Trust, Salience and Deterrence*

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Abstract

We present results from a laboratory experiment identifying the main channels through which different law enforcement strategies deter organized economic crime. The absolute level of a fine has a strong deterrence effect, even when the exogenous probability of apprehension is zero. This effect appears to be driven by distrust or fear of betrayal, as it increases significantly when the incentives to betray partners are strengthened by policies offering amnesty to "turncoat whistleblowers". We also document a strong deterrence effect of the sum of fines paid in the past, which suggests a significant role for salience or availability heuristic in law enforcement.

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1 Introduction

Cartels, corruption, financial fraud, smuggling, money laundering, and tax evasion are only some of the many forms organized economic crime can take. This hard-fought phenomenon is widely perceived to be increasing with globalization (US CRS 2010, UK CIFAS 2010, Glenny 2008). The economics of public law enforcement, from Becker (1968) to the present, has offered crucial insights on efficient crime deterrence, focusing mainly on an individual's decision to commit one or more 'solo' crimes (see e.g. Polinsky and Shavell 2000, Levitt 2004). But organized crime differs substantially from individual crime. Two features of organized crime are particularly important for the optimal design of law enforcement policy.

The first feature is that criminal organizations must deal with the temptation of members of criminal teams to betray each other, as first recognized by Stigler (1964) for price-fixing conspiracies. Since illegal contracts cannot be enforced, criminal organizations must rely on self-enforcing agreements to govern internal agency problems: they must be a 'cooperative' equilibrium of the ongoing dynamic game between wrongdoers.[1] To sustain a criminal organization as an equilibrium it is not sufficient that each wrongdoer finds participation profitable in expectation. It is also necessary that the criminal agreement is 'incentive compatible' in the sense that each wrongdoer prefers to respect the criminal agreement rather than unilaterally deviating from it – e.g. by betraying partners and 'running away with the money'. Beyond this, wrongdoers must also be able to coordinate on the criminal equilibrium and maintain trust in the organization, i.e. remain confident in each other's trustworthiness with respect to the agreed upon criminal plans.[2] Therefore, deterrence can be achieved through additional channels. While individual crime must be deterred by large enough expected sanctions so that the Participation Constraint (PC) is violated, organized crime can also be deterred:

[1]This is now well recognized in the economic literature (e.g., Garoupa 2007, Baccara and Bar-Isaac 2008, and references therein). Third party enforcement of illegal contracts is sometimes provided by other criminal organizations, like Mafia, but typically at very high cost (e.g., Reuter 1983, Gambetta 1993, and Dixit 2003). Our focus here is on forms of organized crime that do not rely on such 'risky' third party enforcement.

[2]That criminal organizations require trust to function and pursue their illegal endeavors has been noted by a number of criminologists in the past (see e.g., Von Lampe and Johansen 2004, and references therein), and more recently also by law and economics scholars (Cooter and Garoupa 2000, Leslie 2004).

- by ensuring that at least one criminal's Incentive Compatibility Constraint (ICC) is violated, so that organized crime – although profitable in expectation – is not an equilibrium; or

- by worsening the 'Trust Problem' (TP), so that wrongdoers cannot be confident that their criminal partners will choose to stick to the criminal equilibrium.[3]

The second important feature is that there are almost always witnesses. By cooperating, criminal partners typically end up having valuable information about each other's crimes that can be elicited to law enforcers by suitably designed revelation mechanisms. Schemes aimed at eliciting such information, like the Prisoner's Dilemma, indeed have often been used throughout history to fight different forms of 'organized crime', from coalitions of tribes resisting the Roman Empire to 'bandits' in 13^{th} century England. More recently similar schemes have been adopted to fight fraud (under the US False Claims Act), cartels (the so-called 'Leniency Policies'), and tax evasion (under IRS's Whistleblower/Informant Program) following their successful use against terrorism and Mafia in the US and Italy. Besides facilitating prosecution these schemes - if well designed and administered - may generate an additional and endogenous probability of conviction (because of a partner's betrayal) that could reinforce ex ante deterrence by tightening the perceived ICC and worsening the TP.[4]

This paper reports results from a laboratory experiment investigating the deterrence properties of different law enforcement instruments. Our aim is to shed light on the behavioral and cognitive channels through which deterrence works. 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 communi-

[3]Theoretically, deterrence should be easier to achieve by tightening one criminal's ICC or worsening the TP than by tightening the PC. An objective of our study is to test experimentally this conjecture.

[4]Note that this second feature is not always relevant as is the first. When firms collude tacitly, for example, the first feature is present but not the second, because no hard information is produced that can be used in court by firms colluding tacitly. Baccara and Bar-Isaac (2008) study the trade off criminal organizations face between the benefits of communication and its cost in terms of the amount of hard information it produces that can be used against them by law enforcers.

cate illegally to fix prices.[5] If players choose to communicate, they are considered as having formed an illegal conspiracy and fall liable to fines. We run several treatments that differ in the presence and size of the fine (F), in the size of the probability (α) of being convicted due to a random audit by the law enforcement agency, and in the possibility of obtaining lenient treatment when self-reporting and betraying partner conspirators.

In line with recent empirical and experimental work, we find that schemes granting leniency (only) to the first self-reporting wrongdoer significantly increase organized crime deterrence. The novel and crucial finding of this work, however, is that *leniency schemes appear to alter the main mechanism through which deterrence works.* Under standard law enforcement policies, i.e. absent leniency for whistleblowers, deterrence increases with the expected fine αF as predicted by classic law enforcement theory (crime becomes less profitable in expectation and the PC is tightened). With leniency policies, instead, *the actual fine F becomes the only law enforcement component influencing behavior.* Wrongdoers no longer react to changes in the probability α, and we observe a *strong deterrence effect of F even when α equals zero.* These findings suggest that the worsening of the Trust Problem – the increased fear of being betrayed and the associated higher level of trust necessary to sustain cooperation when leniency renders self-reporting both more attractive and more costly to others – dominates all other considerations. We also find a significant deterrence effect of the *sum of fines paid in the past* on the rate of attempts to establish a new conspiracy. The most plausible explanation for this finding is that agents who experienced fines recently perceive them as more 'salient'; under traditional law enforcement (in the absence of leniency) our subjects' willingness to form conspiracies indeed decreases after detection through a random audit, even though incentives are unchanged and no unilateral deviation has taken place.

To the extent that these results are confirmed in future studies and apply

[5] Insights from laboratory experiments may not generalize to real world markets (although recent evidence suggests that they do as long as the experiment is well designed and run; see Falk and Heckman 2009; Baran et al. 2010). However, experiments are particularly well-suited for our purposes because economic crimes are often not observed except when detected by the law enforcement agency. This makes it extremely difficult to empirically evaluate the effects of the many different aspects of complex law enforcement policies on the total number of infringements.

also outside the laboratory, they have important policy implications. First, they suggest that well designed policies in favor of 'turncoat whistleblowers' have the potential to dramatically increase the efficiency of law enforcement against organized crime. Second, the results point to the importance of complementing leniency-based revelation schemes with high absolute sanctions rather than with a high probability of apprehension. Concerns that the many leniency applications to competition authorities could undermine cartel deterrence by keeping authorities too busy to undertake random audits (reducing α substantially, see Riley 2007 and Chang and Harrington 2010) may therefore be unwarranted, at least when sanctions are sufficiently robust and the leniency program is well designed and run. Finally, our results on salience suggest that the gains from introducing leniency programs may be even larger, since without such schemes, conspicuous investments could be necessary to keep subjects aware of the expected cost of conviction.

Our work contributes to a recent experimental literature evaluating the hard-to-measure deterrence effects of differently designed leniency policies against cartels and corruption, which includes Apesteguia et al. (2007), Hamaguchi et al. (2007), Hinloopen and Soetevent (2008), Bigoni et al. (2009), among others.[6] These studies are in turn based on the theoretical literature on leniency policies in antitrust, which extends to multi-agent conspiracies Kaplow and Shavell (1994)'s seminal analysis of self-reporting for individual crimes.[7] Closely related are also Miller (2009) and Acconcia et al. (2009), who empirically evaluate the deterrence effects of leniency policies by looking at changes in the rate of detected cartels after the introduction of such policies.[8] To our knowledge, ours is the first laboratory experiment considering different levels of fines and probabilities of apprehension trying

[6]See also Krajčcová and Ortmann (2008) and Hamaguchi et al. (2009). Our work is of course also related to recent experiments on collusion and oligopoly like Huck et al. (1999), Offerman et al. (2002), Huck et al. (2004), Engelmann and Müller (2008), Potters (2009).

[7]This literature, started 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 and Spagnolo (2004) for a theoretical study close to our experimental set-up.

[8]The former finds a significant deterrence effect of the 1993 leniency policy in US Antitrust, the second finds a significant deterrence effect of the 1991 leniency policy against Mafia crimes in Italy. See also Brenner (2009), who instead finds no deterrence effects of the (weakly designed) EU leniency notice of 1996; and Chang and Harrington (2010), who develop an alternative empirical methodology based on observed changes in the duration of detected cartels.

to disentangle the role of trust and salience from other possible channels through which law enforcement instruments may deter organized crime.[9]

The importance of accounting for behavioral considerations in the analysis of law enforcement was first pointed out by Jolls et al. (1998).[10] Our finding that the fine matters *per se*, however, does not seem to be linked to its possible symbolic value as in Funk (2007); nor to its norm-breaking informational content as in Gneezy and Rustichini (2000). The result appears instead driven by changes in the cost and perceived likelihood of being betrayed/detected, and in the associated changes in the 'demand for trust' from members of a potential conspiracy. Our work therefore 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.[11] 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 belief' (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 and self-reporting. In the vein of Bohnet et al. (2008), 'betrayal aversion' – the additional perceived cost of being betrayed by a peer relative to that of being discovered and fined by a more neutral 'law enforcement agency' – is also likely to have contributed to the strong deterrence we observe with leniency (even when the exogenous conviction probability α is zero).

Our results on salience are related to Akerlof (1991) – who stressed that outstanding events and vivid information may exert undue influence on decisions – and to the closely related concept of "availability heuristic" coined by Kahneman et al. (1982) (see also Gennaioli and Shleifer, forthcoming). On the empirical ground, they are consistent with those of Fishman and Pope (2006) and Agarwal

[9]The new experimental study by Charness and DeAngelo (2009) investigates the effects of expected fines on deterrence and finds that uncertainty about punishment enhances deterrence. Though interesting and related in spirit, this new study focuses exclusively on individual crime.

[10]See Jolls (2007) for an extended survey of recent developments in behavioral law and economics, and Garoupa (2003) for a critical review.

[11]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.

et al. (2008) who identify similar patterns in connection with delays in returning rented movies and with credit card overdraft charges respectively. Our results also match well with Chetty et al. (2009) and Finkelstein (2009), who document strong salience effects in the context of taxation.

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.

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.[12] 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

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

		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**

first treatment variable. The ANTITRUST 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, ANTITRUST 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 treatments with a high expected fine ($\alpha = 0.2$ and $F = 300$) as well as treatments 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 COMMUNICATION corresponds to a laissez faire regime where forming a cartel by discussing prices is legal ($\alpha = F = 0$).[13] The differences between the treatments are summarized in table 2.

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.

[13] To simplify the instructions and to eliminate irrelevant alternatives, subjects were not allowed to report cartels in COMMUNICATION. In all other treatments cartel members were allowed to report cartels in which they participated.

Treatment	fine (F)	probability of detection (α)	report	report's effects
ANTITRUST	200	0.10	Yes	pay the full fine
	1000	0.02		
	300	0.20		
	1000	0		
LENIENCY	200	0.10	Yes	no fine (half the fine if both report)
	1000	0.02		
	300	0.20		
	1000	0		
COMMUNICATION	0	0	No	–

Table 2: **Treatments**

2.2 The timing of the stage game

With the exception of COMMUNICATION, a stage game consisted of 7 steps. In COMMUNICATION, 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 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.[14]

Step 3: Pricing. Each subject had to choose his price from the choice set

[14]This iterative procedure aimed at helping subjects to agree on a minimum acceptable price in a reasonably short lapse of time.

$\{0, ..., 12\}$. 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 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).[15] Sessions lasted on average 2 hours, including instructions and payment. We ran nine sessions (one per treatment), with 32 subjects per session. The experiment

[15] Antitrust 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.

involved 282 subjects in all.[16] 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 Communication, Antitrust and Leniency treatments (see Appendix B.1). No hypotheses can thus be stated on the ground that collusive outcomes do not constitute an equilibrium in some of the treatments.

Standard Equilibrium Conditions and Deterrence The participation constraint (PC) and incentive compatibility constraint (ICC), two necessary condi-

[16] In Leniency with $F = 300$ and $\alpha = 0.2$ we only had 26 subjects, as an unusual number of subjects failed to show up. Table 2 in Appendix C reports more detailed information on the 9 experimental sessions.

tions for the existence of a collusive equilibrium, provide valuable insights on possible effects of law enforcement institutions. All else equal, the PCs in ANTITRUST and LENIENCY treatments are identically tighter than in COMMUNICATION due to the expected fine payment. Moreover the ICCs are tighter in LENIENCY than in ANTITRUST or in COMMUNICATION, since a deviation in LENIENCY is optimally combined with a secret report providing protection against the fine.[17] 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 however 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. 2009). We therefore provide a simple formal analysis of the demand for trust required to enter an illegal price-fixing conspiracy, 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 sustainable, and entering a conspiracy worthwhile, in treatment $K \in \{Comm, Anti, Len\}$ can then be viewed as a measure of the 'demand for trust' in this treatment. Clearly collusion is sustainable only if $\beta \geq \beta_K$.

Let V_K^{ss} (V_K^{ds}) denote the values of sticking to (deviating from) the collusive

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

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 is reminiscent of the 'basin of attraction' or 'resistance' of the cooperative strategy as defined in evolutionary game theory (see also Myerson 1991, sect. 7.11). 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 B.2 provides a formal expression for β_K and characterizes for each treatment the minimum level of trust, showing that $\beta_{Comm} = \beta_{Anti} < \beta_{Len}$. The amount of trust required by the price-fixing conspiracy is thus higher in Leniency (but not in Antitrust) than in Communication. The reason is twofold. First, an optimal deviation is combined with a simultaneous report under Leniency. 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, cartel deterrence is lowest in Communication, followed in order of magnitude by Antitrust and Leniency.

The deterrence effect of Antitrust relative to Communication is driven only by different PCs. Both the ICC and the minimum level of trust drive the higher deterrence effect of Leniency relative to Antitrust.

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_{Anti} since the expected fine payment EF is the same under ANTITRUST 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 B.3 and lead to our second hypothesis.

Hypothesis 2 (increased expected fine) An increase in the per period expected fine increases deterrence under ANTITRUST and even more so under LENIENCY.

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 $V_{Len}^{dd} - V_{Len}^{sd}$). These observations are given a more formal treatment in Appendix B.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 may slightly increase deterrence under ANTITRUST, and should strongly increase deterrence under LENIENCY.

The deterrence effect under ANTITRUST is driven solely by the small increase in the expected fine payment EF. This increase may be viewed as subtle, however, as it is difficult to calculate and not very intuitive, given that 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 primarily may have a deterrence effect under Leniency. Moreover 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, Antitrust and Leniency should have no deterrence effect relative to Communication. The fact that the sucker's payoff is much worse under Leniency than under Antitrust and Communication motivates the following hypothesis, however (see also Appendix B.5).

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

Finally, note that the game is stationary. One may conjecture therefore that players' strategies and equilibrium behavior should not change with individual experiences of detection and punishment. This motivates our last hypothesis.

Hypothesis 5 (no salience effect) The size of the fines actually paid by a subject in previous periods and the experienced frequency of detection should not affect the subject's choices in subsequent rounds of the game.

If players are subject to the effects of "availability heuristic", Hypothesis 5 would fail, however, since the experience of a very harsh sanction in the past may alter the perception of the probability or cost of being fined in the future.

4 Results

This section presents our main experimental results. We are aiming at a deeper understanding of the channels through which the different law enforcement policies affect subjects' decisions to communicate and form illegal conspiracies. We begin with an overall description of behavior and then back up our discussion with formal statistical tests.

4.1 General description of behavior

Figure 1 provides an overview of how the legal framework affects the subjects' decision of joining a conspiracy. All else equal, there are fewer attempts to communicate when incentives to betray partners are stronger because leniency is granted to self-reporting wrongdoers. This finding is consistent with previous experiments on the subject and confirms Hypothesis 1.

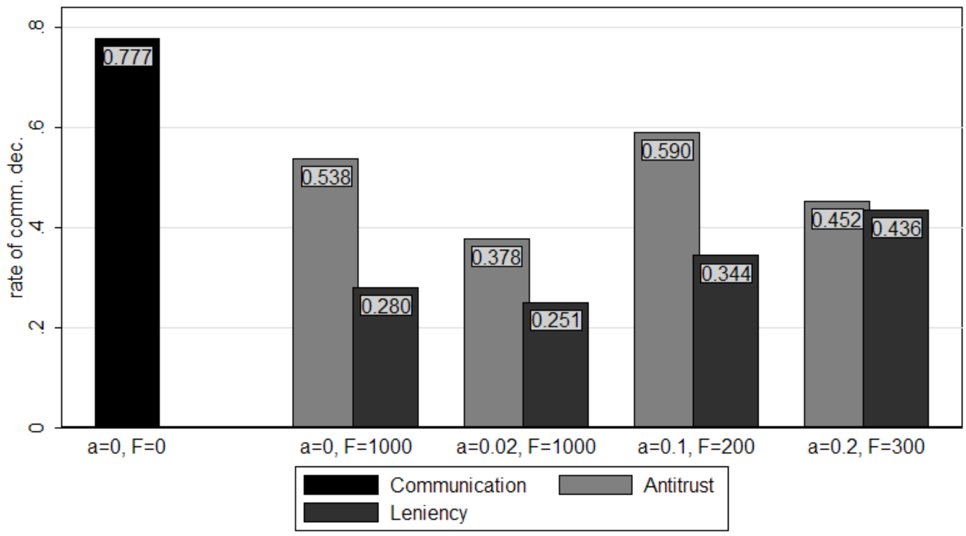

Figure 1: Rates of communication decision

More interestingly, the same expected fine ($\alpha F = 20$) appears to deter illegal conspiracies more when the fine is high and the exogenous probability of detection is low ($F = 1000$, $\alpha = 0.02$) than in the opposite case ($F = 200$, $\alpha = 0.1$). Even more striking perhaps is the robust deterrence effect emerging in treatments with a high fine ($F = 1000$) but zero exogenous probability of detection ($\alpha = 0$), both with and without leniency programs. This pattern suggests that the size of the fine F matters *per se* for organized crime. An increase in the expected fine appears instead to have ambiguous effects on deterrence. Finally, note that in line with our assumption in section 3, communication (that is, forming a conspiracy) appears critical to sustaining high prices in all treatments.[18]

[18]On average, prices equal 3.5 when no communication takes place, and 5.6 when it does. The

To assess the strength of these qualitative findings and to further clarify subjects' behavior, we now turn to a deeper statistical analysis.

4.2 Expected vs. Actual Fine: Trust and Deterrence

Illegal conspiracies could be detected in two ways: either 'exogenously' (with probability α) through an autonomous investigation by the law enforcement authority; or 'endogenously' if (at least) one player betrays and reports the conspiracy. The per period expected cost of exogenous detection equals the standard 'Beckerian' expected fine αF from exogenous detection by an audit of the law enforcement agency. The expected cost of endogenous detection depends on the size of the actual fine, F, and on the subject's *trust* in the competitor – his prior on the (non-observable) probability that the partner conspirator will betray and report the conspiracy to the authorities. Clearly the expected costs of both exogenous and endogenous detection matter for deterrence. The analysis below attempts to disentangle the two effects by investigating separately the effects of changes in the expected fine from exogenous detection αF and in the actual fine F.

Table 3 reports a logit regression assessing how the institutional framework affects subjects' decisions to form a conspiracy. The outcome variable is the decision to communicate when subjects are not already members of an existing conspiracy. The covariates (including a constant) are (i) the dummy variables *Antitrust* and *Leniency* indicating the presence of antitrust laws with and without leniency programs and (ii) *Antitrust* and *Leniency* interacted with $Fine$ (the fine F to be paid in case of detection) and $Exp.Fine$ (the per period expected fine αF).[19] These interaction terms measure the deterrence effects of the actual and expected fines, allowing these effects to vary across institutional frameworks.[20]

difference is even bigger in ANTITRUST (3.5 vs. 6.3) and in LENIENCY (3.6 vs. 6.7) treatments. See Table 6 in Appendix D for more details on prices. These findings are also consistent with results in the literature on communication and coordination (see e.g., Crawford 1998).

[19] The regression accounts for subjects' limited liability. The actual fine corresponds to the minimum between the accumulated payoff and the fine of the treatment. Note also that the fine and expected fine have larger magnitudes than the other regressors; those numbers are therefore divided by 1000 and 100 respectively so that all variables approximately have the same scale.

[20] The regression also includes random intercepts at the duopoly level to account for correlations between observations from the same subject in a single match, and random intercepts at the subject level to account for correlations between observations from the same subject but in

Dependent variable: decision to communicate

	coefficient	**s.e.**
Antitrust (dummy)	0.035	0.690
Leniency (dummy)	-2.273***	0.590
Antitrust X Fine	-1.178*	0.678
Leniency X Fine	-1.168**	0.588
Antitrust X Exp.Fine	-2.906***	1.130
Leniency X Exp.Fine	0.351	1.012
Constant	1.797	0.244
Log Likelihood	-2689.110	
N	5398	

Note: In this and the following table, ***, ** and * indicate significance at the 1%, 5% and 10% levels.

Table 3: **Logit regression with multilevel random effects.**

The 'Beckerian' expected fine αF. Table 3 suggests that the expected fine from exogenous detection αF matters absent leniency, only partially confirming Hypothesis 2. Under Antitrust the expected fine has a negative and highly significant impact on players' willingness to communicate and form a conspiracy. Faced with a higher expected fine αF and thereby a tightened participation constraint, subjects thus appear to react in accordance with theory. By contrast, the expected fine αF does not seem to affect subjects' willingness to form conspiracies under Leniency, while as discussed below, the size of the fine F does.

The absolute size of the fine F. Table 3 shows that the size of the fine matters not only under Leniency but also under Antitrust. This pattern confirms Hypothesis 3, but Hypothesis 4 only partially.

Under Leniency, 54% of the deviating players simultaneously self-report to obtain leniency, thereby avoiding the risk of being detected and fined. When

different matches (see Appendix E for a detailed description of our empirical methodology). Note also that controlling for subjects' attitudes toward risk (using individual data taken from an investment game played by each subject) does not affect our results. For the sake of conciseness, we report only regressions without controls for risk aversion.

this happens, the cheated upon party has to pay the fine. As a consequence, the expected profits for the cheated upon party under LENIENCY are inversely related to the absolute size of the fine F (even with a $\alpha = 0$). An increase in the actual fine thus worsens the consequences of a deviation by the opponent, making a price-fixing conspiracy less appealing.

Presumably this is not the case under ANTITRUST since reports there are costly, and indeed defecting subjects very rarely combined their price deviation with a simultaneous report (reports only took place in about 0.3% of the cases when a subject deviated). Nevertheless, the actual fine F also has a significant effect under ANTITRUST. The most plausible explanation is that subjects planning to form a conspiracy with the aim of subsequently deviating from the agreement and exploiting the other party are deterred from doing so by the threat of the public report as a punishment, which is particularly harmful when the fine is high. One might dismiss such threats as non-credible, since public reports are costly also to the reporting party. Still, this explanation probably has some merit as cheated upon subjects do incur the cost of reporting to punish a price deviation in 14.1% of the cases.[21] We summarize our findings as follows.

Result 1. *An increase in the 'Beckerian' expected fine αF increases deterrence only in the absence of leniency. An increase in the absolute size of the fine F increases deterrence both with and without leniency.*

Our Interpretation: Trust, Leniency, and Deterrence. Result 1 suggests that the presence of leniency changes the main channel through which deterrence is achieved.

Under ANTITRUST, the main driver of deterrence appears to be the expected fine from exogenous detection αF, which tightens the Participation and Incentive Compatibility Constraints, even though the absolute size of the fine also matters. Under LENIENCY, instead, deterrence appears to be driven mainly by the worsening of the Trust Problem, i.e., by the increased fear of being endogenously detected

[21] This last deterrence channel may have little policy relevance, as profit maximizing wrongdoers may be unwilling to inflict large costs on themselves to punish deviators, as some subjects do in our experiment. It is also a rather limited effect, acting only on those who enter a conspiracy with the intent of breaking the collusive agreement immediately after.

by a report of the partner conspirator. This effect is strong enough to completely obscure the role of the probability α of being exogenously detected by the law enforcement agency.

Finally, the estimated coefficient for *Leniency* in Table 3 is also negative and significant at the 1% level even after controlling for the level of the expected and actual fine, i.e., for the additional *cost* of being cheated upon with leniency. Leniency schemes thus appear to generate an additional demand for trust, which could be linked to betrayal aversion − the additional perceived cost of being reported by a partner (Bohnet et al. 2008).[22]

4.3 History of play and deterrence

This section examines how communication decisions change in response to the history of play. Experiencing an endogenous detection – a betrayal – reduces trust in the opponent, thus affecting subjects' willingness to collude again. By contrast, an exogenous detection seems less likely to affect subsequent communication decisions, since the discount factor, the probability of detection and the size of the fine are constant across periods and since information is perfect. Still, the history of play may well matter if being detected and paying a fine constitutes an easily recollected – a *salient* – event, particularly so when past fines were high or past detections occurred frequently.

To investigate these effects we run a logit regression. As in the previous model, the outcome variable is the binary decision to communicate when a conspiracy is not yet in place. Among the covariates, we include two variables controlling for players' experience: the number of periods elapsed since the beginning of the current match ($PeriodInMatch$), and the number of matches played since the beginning of the game ($Match$). We also include covariates to test for the presence of learning from personal experience of punishment or of betrayal. Dev_C (Dev_P) is the frequency of observed deviations in the current (previous) match(es), measured as the number of deviations observed in the current (previous) match(es) over the number of periods in which a cartel was active (so that a deviation could

[22] If individuals have an aversion to betrayal, the mere presence of an additional and costless option to betray (provided by the secret report in the Leniency treatments) would reduce their willingness to cooperate. Our set up, however, does not allow for a rigorous test of this conjecture.

take place). We interpret Dev_C as a measure of the trustworthiness of the current opponent. *Rep* represents the frequency of reports that a subject has experienced so far, in the current match (Rep_C) and in previous matches (Rep_P). *Det* measures the frequency of observed exogenous detections in past periods of the current and previous matches. Finally, $PaidFine$ represents the sum of the fines paid by the subject up to the current period, a proxy meant to measure how strong the memory of punishment is in the player's mind. We make a distinction between the accumulated fines paid due to 'exogenous' detection ($PaidFineDet$) and those paid due to betrayal/reporting ($PaidFineRep$). Again, we also distinguish between the fines paid in the current and in previous matches. The model is estimated separately for Communication and for the Antitrust and Leniency treatments, and the different treatments are controlled for through the fine to be paid in case of detection ($Fine$) and through the expected fine ($Exp.Fine$).

	Communication		Antitrust		Leniency	
	coeff.	s.e.	coeff.	s.e.	coeff.	s.e.
Dev_P	1.086	0.947	0.295	0.739	-0.293	0.922
Dev_C	-0.290	0.525	0.342	0.665	-1.642**	0.835
Rep_P			0.245	1.778	-0.153	0.588
Rep_C			-1.821	1.191	0.272	0.486
Det			-2.971*	1.711	-2.411	2.746
PaidFineDet_P			-1.025	1.443	1.958	2.825
PaidFineDet_C			-4.564***	1.596	3.171	3.249
PaidFineRep_P			-1.019**	0.416	-0.470	0.340
PaidFineRep_C			-1.789***	0.591	-1.206***	0.321
Match	-0.105	0.176	0.250*	0.139	-0.180	0.192
Period in Match	-0.129***	0.038	0.023	0.061	-0.065**	0.027
Fine			-0.696	0.819	-1.093*	0.638
Exp.Fine			-2.026	1.417	0.209	1.131
Constant	2.437***	0.707	1.823**	0.863	0.983	0.657
Log Likelihood	-326.762		-529.671		-849.975	
N	684		1059		1600	

Table 4: Logit regression with multilevel random effects.

Trust Table 4 shows that the history of play in the current match – the frequency of deviation in the current match, Dev_C, and the accumulated paid fines due to reporting, $PaidFineRep\_C$ – negatively affect subjects' willingness to communicate in LENIENCY. This pattern suggests that price deviations combined with simultaneous reports strongly reduce trust and thereby increase post-conviction deterrence. The significant coefficient on $PaidFineRep\_C$ further indicates that the breach in trust is stronger the larger the fine.[23] We summarize these observations as follows:

Result 2. *The frequency of deviation and the sum of the fines paid because of reporting increase deterrence under* LENIENCY.

Saliency People's perception of an uncertain event may be based not only on the event's actual probability, but also on its vividness. This conjecture is partly validated by our data. Table 4 indicates that the sum of the fines paid by a subject in previous periods due to exogenous detection ($PaidFineDet$), as well as the frequency of exogenous detections in past periods (Det), have a significant and substantial negative effect on subjects' willingness to communicate in the ANTITRUST treatments. In those treatments, subjects who have been detected many times, or have paid a very high accumulated amount of fines, thus appear less inclined to recidivism. By contrast, past detections do not affect deterrence significantly under the LENIENCY treatments, confirming that the fear of betrayal due to reporting, rather than the risk of an exogenous detection, drives deterrence in those treatments.

Table 4 also shows that in the ANTITRUST treatments, the accumulated fines due to reporting have a deterrence effect. In this treatment reporting is generally used by cheated upon parties as a form of punishment against deviators. The negative and significant effect of $PaidFineRep\_P$ and $PaidFineRep\_C$ on subjects' willingness to communicate under ANTITRUST suggests that those who defected and were punished in the past are less inclined to communicate again in the future, especially when the punishment was particularly harsh or if they were punished more than once. We summarize our findings as follows:

[23] Interestingly, the coefficient on $Fine$ is also significantly negative in the LENIENCY regression. Besides confirming the importance of the fine as documented in Result 1, this finding also suggests that under LENIENCY, higher fines have an ex ante deterrence effect.

Result 3. *The frequency of exogenous detections and the associated accumulated fine payments increase deterrence in* Antitrust *but not in* Leniency*.*

Results 2 and 3 suggest that the history of play matters for deterrence for at least two reasons. First, players use the history to update their beliefs about their opponent. Betrayals by the opponent probably generated distrust, particularly so in the Leniency treatments due to the frequent reports, and thereby induced deterrence. Second, subjects appear to have perceived past fine payments as particularly salient events, and therefore were less inclined to re-form conspiracies.

5 Conclusion

Our laboratory experiment highlights the importance of deterrence channels relating to organized forms of economic crime that are different from those relating to individual crime. In particular, Prisoner's Dilemma-like leniency policies appear to produce a strong deterrence effect for organized crime mainly through 'induced distrust': by increasing the likelihood and the cost of being betrayed by a criminal partner, the programs generate higher demand for trust among criminals, hence less crime for any given level of trust. Our study also points to the importance of salience for deterrence. The experience of detection and associated fine payments generate higher post-conviction deterrence (lower recidivism), as subjects perceive such threats as more salient after having paid large fines.

These forces, rarely accounted for in theory and in practice, call for further, more specific experimental tests. If confirmed, and to the extent that they apply to real world settings, they have important policy implications.

First, they suggest that the benefits of tough sanctions may have been underestimated. When whistleblowing is an option, tough sanctions have a direct effect on organized crime deterrence, independent of their effect on the level of the 'Beckerian' expected sanction. The deterrence effect is particularly strong when well designed Leniency policies make betrayal and self-reporting highly attractive and likely (in addition to the saliency bias that is likely to apply in general).

Second, our results cast some doubt on recent concerns that too many leniency applications in antitrust could undermine cartel deterrence by keeping competition authorities too busy to handle random industry audits, at least if sanctions are sufficiently severe and leniency programs well designed and administered.

Interesting avenues for related research include in our view robustness checks, like changes in the parametrization and the framing of the experiment (although recent work by Krajčcová and Ortmann 2008 suggests that our results should be robust); identifying the exact role played by 'betrayal aversion' in the presence of Prisoner's Dilemma-like leniency schemes; 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).

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 Appendix to the theoretical predictions

B.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.[24] 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

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

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 Communication and in the policy treatments can then be expressed as

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

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 Antitrust and Leniency treatments, and are tighter in the policy treatments than in Communication 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. Punishments are assumed to take the standard form of a price war.[25] 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

[24]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.

[25]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 Antitrust treatments. In fact, we show in a companion paper, Bigoni et al. (2009), 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.

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

$$\frac{\pi^c}{1-\delta} \geq \pi^d + \delta V^p, \tag{ICC-Communication}$$

$$\frac{\pi^c}{1-\delta} - EF \geq \pi^d - EF + \delta V^p, \tag{ICC-Antitrust}$$

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

where π^d denotes the deviation profit. Following a deviation, a player risks to be fined in ANTITRUST 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-Antitrust) 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 COMMUNICATION and ANTITRUST treatments and (ii) all else equal, tighter in LENIENCY than in ANTITRUST 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. It is easy to show that the PC holds in all treatments when the collusive price equals the joint profit maximizing price. Note from the ICCs that a collusive price is sustainable in all treatments if it is sustainable in the LENIENCY treatment with the largest EF. Thus, let $\alpha = 0.2$ and $F = 300$ (as in the treatments 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 $EF = 187.5$ and $V^p = \pi^b / (1-\delta) = 666.67$ so that (ICC-Leniency) holds with strict inequality. Thus the joint profit-maximizing price is sustainable in all treatments.

B.2 The determinants of the minimum level of trust

This Appendix formally offers a formal comparison of the *minimum level of trust* across treatments.[26] 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

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

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

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

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

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

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

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

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 $V^{ss}_{Comm} - V^{ds}_{Comm} = V^{ss}_{Anti} - V^{ds}_{Anti} > V^{ss}_{Len} - V^{ds}_{Len}$ and $V^{dd}_{Comm} - V^{sd}_{Comm} = V^{dd}_{Anti} - V^{sd}_{Anti} < V^{dd}_{Len} - V^{sd}_{Len}$. Hence, $\beta_{Comm} = \beta_{Anti} < \beta_{Len}$.

Note that the ICC (as defined in B.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

[26] 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.

from 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 $\pi^b \leq \pi^{d2} < \pi^{d1}$.[27]

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).

B.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 Antitrust (since EF increases) but has no effect on the ICC nor on β_{Anti} (as EF cancels out in (ICC-Antitrust) 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).

B.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 Antitrust while both the ICC and β_{Anti} 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.

[27] 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.

B.5 Zero expected fine

This appendix motivates Hypothesis 4. Based on the PCs and the ICCs, neither ANTITRUST nor LENIENCY should have a deterrence effect relative to COMMUNICATION when the per period expected fine is 0. Note also that ANTITRUST does not require more trust than COMMUNICATION as $\beta_{Comm} = \beta_{Anti}$. 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 $\beta_{Anti} < \beta_{Len}$ (since $V_{Anti}^{dd} - V_{Anti}^{sd} < V_{Len}^{dd} - V_{Len}^{sd}$).

B.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 ANTITRUST, the ICC is tightened (and thereby β_{Anti} 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 COMMUNICATION) 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.

C 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**
ANTITRUST	31/05/2007	32	26	6
	04/06/2007	32	27	2
	07/06/2007	32	20	6
	14/12/2007	32	25	3
LENIENCY	04/06/2007	32	25	2
	05/06/2007	32	26	3
	07/06/2007	26	23	4
	08/06/2007	32	22	3
COMMUNICATION	30/05/2007	32	26	4

Table 5: **Treatments**

D Results on Prices

Treatment	*average price* without communication	with communication
ANTITRUST		
$F = 200,\ \alpha = 0.10$	3.4	5.7
$F = 1000,\ \alpha = 0.02$	3.4	6.1
$F = 300,\ \alpha = 0.20$	3.3	6.3
$F = 1000,\ \alpha = 0$	3.8	6.8
LENIENCY		
$F = 200,\ \alpha = 0.10$	3.6	5.7
$F = 1000,\ \alpha = 0.02$	3.5	7.2
$F = 300,\ \alpha = 0.20$	3.2	6.1
$F = 1000,\ \alpha = 0$	3.9	7.9
COMMUNICATION	3.4	5.0
Total	3.5	6.1

Table 6: **Average price with and without communication.**

E 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:

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

where $\pi_{nms} = Pr(CommDec_{nms}|\mathbf{x}_{nms}, \eta_{ms}^{(2)}, \eta_{s}^{(3)})$. 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 β. $\eta_{ms}^{(2)}$ represents the random intercept for subject s in match m (second level), and $\eta_{s}^{(3)}$ 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.[28]

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,

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

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 $\{0, 1, 2, \dots, 12\}$. 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, ... , 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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