels charge the same price on the collusive path, the PCs in L-Faire and in the policy treatments can then be expressed as

$$\frac{\pi^c - \pi^b}{1-\delta} \geq 0 \text{ and } \frac{\pi^c - \pi^b}{1-\delta} \geq EF, \tag{PC}$$

where π^b denote the profits in the competitive Bertrand equilibrium and π^c the profits on the collusive path. Given α and F, the PCs are the same in Fine and Leniency treatments, and are tighter in the policy treatments than in L-Faire due to the expected fine payment, EF.

The Incentive Compatibility Constraints (ICC) The ICC states that sticking to an agreement is preferred over a unilateral price deviation followed by a punishment. Pun-

[14] This assumption implies that the subsequent expressions are relevant mainly for decisions to form cartels given that subjects are not currently members of a successful cartel.

ishments are assumed to take the standard form of a price war.[15] In addition, cartels are assumed not to re-form once they have been dismantled following a price deviation. This assumption implies that the present value in the beginning of the punishment phase (net of potential fine payments), V^p, can be generated by optimal symmetric punishments (given the above stated assumptions). Alternatively, V^p can be viewed as resulting from some weaker form of punishment, which by assumption is the same across treatments.

All else equal, the ICCs can then be expressed as

$$\frac{\pi^c}{1-\delta} \geq \pi^d + \delta V^p, \qquad \text{(ICC-L-Faire)}$$

$$\frac{\pi^c}{1-\delta} - EF \geq \pi^d - EF + \delta V^p, \qquad \text{(ICC-Fine)}$$

$$\frac{\pi^c}{1-\delta} - EF \geq \pi^d + \delta V^p, \qquad \text{(ICC-Leniency)}$$

where π^d denotes the deviation profit. Following a deviation, a player risks to be fined in Fine only, since an optimal deviation in Leniency is combined with a simultaneous secret report. After reporting the defecting player is protected against the fine, not only because the risk of being detected by the competition authority is eliminated, but also because the competitor cannot use the public report to punish. Note in (ICC-Fine) that EF appears on both sides of the inequality, since dismantled cartels are assumed not to re-form, either on the collusive path or on the punishment path. Thus the ICCs are (i) the same in L-Faire and Fine treatments and (ii) all else equal, tighter in Leniency than in Fine treatments (since a deviation combined with a secret report provides protection against the fine, EF).

Finally, collusive equilibria exist if the PC and the ICC hold. Note from the PCs and ICCs that a collusive price is sustainable in all treatments if it is sustainable in the Leniency treatment with the largest EF. Thus, let $\alpha = 0.02$ and $F = 1000$ (as in the treatment with the largest EF) and consider a collusive equilibrium sustained through grim trigger strategies where the collusive price equals 9. The rematching procedure implies for risk neutral subjects that $\delta = 0.85$. Moreover, $\pi^b = 100$, $\pi^c = 180$ and $\pi^d = 296$. Then $EF = 119.76$ and $V^p = \pi^b/(1-\delta) = 666.67$ so that both (PC) and (ICC-Leniency)

[15] We also assume that reports are not used on the punishment path. Public reports as punishments against a price deviation can however be credible in the Fine treatments. In fact, we show in a companion paper, Bigoni et al. (forth.), that optimal punishments involve public reports. Subjects nevertheless appear not to use such strong punishments and therefore we disregard them when stating our theoretical predictions.

hold with strict inequality. Thus the joint profit-maximizing price is sustainable in all treatments.

C.2 The determinants of the minimum level of trust

This Appendix offers a formal comparison of the *minimum level of trust* across treatments.[16] We assume symmetric punishment strategies. That is, the payoff on the punishment path is given by V^p regardless of whether one or both subjects defect, and is the same for defecting and cheated upon subjects. We get

$$V^{ss}_{L-Faire} - V^{ds}_{L-Faire} = \frac{\pi^c}{1-\delta} - \left(\pi^{d1} + \delta V^p\right), \tag{2}$$

$$V^{ss}_{Fine} - V^{ds}_{Fine} = \frac{\pi^c}{1-\delta} - EF - \left(\pi^{d1} - EF + \delta V^p\right), \tag{3}$$

$$V^{ss}_{Len} - V^{ds}_{Len} = \frac{\pi^c}{1-\delta} - EF - \left(\pi^{d1} + \delta V^p\right), \tag{4}$$

where π^{d1} denotes the one period payoff from a unilateral price deviation, and

$$V^{dd}_{L-Faire} - V^{sd}_{L-Faire} = \pi^{d2} + \delta V^p - (\pi^s + \delta V^p), \tag{5}$$

$$V^{dd}_{Fine} - V^{sd}_{Fine} = \pi^{d2} - EF + \delta V^p - (\pi^s - EF + \delta V^p), \tag{6}$$

$$V^{dd}_{Len} - V^{sd}_{Len} = \pi^{d2} - \frac{F}{2} + \delta V^p - (\pi^s - F + \delta V^p), \tag{7}$$

where π^{d2} denotes the deviation payoff if both players undercut and π^s the "sucker's payoff" following a unilateral deviation by the opponent. It can be easily verified that $V^{ss}_{L-Faire} - V^{ds}_{L-Faire} = V^{ss}_{Fine} - V^{ds}_{Fine} > V^{ss}_{Len} - V^{ds}_{Len}$ and $V^{dd}_{L-Faire} - V^{sd}_{L-Faire} = V^{dd}_{Fine} - V^{sd}_{Fine} < V^{dd}_{Len} - V^{sd}_{Len}$. Hence, $\beta_{L-Faire} = \beta_{Fine} < \beta_{Len}$.

Note that the ICC (as defined in C.1) affects the demand for trust through $V^{ss}_K - V^{ds}_K$: the basin of attraction of sticking to the cooperative strategy expands as the ICC gets looser (since β_K decreases as $V^{ss}_K - V^{ds}_K$ increases). Yet there is also a notable difference between the expressions for $V^{ss}_K - V^{ds}_K$ and the ICCs: π^{d1} replaces π^d in $V^{ss}_K - V^{ds}_K$. This difference stems from the fact that the size of an optimal price deviation must be (weakly) larger if the defecting subject believes that the opponent also undercuts with some positive probability. As a result, the payoff following a unilateral deviation ranges from the payoff resulting from

[16] The comparisons between treatments do not depend on the exact deviation strategy considered. It is however important to assume that subjects undercut by the same amount (and attempt to collude on the same price) across treatments.

a “safe” Bertand price (when the opponent chooses the collusive price) and the payoff from an optimal unilateral defection, π^d. Hence $\pi^b < \pi^{d1} \leq \pi^d$ and $\pi^b \leq \pi^{d2} < \pi^{d1}$.[17]

Note also that β_K increases with $V_K^{dd} - V_K^{sd}$: the basin of attraction of sticking to the cooperative strategy shrinks as $V_K^{dd} - V_K^{sd}$ increases (i.e., since the gains from defecting relative to sticking to the agreement, given that the opponent is not trustworthy, increase).

C.3 Increased expected fine

This appendix motivates Hypothesis 2. A change in αF affects the PC, the ICC and β_K either through its impact on the expected fine payment, EF, or through its effect on the size of the absolute fine, F. Given the combinations of α and F considered in our treatments, however, both EF and F increase whenever αF increases. Therefore an increase in αF tightens the PC under Fine (since EF increases) but has no effect on the ICC nor on β_{Fine} (as EF cancels out in (ICC-Fine) as well as in (3) and (6)). Similarly, an increase in αF tightens the PC under Leniency. Under Leniency, however, an increase in αF also tightens the ICC (through an increase in EF) and increases β_{Len} (since $V_{Len}^{ss} - V_{Len}^{ds}$ decreases as EF increases and since $V_{Len}^{dd} - V_{Len}^{sd}$ increases as F increases).

C.4 Constant expected fine

This appendix motivates Hypothesis 3. An increased F compensated by a reduced α so as to keep αF constant increases EF. Therefore the PC is tightened under Fine while both the ICC and β_{Fine} are unaffected by the change (as EF does not enter the relevant expressions). Similarly, such a change tightens the PC under Leniency. In addition, the increase in EF also tightens the ICC under Leniency and thereby also increases β_{Len}. The effect on β_{Len} is exacerbated since $V_{Len}^{dd} - V_{Len}^{sd}$ increases in F.

C.5 Zero expected fine

This appendix motivates Hypothesis 4. Based on the PCs and the ICCs, neither Fine nor Leniency should have a deterrence effect relative to L-Faire when the per period expected fine is 0. Note also that Fine does not require more trust than L-Faire as

[17] The gains from a unilateral deviation are thus (weakly) lower than those indicated by the ICCs, since the defecting subject may find it profitable to undercut the agreed upon price by a larger amount. Conditional on all other assumptions, however, this fact does not affect the ranking of the ICCs across treatments.

$\beta_{L-Faire} = \beta_{Fine}$. Therefore only LENIENCY should have a deterrence effect when the per period expected fine is 0 (and $F > 0$) as it requires more trust in the sense that $\beta_{Fine} < \beta_{Len}$ (since $V^{dd}_{Fine} - V^{sd}_{Fine} < V^{dd}_{Len} - V^{sd}_{Len}$).

C.6 Robustness

Two assumptions underlying the above analysis are worth emphasizing. First, subjects collude tacitly following an exogenous detection on the collusive path and, second, cartels are not re-formed on the punishment path. Provided the cartel is not reported following a deviation (as it is under LENIENCY) the expected fine payment, EF, is therefore the same on the collusive and the punishment paths.

These assumptions are not innocuous. Suppose that successful collusion requires cartels to be re–formed on the collusive path, even after an exogenous detection by the competition authority. All else equal, this alternative assumption introduces additional deterrence channels. Under FINE, the ICC is tightened (and thereby β_{Fine} also increases) since expected fine payments on the collusive path, given by $EF^c = \alpha F/(1-\delta)$, are larger than the expected fine payment, EF, on the punishment path. The ICC is also tightened under LENIENCY, as the secret report (associated with a price deviation) provides protection against the larger expected fine payments, EF^c. Most hypotheses nevertheless remain unchanged. The exception is Hypothesis 3 as an increase in F, compensated by a fall in α so as to keep the per period expected fine constant, leaves EF^c (but not EF) unchanged. Thereby such a change in the mix of α and F should only have a deterrence effect under LENIENCY since the increase in F per se worsens the sucker's payoff and thereby increases the demand for trust.

Consider next the assumption that cartels are not re–formed on the punishment path. Presumably it holds if the punishment is carried out through a grim trigger strategy. By contrast, a stick and carrot type of punishment probably requires cartels to be formed during the 'carrot' phase, and possibly also during the 'stick' phase. Relaxing the assumption would alter the analysis in two ways. First, it would strengthen the punishment in the policy treatments (though not in L-FAIRE) as subjects run the risk of being fined also on the punishment path. Second, it would affect the scope for punishing defectors, particularly in the LENIENCY treatments because the deviation incentives (from the punishment path) would be magnified by the possibility to report. A formal treatment of these complicating factors is beyond the scope of this experimental paper.

D Empirical methodology

A critical point in our analysis is how to control for repeated observations of the same subject or the same duopoly, when testing the significance of observed differences across treatments. Given the re–matching procedure, we need to account for correlations between observations from the same individual and between observations from different individuals belonging to the same duopoly. To this end, we adopted multilevel random effect models.

The random effects at the subject and duopoly levels are not nested, since subjects participated in more than one duopoly. This makes it difficult to estimate a model including a random effect both at the duopoly and at the subject levels. To overcome this difficulty, we hypothesize the presence of a random effect for every subject within any particular match (which accounts for correlations between observations from the same match), nested with a random effect for every subject across different matches.

We model the binary response $CommDec_{nms}$ by a random intercept three-levels logit model of the following form:

$$(CommDec_{nms}|\mathbf{x}_{nms}, \eta^{(2)}_{ms}, \eta^{(3)}_{s}) \sim \text{binomial}(1, \pi_{nms})$$
$$logit(\pi_{nms}) = \boldsymbol{\beta}\mathbf{x}_{nms} + \eta^{(2)}_{ms} + \eta^{(3)}_{s} = \nu_{nms}$$

where $\pi_{nms} = Pr(CommDec_{nms}|\mathbf{x}_{nms}, \eta^{(2)}_{ms}, \eta^{(3)}_{s})$. n, m and s are indices for measurement occasions, subjects in matches, and subjects across matches, respectively. $CommDec_{nms}$ represents the n-th communication decision of subject s in match m. $\mathbf{x}_{nms}$ is a vector of explanatory variables (including the constant), with fixed regression coefficients $\boldsymbol{\beta}$. $\eta^{(2)}_{ms}$ represents the random intercept for subject s in match m (second level), and $\eta^{(3)}_{s}$ represents the random intercept for subject s (third level). Random intercepts are assumed to be independently normally distributed, with a variance that is estimated through our regression. To estimate our model we use the GLLAMM commands in Stata.[18]

[18]see Skrondal and Rabe-Hesketh (2004) and http://www.gllamm.org

E Additional tables

E.1 Regressions

[not for publication]

	Fine	Leniency
$\alpha = 0;\ F = 1000$	-0.160***	-0.440***
	(0.040)	(0.005)
Log-Likelihood	-570.526	-680.948
N	1108	1350

(a) Communication vs. $\alpha = 0;\ F = 1000$

	Fine	Leniency
$\alpha = 0.02;\ F = 1000$	-0.311***	-0.071*
	(0.063)	(0.041)
Log-Likelihood	-416.821	-660.115
N	838	1414

(b) $\alpha = 0;\ F = 1000$ vs. $\alpha = 0.02;\ F = 1000$

	Fine	Leniency
$\alpha = 0.10;\ F = 200$	0.328***	0.141***
	(0.050)	(0.049)
Log-Likelihood	-524.298	-781.619
N	1010	1552

(c) $\alpha = 0.02;\ F = 1000$ vs. $\alpha = 0.10;\ F = 200$

Table E.1.1: Differences in deterrence across treatments.

Note: Results from logit regressions with three-level random effects. The dependent variable is the binary decision whether to communicate or not when subjects would not otherwise be liable for collusion. The main independent variable is a dummy taking value one for the treatment of interest, and zero for the reference treatment. Standard errors are robust for heteroskedasticity. The symbols ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

	$\alpha = 0.1, F = 200$ vs. NoReport	$\alpha = 0.02, F = 1000$ vs. NoReport
NoReport	-0.410***	-0.149**
	(0.026)	(0.064)
Log-Likelihood	-681.425	-591.044
N	1218	1140

Table E.1.2: Deterrence in the 'NoReport' treatment

Note: Results from logit regressions with three-level random effects. The dependent variable is the binary decision whether to communicate or not when subjects would not otherwise be liable for collusion. The main independent variable is a dummy taking value one for the treatment of interest, and zero for the reference treatment. Standard errors are robust for heteroskedasticity. The symbols ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

E.2 Prices

Treatment	*average price* without communication	with communication
FINE		
$F = 200,\ \alpha = 0.10$	3.4	5.7
$F = 1000,\ \alpha = 0.02$	3.4	6.1
$F = 1000,\ \alpha = 0$	3.8	6.8
LENIENCY		
$F = 200,\ \alpha = 0.10$	3.6	5.7
$F = 1000,\ \alpha = 0.02$	3.5	7.2
$F = 1000,\ \alpha = 0$	3.9	7.9
L-FAIRE	3.4	5.0
Total	3.5	6.1

Table E.2.1: **Average price with and without communication.**

E.3 Reports

	Treatment FINE	LENIENCY
$\alpha = 0;\ F = 1000$	0.005	1.000
N	*186*	*20*
$\alpha = 0.02;\ F = 1000$	0.000	0.538
N	*127*	*13*
$\alpha = 0.10;\ F = 200$	0.000	0.577
N	*211*	*71*

Table E.3.1: Rate of "secret" reports (given own price deviation)

F Instructions for Leniency

Welcome to this experiment about decision making in a market. The experiment is expected to last for about 1 hour and 45 minutes. You will be paid a minimum of 50 SEK for your participation. On top of that you can earn more than 300 SEK if you make good decisions. We will first read the instructions aloud. Then you will have time to read them on your own. If you then have questions, raise your hand and you will be helped privately.

In summary, the situation you will face is the following. You and one other participant referred to as your competitor produce similar goods and sell them in a common market. As in most markets, the higher the price you charge, the more you earn on each sold good, but the fewer goods you sell. And, as in many markets, the lower the price charged by your competitor, the more customers he or she will take away from you and the less you will sell and earn. It is possible, however, to form a cartel with your competitor, that is, you will have the possibility to communicate and try to agree on prices at which to sell the goods. In reality, cartels are illegal and if the government discovers the cartel, cartel members are fined. In addition members of a cartel can always report it to the government. The same happens in this experiment. If you communicate to discuss prices, even if both of you do not report, there is still a chance that the 'government' discovers it and if this happens, you will have to pay a 'fine'. If you report, and if you are the only one to report, you will not pay any fine but your competitor will pay the full fine. Conversely, if only your competitor reports the cartel, you will pay the full fine and your competitor will not pay any fine. If instead both of you report the cartel you will both pay 50% of the fine.

Timing of the experiment In this experiment you will be asked to make decisions in several periods. You will be paired with another participant for a sequence of periods. Such a sequence of periods is referred to as a match. You will never know with whom you have been matched in this experiment.

The length of a match is random. After each period, there is a probability of 85% that the match will continue for at least another period. So, for instance, if you have been paired with the same competitor for 2 periods, the probability that you will be paired with him or her a third period is 85%. If you have been paired with the same competitor for 9 periods, the probability that you will be paired with him or her a tenth period is also 85%.

Once a match ends, you will be paired with another participant for a new match, unless 20 periods or more have passed. In this case the experiment ends. So, for instance, if 19 periods have passed, with a probability of 15% you are re-matched, that is you are paired with another participant. If 21 periods have passed, with a probability of 15% the experiment ends.

When you are re-matched you cannot be fined anymore for a cartel formed in your previous match with your previous competitor.

The experimental session is expected to last for about 1 hour and 45 minutes but its actual duration is uncertain; that depends on the realization of probabilities. For this reason, we will end the experimental session if it lasts more than 2 hours and 30 minutes.

Before the experiment starts, there will be 5 trial periods during which you will be paired with the same competitor. These trial periods will not affect your earnings. When the experiment starts, you will be paired with a new competitor.

Prices and Profits In each period you choose the price of your product. Your price as well as the price chosen by your competitor determines the quantity that you will sell. The higher your price, the more you earn on each sold good, but the fewer goods you sell. Therefore your price has two opposing effects on your profit. On the one hand, an increase in your price may increase your profit, since each good that you sell will earn you more money. On the other hand, an increase in your price may decrease your profit, since you will sell less. Furthermore, the higher the price of your competitor, the more you will sell. As a result, your profits increase if your competitor chooses a higher price.

To make things easy, we have constructed a profit table. This table is added to the instructions. Have a look at this table now. Your own prices are indicated next to the rows and the prices of your competitor are indicated above the columns. If, for example, your competitor's price is 5 and your price is 4, then you first move to the right until you find the column with 5 above it, and then you move down until you reach the row which has 4 on the left of it. You can read that your profit is 160 points in that case.

Your competitor has received an identical table. Therefore you can also use the table to learn your competitor's profit by inverting your roles. That is, read the price of your competitor next to the rows and your price above the columns. In the previous example where your price is equal to 4 and your competitor's price is equal to 5, it follows that your competitor's profit is 100 points.

Note that if your and your competitor's prices are equal, then your profits are also equal and are indicated in one of the cells along the table's diagonal. For example, if your price and the price of your competitor are equal to 1, then your profit and the profit of your competitor is equal to 38 points. If both you and your competitor increase your price by 1 point to 2, then your profit and the profit of your competitor becomes equal to 71.

Note also that if your competitor's price is sufficiently low relative to your price, then your profit is equal to 0. The reason is that no consumer buys your good, since it is too expensive relative to your competitor's good.

Fines In every period, you and your competitor will be given the opportunity to communicate and discuss prices. If both of you agree to communicate, you will be considered to have formed a cartel, and then you might have to pay a fine F. This fine is given by:

$$F = 200 \text{ points.}$$

You can be fined in two ways. First, you and your competitor will have the opportunity to report the cartel. If you are the only one to report the cartel, you will not pay any fine but your competitor will pay the full fine, that is 200 points. Conversely, if only your competitor reports the cartel and you do not, then you will have to pay the full fine equal to 200 points and your competitor will not pay any fine. Finally, if both of you report the cartel, you will both pay 50% of the fine, that is 100 points.

Second, if neither you nor your competitor reports the cartel, the government discovers it with the following probability.

$$\text{Probability of detection} = 10\%.$$

Note that you will run the risk of paying a fine as long as the cartel has not yet been discovered or reported. Thus you may pay a fine in a period even if no communication takes place in that period. This happens if you had a meeting in some previous period which has not yet been discovered or reported.

Once a cartel is discovered or reported, you do not anymore run the risk of paying a fine in future periods, unless you and your competitor agree to communicate again.

Earnings The number of points you earn in a period will be equal to your profit minus an eventual fine. Note that because of the fine, your earnings may be negative in some periods. Your cumulated earnings, however, will never be allowed to become negative.

You will receive an initial endowment of 1000 points and, as the experiment proceeds, your and your competitor's decisions will determine your cumulated earnings. Note that 20 points are equal to 1 SEK. Your cumulated earnings will be privately paid to you in cash at the end of the session.

Decision making in a period Next we describe in more detail how you make decisions in each period. A period is divided into 7 steps. Some steps will inform you about decisions that you and your competitor have made. In the other steps you and your competitor will have to make decisions. In these steps, there will be a counter indicating how many seconds are left before the experiment proceeds to the next step. If you fail to make a decision within the time limit, the computer will make a decision for you.

Step 1: Pairing information and price communication decision Every period starts by informing you whether or not you will play against the same competitor as in the previous period.
Remember that if you are paired with a new competitor, you cannot be fined anymore for cartels that you formed with your previous competitors.
In this step you will also be asked if you want to communicate with your competitor to discuss prices. A communication screen will open only if BOTH you and your competitor choose the "YES" button within 15 seconds. Otherwise you will have to wait for an additional 30 seconds until pricing decisions starts in Step 3.

Step 2: Price communication After the communication screen has opened, you can "discuss" prices by choosing a price out of the range $\{0, 1, 2, \ldots, 12\}$. In this way you can indicate to your competitor the minimum price that you find acceptable for both of you. When both of you have chosen a price, these two prices are displayed on the computer screen. You can then choose a new price but now this price should be greater or equal to the smaller of the two previously chosen prices. This procedure is repeated until 30 seconds have passed. The screen then displays the smaller of the two last chosen prices, which is referred to as the agreed-upon price. Note, however, that in the next step, neither you nor your competitor is forced to choose the agreed-upon price.

Step 3: Pricing decision You and your competitor must choose one of the following prices: $0, 1, 2, \ldots, 12$. When you choose your price, your competitor will not observe your choice nor will you observe his or her price choice. This information is only revealed in Step 5. The experiment proceeds after 30 seconds have passed. If you fail to choose a price within 30 seconds, then your price is chosen so high that your profits will be 0.
The experiment proceeds to the first reporting decision in Step 4 if you communicated in Step 2 or if in previous periods you formed a cartel not yet discovered or reported. Otherwise you have to wait for 10 seconds until market prices are revealed in Step 5.

Step 4: First (secret) reporting decision By choosing to push the "REPORT" button, you can report that you have been communicating in the past. As described above, if you are the only one to report, you will not pay the fine; the opposite happens if only your competitor reports; and if both of you report, you will both pay 50% of the fine. If you do not wish to report, push instead the "DO NOT REPORT" button.
When you decide whether or not to report, your competitor will not observe your choice, nor will you observe his or her choice. This information is only revealed when market prices are revealed in Step 5.
If you do not reach a decision within 10 seconds, your default decision will be "DO NOT REPORT".

Step 5: Market prices and second reporting decision In this step your and your competitor's prices and profits are displayed. In case you have formed a cartel not yet discovered or reported, the screen will also display whether or not you or your competitor reported it in the first reporting step (Step 4). If not, you will get a new opportunity to report. If you wish to report, push the "REPORT" button. If you do not wish to report, push instead the "DO NOT REPORT" button. Again, if you are the only one to report, you will not pay the fine. On the contrary, if your competitor reports and you don't you will have to pay the fine and he will not. If both you and your competitor report, you will both pay 50% of the fine, that is 100 points.

Step 6: Detection probability If this step is reached, you formed a cartel either in the current period or in previous periods. Furthermore the cartel has not yet been discovered or reported. The cartel can nevertheless be discovered. This happens with a probability of 10%. If the cartel is discovered, you and your competitor will have to pay the full fine of 200 points.

Step 7: Summary In this step you learn the choices made in the previous steps: your and your competitor's price choices and profits, your eventual fine, and your earnings. If you paid a fine in this period, you will also know whether your competitor reported the cartel or the government discovered it.
In case a cartel was detected or reported in this period, you will not run any risk of being fined in future periods, unless you and your competitor discuss prices again.
Step 7 will last for 20 seconds.

Period ending and ending of the experimental session After Step 7, a new period starts unless 20 or more periods have passed and the 15% probability of pair dismantling takes place. In that case, the experiment ends.

History table Throughout the experiment, a table will keep track for you of the history with your current competitor. For each previous period played with your current competitor, this table will show your price and profit, your competitor's price and profit as well as your eventual fine.

Payments At the end of the experiment, your earnings in points will be exchanged in SEK. In addition you will be paid the show up fee of 50 SEK. Before being paid in private, you will be asked to answer a short questionnaire about the experiment and you will have to handle back the instructions. Please read now carefully the instructions on your own. If you have questions, raise your hand and you will be answered privately.

THANK YOU VERY MUCH FOR PARTICIPATING IN THIS EXPERIMENT AND GOOD LUCK!

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