Trust, Salience, and Deterrence: Evidence From an Antitrust Experiment *

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Abstract

Organized economic crime - cartels, collusion, corruption, fraud - requires cooperation between wrongdoers and can therefore be deterred by ensuring that cooperation is not an equilibrium, or by generating 'distrust' that prevents coordination. We present results from a laboratory experiment identifying the main cognitive and behavioral channels through which different law enforcement strategies deter organized economic crime. The *absolute level of the fine* a strong deterrence effect even when the probability of direct apprehension by law enforcers is zero. The effect appears driven by *distrust*, as it increases when the incentives to betray partners are

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strengthened by leniency policies offering amnesty to “turncoat whistleblowers”. Then the expected fine in the sense of Becker (1968) loses significance. We also document a strong deterrence effect of *the sum of the fines paid* in the past, which suggests a significant role for *salience* and *availability heuristic* in law enforcement.

KEYWORDS: Antitrust, Availability heuristic, Behavioral economics, Betrayal aversion, Cartels, Collusion, Coordination, Corruption, Crime and Punishment, Deterrence, Distrust, Experiment, Strategic risk, Trust, Whistleblowers.

JEL CODES: C92, D03, D80, K21, K42, L41

1 Introduction

Law enforcement is an important dimension of the quality of institutions, widely thought to affect economic transactions, investments, and long term growth.[1] Crime deterrence, on the other hand, is the main objective of public law enforcement and a main function and *raison d'etre* of the modern State (Barzel, 2001). This paper focuses on the deterrence of ‘organized economic crime’ defined broadly to include endeavours involving multiple coordinated wrongdoers engaged in joint non-violent illegal economic activities like cartels and and related anticompetitive agreements, corruption, financial fraud, smugglig, mass tax evasion, etc. It reports results from a laboratory experiment examining the main cognitive and behavioral channels through which traditional law enforcement policies — fines and the probability of detection – and more innovative ones – amnesty to wrongdoers that self-report turning in their partners — affect the deterrence of these complex forms of crime.

The modern economics of public law enforcement, from Becker (1968) to our days, has offered crucial insights by focusing on individual crimes seen as an individual's decision (or series of decisions; see Polinsky and Shavell 2000 for an excellent survey). Organized crime, however, differs crucially from individual crime because – as first recognized by Stigler (1964) for price-fixing conspiracies – it

[1] See e.g. Acemoglu *et al.* (2005), Glaeser *et al.* (2004), and Beck and Levine (2005).

must deal with the free-riding temptation of members of the criminal team. Since publicly enforced contracts cannot be used, to govern internal agency problems and maintain cooperation criminal organizations must rely on self-administered sanctions.[2] That is, organized crime must be a self-enforcing cooperative equilibrium of a dynamic multi-agent game, not just a set of coordinated individual decisions to commit crime together.[3]This feature has crucial implications for the design of law enforcement policy, in part recognized by the recent literature on cartel deterrence.[4]

The first crucial implication is that there are *novel forms of deterrence* to consider. To sustain a criminal organization as a cooperative equilibrium it is not sufficient that (a) each wrongdoer finds organized crime profitable (that the Participation Constraint is satisfied). In addition, it is also necessary: (b) that cooperation is a subgame perfect equilibrium, so that wrongdoers prefer cooperating rather than betraying their partners, say, running away with the money (the Incentive Compatibility constraints must be satisfied); and (c) that criminals trust each other, so that that they are able to coordinate on the cooperative equilibrium and remain sufficiently confident in each other's cooperation (the 'Trust Problem' must be solved).[5]

So, while to deter an individual crime expected sanctions must be large enough to make it unprofitable, so that the Participation Constraints (PCs) are not satisfied, organized crime may also be deterred by ensuring that necessary conditions (b) or (c) are not satisfied. Deterrence of organized crime can alternatively be achieved by ensuring that at least one criminal's Incentive Compatibility Constraint (ICC) is not satisfied (so that though profitable, organized crime is not an equilibrium); or by worsening the Trust Problem (TP) by structuring incentives to ensure that wrongdoers cannot trust each other, that they do not have suffi-

[2]Third party enforcement of illegal contracts is sometimes provided by other criminal organizations, like Mafia (typically at very high cost; see e.g. Reuter 1983, Gambetta 1993, and Dixit 2003). Here we focus on illegal organizations that do not rely on such third party enforcement.

[3]This is by now well recognized in the economic literature (see e.g. Garoupa 2007, Baccara and Bar-Isaac 2008, and references therein).

[4]We mean here the literature on Antitrust enforcement started by the contributions of McCutcheon (1997), Cyrenne (1999), and Harrington (2004).

[5]Recent experimental evidence in Dal Bó and Fréchette (forth.) and Blonski *et al.* (2009) shows how difficult it may be for subjects to coordinate and sustain cooperation even when it is sustainable as an equilibrium.

cient confidence in others respecting the prescriptions of the criminal equilibrium to select it among other existing equilibria.

Theoretically, deterrence should be easier to achieve tightening by one criminal's ICC, or worsening the TP by making coordination harder or miscoordination more costly, rather than by tightening the PC as necessary for individual crime. One main objective of our study is to verify this theoretical conjecture by understanding which of these three possible deterrence channels is more effective when real world subjects play the criminal game.

A second peculiarity of organized crime crucial to law enforcement is that *there are always 'witnesses'*: by cooperating, criminal partners typically end up having some information on each other that could be elicited by suitably designed revelation mechanisms. This has been 'folk wisdom' for centuries and was first recognized in economics by Albert W. Tucker when in the 50s he coined the story of the two convicted members of a criminal organization questioned in separate rooms with the promise of leniency against betrayal to clarify the properties of Flood and Dreshers' game matrix, the Prisoner's Dilemma.[6] Mechanisms like the Prisoner's Dilemma have been used in the fight of many forms of 'organized crime' in history, from coalitions of tribes resisting Roman invaders, to 'bandits' in XIII century England, to the Resistance in Nazi-occupied war regions. In the the 60s and 70s they have also been extensively used in Italy to fight terrorism and the Sicilian Mafia (see Spagnolo 2008). Not surprisingly, the recent economic literature on leniency programs in antitrust points at their likely effectiveness also in deterring price-fixing conspiracies.[7] However, this literature also highlights several possible counterproductive effects of these policies, and disregards how cognitive or behavioral biases might change the picture, leaving many empirical questions

[6]Most existing theoretical work on organized crime did not focus on these mechanisms. It either followed Buchanan (1973) in focusing on the (possibly negative) effects of deterrence on criminal market structure (see e.g. Mansour, Marceau, and Mongrain 2006, and references therein), or focused on the role of violence (e.g. Konrad and Skaperdas 1997), or dealt with optimal on organizational design (e.g. Garoupa 2007 , and Baccara and Bar-Isaac 2008). A notable exception is the work of (Kofman and Lawarrée 1996).

[7]This literature extends the analysis of self-reporting in law enforcement from individual crime, as in started by Kaplow and Shavell (1994) and Koffman and Lawarre (1996), to general cartel deterrence in dynamic oligopoly. See Rey (2003) and Spagnolo (2008) for surveys, Spagnolo (2004) for a theoretical analysis of the general deterrence effects of these schemes, and Miller (2009) for an empirical evaluation.

unanswered.

Our laboratory experiment examines the effects of different law enforcement policies on the general deterrence of criminal organizations explicitly framed as price-fixing conspiracies. These are probably the mildest form of organized crime one can think of, but they share the crucial features discussed above with most other forms of non-violent organized crime.[8]

In our set up, subjects play a repeated Bertrand duopoly game with differentiated goods and uncertain end, where subjects can choose to communicate, in which case they are considered having formed a possibly illegal conspiracy/organization. This underlying game can be directly rephrased as a corruption or 'group fraud' game by renaming variables.

We then run several treatments which differ in the law enforcement parameters, including the presence and size of fines against the illegal conspiracy, the probability of being discovered by a successful audit by the law enforcement agency, and the possibility of obtaining leniency when self-reporting and betraying criminal partners. We analyze how fines, probability of apprehension and leniency programs interact and produce deterrence, assuming that the latter is welfare improving.[9] In particular, we try to figure out which are the main determinants of deterrence when leniency is granted to turncoat whistleblowers, and when it is not.

We find that, consistent with other experiment on the subject, the introduction of programs granting leniency to wrongdoers that self-report, turning their former criminal partners in, increases deterrence. A more crucial finding is however that the introduction of these programs appears to change the main mechanism through

[8]And even with more dangerous, violent criminal organizations. Indeed, the fact that leniency policies – traditional instruments for the fight of Mafia and terrorism – were recently successfully imported in Antitrust to fight cartels, speaks loud about how similar are these forms of crime in terms of strategic structure. Cartels are sustained by 'price wars', violent criminal organizations by the threat of 'guns wars'. The difference is more quantitative (the strength of the punishment phase) than qualitative: they are all ongoing self-enforcing agreements sustained by the threat of a self-administered punishment (see Abreu 1988).

[9]In a companion paper (Bigoni et al. 2009) we study the effects of leniency programs and of other antitrust policies on explicit and tacit collusion, focusing on market prices before and after an antitrust conviction. There we find that antitrust policies are somewhat special, as even when a policy has deterrence effects in terms of reducing cartel formation, it may fail in reducing prices and increasing welfare, the ultimate aim of competition law and policy.

which deterrence works. When leniency makes betrayal so much more attractive, the absolute fine becomes the only component of law enforcement to influence behavior. Wrongdoers do not react anymore to changes in the probability of being detected by the law enforcing agency probably because they are entirely focussed on the risk to be betrayed.

In the ANTITRUST treatments, i.e. absent leniency, deterrence increases with the *expected fine* – the probability of being detected by the law enforcement agency multiplied by its consequences – as predicted by classic law enforcement theory (the PC becomes more stringent, crime becomes less profitable). Increases in the *absolute level of the fine* also significantly increase deterrence, suggesting that subjects are concerned about the possibility of other subjects self-reporting even when this is costly. Reducing the probability of apprehension down to 2% while keeping the expected fine constant increases deterrence, and does not lead subjects to disregard the risk of conviction – as one might have conjectured under some interpretations of Prospect Theory (Kahneman and Tversky 1979).

In the LENIENCY treatments, instead, deterrence *only* increases with the *absolute* level of the fine: it does not respond to changes in the expected fine or in the probability of being discovered by the law enforcement agency, even when this falls to zero. These findings suggest that the worsening of the Trust Problem – the increased fear of being betrayed by partners and the higher minimum level of trust necessary to sustain cooperation when leniency makes defections and self-reporting more attractive for defectors and more costly to non-defectors – dominates all other considerations. With leniency the higher perceived likelihood and cost of being betrayed by a partner appears the only significant driver of behavior.

We also find a significant deterrence effect of the *sum of the fines paid* in the past on the rate of attempts to establish a new conspiracy. This effect has been sometimes named 'punishment-induced deterrence' and is consistent with fines being more 'salient' for subjects that actually experienced them, as suggested by theories on "availability heuristic". These behavioral biases appear also the most plausible reason why in ANTITRUST players' willingness to form conspiracies decreases after detection, even if no unilateral deviation has previously taken place: a fresh memory of the punishment seems to significantly increase the perceived probability of detection.

To the extent that these results apply also outside the laboratory, they have clear policy implications. For example, they point at the importance of complementing leniency schemes with high absolute sanctions, rather than with a high probability of apprehension; and suggest that recent concerns that the many applications to the antitrust leniency programs could undermine cartel deterrence by keeping competition authorities too busy to inspect industries may be misplaced, if sanctions are high and the leniency program is well designed and administered.

Our results on the importance of the cost and risk of been cheated upon on the amount of cooperation and on the different 'demand for trust' that consequently emerges in different set-ups is related to the literatures on trust and on coordination and strategic risk in repeated games. The concept of trust includes many aspects, and the most relevant to our set up appears that of 'trust as belief', as that defines the likelihood that the other party betrays and self-reports.[10] The results of Bohnet *et al.* (2008) suggest that the stronger deterrence obtained with leniency may have been driven, or strengthened, by 'betrayal aversion', as that increases the cost of being cheated upon by the opponent relative to that of being discovered and fined by a more neutral 'law enforcement agency', a third party. The closest papers on coordination in repeated game and the role of strategic risk are the recent experimental investigations by Dal Bó and Fréchette (forth.) and Blonski et al. (2009), that show how difficult it is for cooperation to emerge even when it is a Pareto-dominant equilibrium, and how important it is to take into account the role of the sucker's payoff, relevant in case of miscoordination, when trying to understand when cooperation is likely to emerge.[11]

The idea of incorporating into the analysis of law enforcement considerations about the behavioral departures form the standard conception of rationality dates back to Jolls et al. (1998), who suggested that models of economic analysis of law that do not keep these factors into account may lead to erroneous conclusions. They therefore developed and proposed a new approach to this branch of studies, "informed by a more accurate conception of choice, one that reflects a better understanding of human behavior and its wellsprings". Since their seminal article,

[10] See Fehr 2009, and Sapienza *et al.* 2007.

[11] See Blonski and Spagnolo (2003) for a theoretical analysis of this issue.

Behavioral Law and Economics has developed and has been applied to several specific topics in economic analysis of law (see Jolls 2007, and Garoupa 2003 for a critical review).

Our results on the role of the salience of fines seem related to Akerlof (1991), who stressed that outstanding events and vivid information may exert undue influence on decisions: he refers to this principle to explain time inconsistent decisions – arguing that present costs and benefits are salient if compared to future ones. Similarly, one could argue that an exacerbation of punishments may increase deterrence since extremely harsh penalties are more salient, thus overweighted.[12]

A closely related behavioral effect concerning probability perception is "availability heuristic". This mechanism was foregrounded by Kahneman et al. (1982), and refers to the fact that events associated with extremely high utilities or disutilities, and more generally sensational or spectacular events, are easier to recollect, therefore their occurrences are perceived as being more frequent than they actually are. The main difference between availability heuristic and salience is that according to the first one risk perception is driven by memory-dependent mechanisms, while the second one states that attention is guided by the most vivid present stimuli, not necessarily linked to past experience.

Availability heuristic has been tested and confirmed by Folkes (1988)'s studies on the risk perceived by consumers when purchasing a product, and by a recent study by Keller et al. (2006) on perception of flood risk, which testifies that past experience of flooding increases risk perception independent on the information exogenously provided about this risk.

The experimental evidence collected to test different theoretical predictions in the specific context of crime deterrence is still rather limted. A number of experiments were recently run to evaluate the deterrence effects of Leniency programs, both in the context of antitrust (e.g. Apesteguia et al. 2007, Hinloopen and Soetevent 2008, Bigoni et al. 2009) and of corruption (e.g. Krajcova 2008 and Krajcova and Ortmann 2008). The first group of experiments find positive deterrence effects of well designed Leniency programs, though prices may not fall with increased deterrence. The latter empirically confirm the risk of counterproductive

[12]Chetty et al. (2009) empirically show in the context of taxation that the effects of salience on real world agents can be substantial.

effects of poorly drafted programs (as characterized in Buccirossi and Spagnolo 2006). None of these studies, however, tries to identify the channels through which these law enforcement instruments produce deterrence.

Among the experiments run to analyze the determinants of peoples responses to legal sanctions, we should mention a study performed by Cason and Gangadharan (2006), who experimentally analyze a model of compliance developed by Harrington (1988) in which the enforcement agency modifies the inspection frequency and severity of the penalties depending on past compliance. They find that the violation rate does not change as sharply as predicted by the model when the probability of detection and size of the fine change, and show that the observed behavior might be captured by a quantal choice model, which accounts for boundedly rational decision making by allowing individuals to make errors, assuming that errors that are more costly are less probable.

A second experimental work testing predictions of behavioral economics in the context of law enforcement has been carried out by Jacquemet et al. (2007), who study the role of optimism bias in the monitoring of illegal activities. They show that subjects exhibit a strong tendency to under-evaluate their own likelihood of experiencing an unfavorable event as compared to the one of others, which leads to a lower level of deterrence.

The 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.

2 Experimental Design

In our experiment, each subject played a repeated duopoly game in anonymous two-persons groups. In every stage game, the subjects had to take three types of decisions. First, the subjects had to choose whether or not they wanted to form a cartel by discussing prices. Second, they had to choose a price in a discrete Bertrand price game with differentiated goods. Third, the subjects could choose to self report cartels to a competition authority. The attractiveness of this latter opportunity depended on the details of the antitrust law enforcement institution — the treatment variables of our experiment.

2.1 The Bertrand game

In each period, each subject had to choose a price from the choice set $\{0, 1, ..., 11, 12\}$. Subjects' individual payoffs depended on their own price choice and on the price chosen by their competitor and were reported in a payoff table distributed to the subjects. This table indicated the subject' profit corresponding to its own price choice and to the price chosen by its competitor (see table 1) and was derived from the following standard linear Bertrand game[13].

The demand function for each firm i was 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 (competitor 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 faced a constant marginal cost, c, and had no fixed costs. The profit function, $\pi_i(p_i, p_j)$, was thus given by

$$\pi_i(p_i, p_j) = (p_i - c)q_i.$$

In our experimental setup, we chose $a = 36$, $c = 0$ and $\gamma = 4/5$ and restricted the subjects' choice set to $\{0, 2, ..., 22, 24\}$. These parameters yield the payoff table distributed to each subject. To simplify the table we also relabeled each price by dividing it by 2 and rounded the payoffs to the closest integer. 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 only earns a profit of 20. Similarly, there are gains from deviating unilaterally from other common prices than the monopoly price as well as associated losses for

[13] The details of the Bertrand game were not described to the subjects.

		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**

the cheated upon firm; in the range of prices in between the Bertrand price and the monopoly price, i.e. in the range $\{4, ..., 8\}$, these gains and losses are smaller than when a subject deviates unilaterally from the monopoly price.

2.2 Cartel formation

Throughout the experiment, the subjects could form cartels by discussing prices. At the beginning of every period, a communication window opened if and only if both subjects agreed to communicate. This communication stage, which is described in more detail below, was designed in such a way that it would result in a common price on which to cooperate. This agreed upon price was non-binding, however, therefore each subject could cheat on the agreement by subsequently charging a price different from the agreed upon price.

Whenever two subjects chose to communicate, they were considered to have formed a cartel and ran the risk of being fined. In case the cartel remained undetected, it could still be discovered and sanctioned in the following periods. This implied that two subjects could be fined in a period even if no communication took place in that specific period; for example, two subjects could be fined in a period in which they did not communicate if they communicated in the previous period and the competition authority did not detect the associated cartel in that period. Once a cartel was detected, however, it was considered to be dismantled and in subsequent periods the former cartelists did not run any risk of being fined unless they communicated again.

2.3 Treatment variables

Whenever two subjects formed a cartel, a competition authority could detect the cartel and convict its members for price fixing. Detection could happen in two ways. First, in every period, the competition authority detected 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 the cartel, 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.

We ran nine treatments of our game, adopting a *between subjects* design, so that every subject only played the game under a single treatment. The nine treatments differ in the specific type of antitrust law adopted (with or without leniency for those who report the cartel), in the probability of detection and in the size of the fine imposed to the detected cartels' members. The differences between the treatments are summarized in table 2.

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**

Antitrust Policy. Our baseline treatment corresponds to a laissez faire regime and is denoted COMMUNICATION: in this treatment, $\alpha = F = 0$ so that forming a cartel by discussing prices is legal. To simplify the instructions and to eliminate irrelevant alternatives, subjects were not allowed to report cartels. In the eight other treatments cartel members were allowed to report cartels in which they participated. The ANTITRUST treatments correspond to traditional antitrust laws without any leniency program: in case a cartel was reported, both cartel members (including the reporting one) had to pay the full fine F. The LENIENCY treatments correspond to current antitrust laws with a leniency program: in case the cartel was reported by one of the cartel members only, the reporting member paid no fine while the other one paid the full fine, F; if instead both cartel members reported the cartel simultaneously, both paid a reduced fine equal to $F/2$. Note that under

Leniency treatments a player who decides to deviate from the agreement is always better off if he reports the cartel immediately after having deviated, that is before deviation is detected by the other party. So, in principle, the introduction of Leniency Programs should tighten the incentive compatibility constraint, since deviating becomes less risky, thus more attractive. Leniency should also harshen strategic risk, because the cheated upon firm not only suffers for the exploitation, but also has to pay the fine for sure.

Probability of Detection and Size of the Fine We then vary the probability of detection and the size of the fine across treatments: in particular, per each of the two considered antitrust policies, we have two treatments with an expected fine of 20 — one with a high probability of detection ($\alpha = 0.10$) and a low fine ($F = 200$), the other in which, vice versa, the probability of detection is low ($\alpha = 0.02$) and the fine is high ($F = 1000$) — and one treatment in which the expected fine is higher: $\alpha = 0.2$ and $F = 300$.

A different mix of magnitude and probability of the fine affects the riskiness of the collusive outcomes, but, as discussed above, it is not obvious what kind of effect this could generate in terms of deterrence. For example, if agents are perfectly rational and risk neutral, and they do not react to strategic risk, their preferences should be only marginally affected by a change in the determinants of the fine which leaves the expected fine constant. Such a change, in fact, has no impact on the expected collusive profits and has at most a marginal effect on the profitability of a deviation from collusion. By contrast, if agents were risk averse we should observe higher deterrence when the size of the fine is higher and the probability lower, whether leniency programs are present or not. In addition, under Leniency Programs an increase of the magnitude of the fine dramatically reduces the profit a firms obtains when "cheated upon" , that is when its opponent deviates from the collusive agreement. As mentioned above, these profits play no role in the standard theory, since they do not affect the conditions for an agreement to be sustainable in equilibrium, but they do matter for strategic risk. Moreover, all the behavioral biases affecting risk perception we enumerated above might play a role in determining the outcome of such changes in the components of the expected fine.

We also run two additional treatments — one with Leniency, one without it — in which the fine is high ($F = 1000$), but can be inflicted only in case of reporting because the probability of detection is set to be null ($\alpha = 0$): that is, the antitrust authority is not able to discover any cartel that is not reported by at least one of its members. Comparing the results of these treatments with those we get from the corresponding treatments where the size of the fine is the same ($F = 1000$) but the probability of detection is positive ($\alpha = 0.02$), we can study if a very small probability of detection is underestimated, and we can also check for the role played by strategic risk in this setting. Indeed, if strategic risk did not affect players' decision, we should not observe any deterrence in the treatment with $\alpha = 0$.

2.4 Experiment's timing and rematching procedure

At the end of each period, subjects were rematched with the same competitor with a probability of 85%. With the remaining probability of 15%, all subjects were randomly matched into new pairs. When this happened, cartels formed within the previous match could not be fined anymore. The experiment lasted at least 20 rounds. From the 21st round on, we introduced a termination probability of 15%, while the probability of rematching was reduced to 0. To pin down expectations on very long realizations, subjects were also informed that the game would have been stopped in case the experiment lasted for more than 2 hours and 30 minutes. This eventuality never took place, all sessions ended naturally within one hour and a half from the beginning.

This re-matching procedure had several advantages. First, subjects were playing truly *indefinitely repeated games* without problems associated with end game effects. Second, each subject played several repeated games against different competitors, which allowed us to observe the subjects' behavior in a larger number of repeated games.

Before the experiment started, subjects played five practice periods in which they were paired with the same competitor. Participants were informed that at the beginning of the 'true' (i.e. remunerated) experiment they would have been matched with another player, different from the one they faced during the trial periods. They were also told that profits realized during the trial periods were not to affect their earnings from the experiment.

2.5 The timing of the stage game

In the ANTITRUST and LENIENCY treatments, a stage game consisted of 7 steps (see figure 1). In the COMMUNICATION treatment steps 4, 5 and 6 were skipped.

Figure 1: Stage game.

We will now describe more in detail each single step.

Step 1: Communication decision. Each subject was asked whether he wished to communicate with his competitor or not. If both subjects pushed the "yes" button within 15 seconds, the game proceeded to step 2. Otherwise the two subjects had to wait for an additional 30 seconds before pricing decisions were taken in Step 3. In all periods, subjects were also informed whether they were matched with the same opponent as in the previous round or if a re-match had taken place.

Step 2: Communication. If both subjects decided to communicate in step 1, a window appeared on their computer screen asking them to simultaneously state a minimum acceptable price in the range $\{0, ..., 12\}$. When both of them 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} was defined as the minimum among the two prices selected in the previous negotiation round. This procedure went on until 30 seconds had passed. The resulting minimum price p_{min} was referred to as the agreed upon price.

Step 3: Pricing. Each subject had to choose his price from the choice set $\{0, ..., 12\}$. Possible price agreements reached in step 2 were not binding. The subjects were informed that if they failed to choose a price within 30 seconds, then their default price would be high enough to yield them a profit equal to 0 regardless of the opponent's price.

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 here as 'secret'.

Step 5: Market prices and public reports. Subjects learnt the competitor's price choice. If communication took place in the current period or in one of the previous periods whithout 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 and had not yet been discovered or reported in steps 4 or 5, the competition authority discovered the cartel with probability α.

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

Note that with our experimental setup subjects have two opportunities to report the cartel: first at step 4, right after having set their price, then again at step 5, after having been informed about the price chosen by their opponent. In our design, reporting can thus be used for two different purposes: (*i*) deviating subjects may report to get protection against prosecution and (*ii*) cheated upon subjects may report to punish their opponents, if they have not reported before.

2.6 Experimental procedure

Our experiment took place in May 2007 at Tor Vergata University (Rome, Italy) [14]. Sessions lasted on average 2 hours, including instructions and payment. We

[14]Treatment Antitrust with $\alpha = 0$ and $F = 1000$ was run in an additional session, taking place at Tor Vergata University in December 2007. Students having taken part to previous sessions

ran nine sessions (one per treatment), with 32 subjects per session. In treatment LENIENCY with F=300 and α=0.2 we only had 26 subjects due to an unusual rate of non show up, thus the experiment involved 282 subjects all in all. The average payment in the main game was equal to 23.60€, with a maximum of 34€and a minimum of 11€, while the average payout for the investment game was 30.33€, with a minimum of 0 and a maximum of 62.5€.

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 was 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 (which always happened after about fifteen minutes), each subject was randomly matched with another subject for the five practice rounds. After the practice rounds, participants had a last opportunity to ask questions about the rules of the game. Again, they were answered privately. Then they were randomly rematched into new pairs and the real game started.

At the end of each session, the subjects were paid privately 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

Our experimental design implements a discounted repeated (uncertain horizon) price game embedded in different antitrust law enforcement institutions. Much of the theory on repeated oligopoly may be interpreted to suggest that antitrust law enforcement should not matter: subjects should collude tacitly and reap the gains from collusion without running the risk of being convicted. This conclusion

were not admitted.

is invalid if pre-play communication (cartel formation in our context) enhances subjects' ability to coordinate and charge high prices, as experimental evidence strongly suggests (see e.g. Crawford 1998). The simple equilibrium analysis below, therefore, presumes cartel formation to be a prerequisite for successful collusion.

The monopoly price can be supported as an equilibrium outcome in all COMMUNICATION, ANTITRUST and LENIENCY treatments. No hypotheses can thus be stated on the ground that collusive outcomes do not constitute an equilibrium in some of the treatments. Yet the participation (P-) and incentive compatibility (IC-) constraints, two necessary conditions for the existence of a collusive equilibrium, provide valuable insights on possible effects of law enforcement institutions. These constraints are tighter in some treatments, and under the standard assumption that tighter equilibrium conditions make it harder to sustain the equilibrium, they should also increase deterrence.

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 PC can be expressed as

$$\frac{\pi^c - \pi^b}{1-\delta} \geq 0 \text{ and } \frac{\pi^c - \pi^b}{1-\delta} \geq \frac{\alpha F}{1-\delta}. \tag{PC}$$

where π^b and π^c denote the profits in the competitive Bertrand equilibrium and on the collusive path respectively, δ denotes the discount factor, α the probability of detection and F the fine. The first inequality is the PC in COMMUNICATION and the second inequality the PC common to the policy treatments. Clearly the PC-constraints hold in all treatments provided the collusive price is sufficiently large.[15]

The Incentive Compatibility Constraints (ICC) The ICC states that sticking to an agreement is preferred over a unilateral price deviation followed by a punishment. We focus on standard punishments carried out through some form of

[15]In the treatments where $\alpha F < 60$ [$\alpha F = 60$], $\pi^c - \pi^b > \alpha F$ for all collusive prices strictly larger than 3 [6] (see the payoff table).

price war: reports are not used on the punishment path.[16] In addition, cartels are assumed not to be re-formed when 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 viewed as being generated by optimal symmetric punishments (conditional on the restrictions imposed by the other assumptions).[17] 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

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

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

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

where π^d denotes the deviation profit. Following a deviation, a player risks to be fined in Antitrust only, as 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 also that $\alpha F/(1-\delta) > \alpha F/(1-(1-\alpha)\delta)$, since dismantled

[16]Public reports as punishments against a price deviation can however be credible in the Antitrust treatments. Consider the following strategy. Do not undercut the collusive price on the collusive path. If *any* player undercuts the collusive price, report the cartel immediately. In the period following the deviation, return to the collusive path unless one or both players did not report the cartel. In the latter event, punish through grim trigger strategies. It is easy to see that if both players use this strategy, any collusive price is sustainable for any $\delta > 0$. This strategy is discussed in more detail in Bigoni et al. (2009), where it is not adopted by subjects in practice. In the present paper, we disregard this strategy when stating the theoretical predictions.

[17]This assumption is not innocuous. 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 (but 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 as the deviation incentives (from the punishment path) are exacerbated by the possibility to report. A formal treatment of these complicating factors is beyond the scope of this experimental paper.

cartels are assumed not to be re-formed on the punishment path. Clearly the ICCs are (i) tighter in LENIENCY than in ANTITRUST (since a deviation combined with a secret report provides protection against the fine, $\alpha F/\left(1-(1-\alpha)\,\delta\right)$) and (ii) tighter in ANTITRUST than in COMMUNICATION (since in ANTITRUST, expected fines reduce the incentives to stick to the agreement more than they reduce the incentives to deviate, $\alpha F/\left(1-\delta\right) > \alpha F/\left(1-(1-\alpha)\,\delta\right)$).

Strategic Risk and the Demand for Trust 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' (Blonski, Ockenfels and Spagnolo 2009), and the additional disutility subjects tend to experience when being betrayed by someone they trusted because of 'betrayal aversion' (Bohnet, Greig, Hermann, and Zeckhauser 2008), are crucial determinants of subjects' decision whether to cooperate or trust.

To formalize this natural concern in a simple way, we define a *minimum level of trust* in the opponent playing cooperatively rather than defecting which makes colluding profitable in the different treatments. This measure defines the 'basin of attraction' or 'resistance' of the cooperative strategy in evolutionary game theory (see Myerson 1991, sect. 7.11), and has been used in recent experiments to capture strategic risk considerations analogous to those focused on here (see Frechette and Dal Bo, 2009).[18]

More specifically, suppose subjects fear that following communication, with some probability $(1-p)$ their opponents will not abide to the agreed upon cooperative/collusive strategies, but will rather choose a 'safe' non-cooperative strategy, or betray by optimally defecting from the agreement. The complementary probability p can then be seen as the agent's 'belief component of trust' (see e.g. Fehr

[18]We thank Georg Weizsaker for suggesting this 'reduced form' presentation of strategic risk concerns in the vein of Myerson (1991) and Dal Bo and Frechette (2009). The latter paper and Blonski et al. (2009) provide robust experimental evidence that these considerations related to the 'risk dominance' selection criterion play a crucial role in the emergence of cooperation in the repeated Prisoner's Dilemma.

2009, or Sapienza et al. 2009). The minimum level of trust p_K that makes cooperation preferable over defection in treatment K, can be seen as a measure of the 'demand for trust' required by treatment K. Cooperation is only sustainable in each treatment K if $p \geq p_K$, where p is also likely to be different across treatments given that these provide different incentives. Let V_K^{ss} and V_K^{ds} denote the values of sticking respectively deviating in treatment K given that the opponent sticks to the agreed upon price. Similarly, let V_K^{sd} and V_K^{dd} denote the values of sticking respectively deviating in treatment K given that the opponent instead deviates from the agreed upon price. Then p_K is defined by the equality

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

p_K is thus determined by two components. The first component, $V_K^{ss} - V_K^{ds}$, is the value of sticking to relative to defecting from the agreement given that the opponent sticks to the agreement. The presence of $V_K^{ss} - V_K^{ds}$ in the expression for p_K essentially means that the ICC affects p_K. Indeed the basin of attraction of sticking to the cooperative strategy expands as the ICC gets looser (since p_K decreases as $V_K^{ss} - V_K^{ds}$ increases). The second component, $V_K^{dd} - V_K^{sd}$, is the value of defecting relative to sticking to the agreement given that the opponent instead deviates from the agreement. Note that p_K increases with $V_K^{dd} - V_K^{sd}$: the basin of attraction of sticking to the cooperative strategy contracts as the value of defecting relative to sticking to the cooperative strategy increases given that the opponent deviates.

Assuming symmetric punishment strategies (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), these determinants of p_K are given by

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

$$V_C^{dd} - V_C^{sd} = \pi^{d2} + \delta V^p - (\pi^s + \delta V^p), \tag{3}$$

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

$$V_A^{dd} - V_A^{sd} = \pi^{d2} - \frac{\alpha F}{1-(1-\alpha)\delta} + \delta V^p - \left(\pi^s - \frac{\alpha F}{1-(1-\alpha)\delta} + \delta V^p\right) \tag{5}$$

$$V_L^{ss} - V_L^{ds} = \frac{\pi^c - \alpha F}{1-\delta} - \left(\pi^{d1} + \delta V^p\right) \tag{6}$$

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

where the sub-indices C, A and L refer to Communication, Antitrust and Leniency treatments respectively, π^{d1} denotes the one period payoff from a unilateral price deviation, π^{d2} the deviation payoff if both players undercut and π^s the 'sucker's payoff' following a unilateral deviation by the opponent. Note the similarity between the expressions for $V_K^{ss} - V_K^{ds}$ and the ICCs, the only difference being that π^{d1} replaces π^d. The reason for this difference is 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 probablility. As a result, the payoff following a unilateral deviation ranges from the payoff resulting from a 'safe' Bertand price (when the opponent chooses the collusive price) and the payoff from an optimal unilateral defection, π^d.[19] Hence $\pi^b < \pi^{d1} \leq \pi^d$. (Note also that $\pi^b \leq \pi^{d2} \leq \pi^{d1}$.)

The amount of trust required to make the cooperative strategy attractive is largest in Leniency followed in order of magnitude by Antitrust and Communication, i.e. $p_C < p_A < p_L$. The reason is twofold. First, and in line with the ICCs, the incentives to stick to the cooperative strategy contributes to the ranking, i.e. $V_C^{ss} - V_C^{ds} > V_A^{ss} - V_A^{ds} > V_L^{ss} - V_L^{ds}$. Second, the risk of being cheated upon exacerbates the effect of Leniency as $V_C^{dd} - V_C^{sd} = V_A^{dd} - V_A^{sd} < V_L^{dd} - V_L^{sd}$.

[19] The hypotheses below do not crucially depend on whether subjects are concerned about the opponent cheating or playng a 'safe' Bertrand equilibrium.

Hypotheses Under the assumptions that tighter PCs and ICCs as well as higher minimum levels of trust increase deterrence, the above analysis leads to our first hypothesis.

Hypothesis 1 (policy effects) Cartel deterrence is lowest in COMMUNICATION, followed in order of magnitude by ANTITRUST and LENIENCY.

An implicit assumption in the analysis leading to Hypothesis 1 is that the probability of detection α and the fine F are the same in the considered ANTITRUST and LENIENCY treatments. We now turn to the deterrence effects of changes in α and F, taking the policy as given. Our second hypothesis is motivated by the following observations. For the combinations of α and F in our treatments and whether or not leniency is granted to whistleblowers, an increase in the expected fine αF tightens both the PC and the ICC as well as increases the minimum level of trust required to make cooperation attractive (see Appendix B.1).

Hypothesis 2 (increased expected fine) Both under ANTITRUST and LENIENCY, an increase in the expected fine increases deterrence.

Consider next variations in α and F which keep the expected fine constant. Clearly such a change has no impact on the PC. The effect on the ICC and on p_K depends on whether or not the policy is embedded with leniency. While the ICC is unaffected under LENIENCY, the effect on p_L is not neutral: an increase in F compensated by a fall in α, worsens the sucker's payoff (as a defecting subject also reports the cartel) and thereby increases p_L (as $V_L^{dd} - V_L^{sd}$ increases). By contrast, an increase in F compensated by a fall in α loosens the ICC under ANTITRUST (see Appendix YY) and thereby also reduces p_A. (Note that $V_A^{dd} - V_A^{sd}$ is unaffected by changes in α anf F.) These observations 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 expected fine constant, reduces deterrence under ANTITRUST but increases deterrence under LENIENCY.

The contrasting effects of ANTITRUST and LENIENCY in Hypothesis 3 offers one channel to try to assess the importance of trust for decisions to form cartels.

Let us now consider the two treatments (with and without leniency for whistle-blowers) in which the size of the actual fine is high ($F = 1000$), but the probability of detection is null. According to the PC and the ICC, ANTITRUST and LENIENCY should have no deterrence effect relative to COMMUNICATION when the fine is positive but the probability of detection α is equal to zero. The fact that the sucker's payoff is much worse under LENIENCY than under ANTITRUST and COMMUNICATION motivates however the following Hypothesis.

Hypothesis 4 (zero expected fine) Even if the probability of detection is zero, a positive fine generates deterrence under LENIENCY but not under ANTITRUST.

Hypothesis 4 offers a second channel to try to assess the importance of trust for decisions to form cartels.

Finally, it is important to notice that under standard assumptions, players' strategies and equilibrium behavior should not change as a response to individual experiences of detection and punishment, as the game is stationary and the probability of detection and size of the fine are constant and common knowledge. 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 in practice affect the subject's strategy in subsequent rounds of the game.

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

4 Results

As pointed out earlier, trust and saliency are two different deterrence channels. This is confirmed by our experimental results. We first present and comment the average frequency of the attempts to form a cartel in the different treatments. We then study what are the drivers of the subjects' decision to communicate. We focus first on how subjects react to the institutional details — the actual fine, the expected fine and the presence or absence of Leniency programs. Then we consider the effects of players' experience during the game, in particular we analyze how their willingness to communicate changes after they observe a deviation, or they pay a fine. In the final part of this analysis, we discuss the effects of very small probabilities of detection on deterrence.

4.1 General description of behavior

We set the stage for our analysis by providing a general description of the observed behavior, across our nine treatments.

First, we observe that in all treatments, communication is crucial to sustain high prices, which is in line with our assumptions. On average, price is equal to 3.5 when no communication takes place, and to 5.6 when it does. The difference is even more sizable in ANTITRUST treatments (3.5 vs. 6.3) and in LENIENCY treatments (3.6 vs. 6.7).[20] This is not surprising and has been already noticed in the literature (see Crawford (1998) for a review).

Figure 2 gives an overview on how the legal framework affects the subject'decision of joining a cartel. Some noticeable results emerge. First, given the probability of detection (α) and the size of the fine (F), deterrence is stronger when Leniency is granted to self-reporting wrongdoers. Second, the same expected fine (equal to 20) leads to more deterrence when the fine is 1000 than with a fine equal to 200. Third, some deterrence is observed with zero probability of detection but with a positive fine, both with and without leniency programs. Thus we argue that the actual fine *per se* does matter, even if the expected fine is zero. Finally, the deterrence effect of the expected fine is not clear-cut. To get a more precise picture, and to assess whether these qualitative results are statistically significant, we carry on a more in-depth analysis in the rest of this section.

[20]See Table 5 in the Appendix for more details on prices.

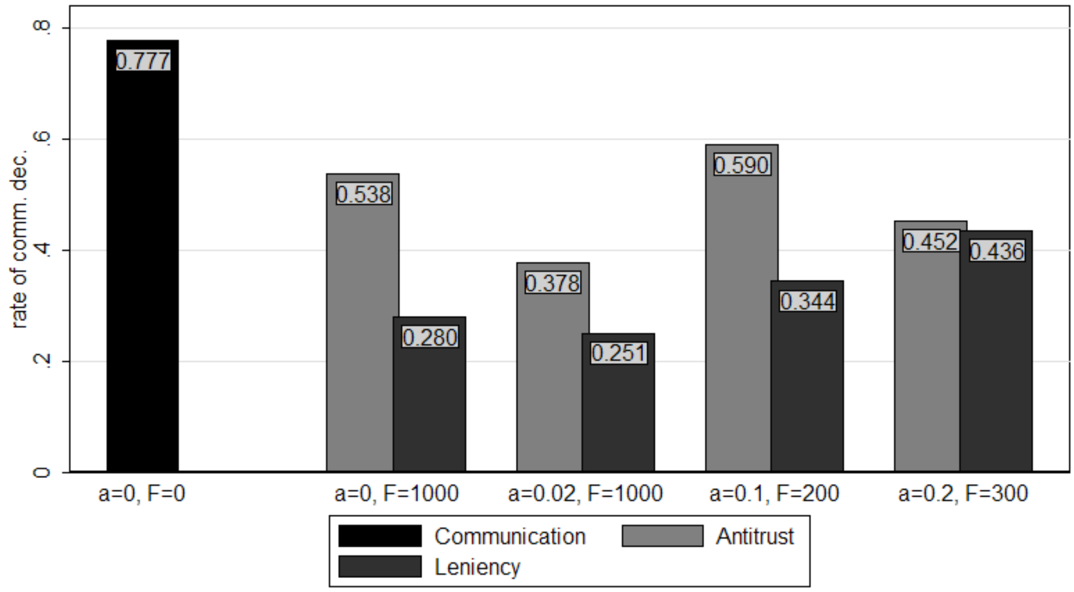

Figure 2: Rates of communication decision

4.2 Deterrence and Expected vs. Absolute Fine

Given our experimental design, there are two ways of being convicted (1) "exogenously", because of an autonomous investigation by the Competition Authority, and (2) "endogenously" because of (at least) one player reports to the Authority.

The expected cost of being exogenously detected is equal to the expected fine. The expected cost of being endogenously detected depends on the size of the actual fine, and on the subject's trust in the competitor — i.e. his prior on the probability that the competitor will report (which is not observable). Both exogenous and endogenous costs of detection obviously matter for cartel deterrence. In our analysis we try to disentangle the two effects by looking, separately, at the expected fine and at the actual fine.

To do so, we run a logit regression to assess how the institutional framework affects subjects' decision to communicate/form a cartel. The outcome variable is the decision to communicate when subjects are not already members of an existing cartel. The covariates are the following. The dummy variables *Antitrust* and *Leniency* indicate the presence of antitrust laws with and without leniency programs respectively. The binary variables *Antitrust* as well as *Leniency* are interacted with *Fine* and with *Exp.Fine*. *Fine* represents the actual fine to be paid in case of detection.[21] *Exp.Fine* is the expected fine, as the product between the actual fine (F) and the probability of detection (α). With these interaction terms, we can measure the deterrence effect of the actual and expected fines, allowing this effect to be different depending on the institutional framework.[22] Results are reported in Table 3.

	Dependent variable: decision to communicate		
	coefficient	**s.e.**	**p-value**
Antitrust (dummy)	0.035	0.690	0.960
Leniency (dummy)	-2.273	0.590	0.000
Antitrust X Fine	-1.178	0.678	0.082
Leniency X Fine	-1.168	0.588	0.047
Antitrust X Exp.Fine	-2.906	1.130	0.010
Leniency X Exp.Fine	0.351	1.012	0.729
Constant	1.797	0.244	0.000
Log Likelihood	-2689.110		
N	5398		

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

[21]We have taken into account the limited liability of the subjects. The actual fine corresponds to the minimum between the accumulated payoff and the fine of the treatment. Moreover note that the fine and expected fine have a much higher magnitude than the other regressors; for this reason, those numbers were divided, respectively, by 1000 and by 100. In this way, all the variables had approximately the same scale.

[22]As explained in more detail in Appendix A, we also introduce a random intercept at the match level to account for the correlation among observations pertaining to the same subject in a single match, and a random intercept at the subject's level to account for correlations between observations relative to a single subject in different matches. Note that we find no difference in the results when controlling for the risk aversion of the subjects (using individual data taken from an investment game played by each subject). For the sake of conciseness, we present the regression without risk aversion.

Size of the fine. Results in Table 3 show that the size of the fine always matters. However, we argue that this may have different reasons in LENIENCY and ANTITRUST.

Under LENIENCY it is rational to always report the cartel when deviating from it, so that the deviator is sure not to run the risk of being detected and fined. This is known in the literature as the "protection from fines" effect (see Spagnolo, 2004). We find evidence of this effect in the LENIENCY treatment, where 54% of the players who deviate simultaneously report. When this happens, the cheated upon party has to pay the fine. As a consequence, in the LENIENCY treatments the expected profits for the cheated upon party are inversely related to the size of the absolute fine: an increase in the fine worsens the consequences of a deviation, thus making collusion less appealing.

Under ANTITRUST treatments however, reporting is possible but costly, so the "protection from fine" effect cannot really exist. This is confirmed by our data where report simultaneous to deviations only takes place in about 0.3% of the cases in the ANTITRUST treatment. However, the size of the fine is also significant in ANTITRUST treatments. This finding confirms our general description of the behavior: even with zero probability of being detected, a fine of 1000 has a deterrence effect in ANTITRUST. We also observe that, in ANTITRUST, the cheated upon party reports the cartel in 14.1% of the cases, even though it is costly to do so. As a consequence, subjects wanting to collude with the aim of subsequently deviating and exploiting the other party, may be deterred by the threat of this punishment, which is particularly harmful when the fine is high. This may explain why, in our experiment, the fine has a weakly significant effect on deterrence also under ANTITRUST. Nevertheless, this effect has little policy relevance. First, because firms are unlikely to use reporting as a punishment to prevent cartel deviations, absent Leniency programs. Second, because this effect only acts on those who communicate with the precise aim of breaking the collusive agreement immediately thereafter.

Expected fine. Results from table 3 suggest that the expected fine matters when there are no leniency programs. Under ANTITRUST the size of the expected fine has a negative and highly significant impact on players' willingness to form a cartel. This is in line with standard theory prediction. Indeed, a higher expected fine reduces the expected utility from collusion, strengthening the participation constraint and the incentive compatibility constraint. So a higher probability of being detected by the Authority increases deterrence. In contrast, under Leniency the expected fine does not seem to affect subjects' willingness to communicate while, as pointed out earlier, the size of the actual fine does.

We summarize our findings as follow:

Result 1. *The absolute size of the fine affects deterrence regardless of the presence of leniency programs. The size of the expected fine, instead, only matters under Antitrust treatments.*

Result 1 supports the idea that deterrence under Leniency is mainly driven by the fear of being betrayed by the partner cartelist rather than the probability of being detected by the law enforcement agency. As noted above, most of the times a player who deviates under Leniency, also simultaneously reports the cartel. This worsens the consequences of a deviation for the cheated upon party, who will have to pay the fine for sure. Thus, a higher absolute fine might increase distrust among partners, which in turn enhances deterrence. By contrast, under Antitrust the main driver of deterrence is the expected fine, even though the size of the absolute fine also matters.

Result 1 also confirms Becker (1968)'s suggestion that it is possible to achieve higher deterrence while decreasing prosecution costs by increasing the size of the fine and reducing the effort spent in investigations. The reason supporting this result, however, differs depending on the presence or absence of Leniency programs. Under Leniency, it is the expected cost of the endogenous detection – only depending on the absolute fine – which induces deterrence. On the contrary, without Leniency programs the expected cost of exogenous detection is the main hindrance to collusion. Such cost can be kept constant while reducing the costs for investigation if the size of the absolute fine is increased and the probability of detection diminished.

This result has important policy implications. Indeed, some concern has been recently expressed *REF* that the many leniency applications keep the agency busy with prosecution. This could be to the detriment of investigation, implying a decrease in the probability that a cartel is detected by the authority (lower α). According to our results, this should not be a serious problem, as we still observe deterrence even if $\alpha = 0.02$, provided that the fine is high enough.

The effect of Leniency. Finally, Table 3 shows that the estimated coefficient for Leniency is negative and significant at the 5% level. Leniency programs still matter after controlling for the level of the actual fine and the expected fine. Betrayal aversion could be one potential explanation (see Bohnet *et al.* 2008 for experimental evidences). If individuals have an aversion to betrayal, they would be less willing to cooperate when there is an option to betray and it is costless, which is the case for the Leniency treatments.

4.3 Experience (History of play) and deterrence

In this section we examine how communication decisions change as subjects gain experience.

Figure 3 shows that different treatments lead to different trends in communication decisions. In Communication the number of attempts to agree on prices within a match tends to decrease — as if players progressively lost their faith in the loyalty of that particular opponent. This is true to some lesser extent under Leniency. On the other hand no clear downward trend emerges in Antitrust treatment.

In theory, experience should not affect the decision to communicate in our game, as there is perfect information and the discount factor, the probability of detection and the size of the fine are constant across periods. Our experimental results, however, suggest that subjects' behavior evolves in the course of the experiment. We next explore in more detail if and how the history of play affects the communication decision. The past play can be first used to learn about the opponent's type, that is, on his trustworthiness. Trust in the opponent might decrease, if the subject observes frequent deviations on behalf of the other cartel member. The history of play can also matter if punishment has some salience effect. The idea is that being detected and paying a fine are events that might be easily recollected when the fine is particularly high, or when detection occurred

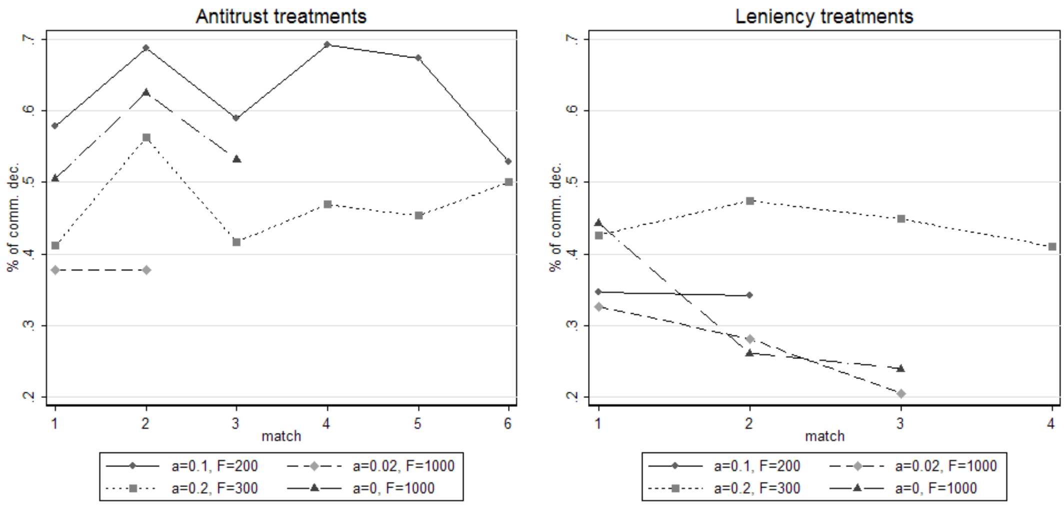

Figure 3: Rate of communication decision, per match.

very frequently in the past. A fresh memory of detection and conviction may induce subjects to perceive the probability of such events as higher than it actually is.

To discuss saliency and learning in our experiment, we run a logit regression. As in the previous model, the outcome variable is the binary decision to communicate when a cartel is not in place.[23]

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_P is the frequency of observed deviations in the previous matches, which is measured as the number of deviations observed an previous matches, over the number of periods in which a cartel was active – so a deviation could take place – in previous matches. Similarly, Dev_C is the frequency of deviations in the current match. The distinction

[23] As for the previous regression, the intercept is allowed to have a random effect for the same subject within a particular match, nested with a random effect for the same subject across different matches. See Appendix A for further details on the empirical methodology.

is important as the latter coefficient can be interpreted as a measure of the trustworthiness of the current opponent, while the former can relate to all opponents, in general. *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 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, and is a proxy to measure how strong the memory of punishment is in the players' mind. We make a distinction between the accumulated fines paid due to detection from the authority (*PaidFineDet*) and the accumulated fines paid due to reporting (*PaidFineRep*). Again, we also distinguish between the fines paid in the current and in previous matches. As in the first regression we control for the actual fine to be paid in case of detection (*Fine*) and for the expected fine (*Exp.Fine*).

The model is estimated separately for COMMUNICATION treatment, for the ANTITRUST treatments and for the LENIENCY treatments.

	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

Table 4: Logit regression with multilevel random effects.

Trust Results in Table 4 show that the frequency of deviation of the current match, and the accumulated paid fines due to reporting, negatively affect subjects' willingness to communicate in LENIENCY. One potential explanation is that reporting and deviating behaviors can be viewed by the subjects as good indicators of the lack of trustworthiness of their opponent. Trust can therefore be broken as the result of playing the same game many periods with the same opponent and observing a high frequency of deviation or having paid a high accumulated fine due to reporting. Remember that in this treatment most of the reports are simultaneous to deviations. Our data suggest that the breach in trust is worse when the opponent reports the cartel when deviating from it, and that it worsens as the size of the fine increases, because the consequences of the breach of trust are more harmful. This finding is in line with Result 1, which showed that a higher absolute fine increased deterrence in the LENIENCY treatments.

We summarize this result as follows:

Result 2. *The frequency of deviation and the sum of the fines paid because of reporting increase deterrence under* LENIENCY*, as they negatively affect trust between potential cartelists.*

Saliency It has been pointed out in the literature that people's perception of an uncertain event may be based not only on its actual probability, but also on its vividness and emotional impact. This conjecture is partly validated by our data. Results in Table 4 indicate that the sum of the fines paid by a subject in previous periods due to detection ($PaidFineDet$) as well as the frequency of detections in past periods (Det) have a significant and substantial negative effect on the subject's willingness to communicate in the ANTITRUST treatment. This means that, in this treatment, subjects who have been detected may times, or have paid a very high accumulated fine are less incline to recidivism. This is in line with recent empirical findings by Fishman and Pope (2006) about "punishment-induced deterrence". Their idea is that the experience of the penalty affects subjects' willingness to commit the crime, and that this effect is stronger, the harsher is the penalty, or more generally the fresher is its memory. We also observe that only the fines paid in the current match have a significant deterrence effect, while the effect of the fines paid in the previous matches is not significant. This is consistent with Agarwal *et al.* (2008), who empirically study the effects of paying fees for not fulfilling the contract with the Bank (late payment, cash advance,...) in the context of credit market, and find that there is some learning after receiving a fine but that there is also knowledge depreciation that partially offsets learning: after a while people start over with late payments.

Under the LENIENCY treatment experiences related to past detections do not seem to affect deterrence in a significant way. This confirms the idea that in this treatment deterrence is more driven by the fear of an endogenous detection, due to reporting, rather than of an exogenous one.

Results in Table 4 also show that in the ANTITRUST treatments, the accumulated fines due to reporting have a deterrence effect. We have already argued that in this treatment reporting is generally used by cheated upon parties, as a form of punishment towards 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 incline 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 follow:

Result 3. *The frequency of exogenous detections and the consequently accumulated fines increase deterrence in the* ANTITRUST *treatments, but not in the* LENIENCY *treatments.*

Results 2 and 3 support the idea that history of play does matter for deterrence for at least two reasons. First players can use the history to update their beliefs about their opponent. If the opponent undercut or reported in earlier periods, this might create distrust among players and might induce deterrence. This finding is line with Result 1. Second, the history of the play can affect deterrence when punishment have a salience effect.

4.4 Additional results. Perception of small probabilities.

We mentioned above that according to the research developed by Kahneman and Tversky (1979), the perception of very small probabilities may have ambiguous outcomes: they are either overemphasized or approximated to zero, depending on the context. The hypothesis that small probabilities are rounded to zero in our context seems to be rejected by a first comparison between the observed rates of communication decision for the two antitrust treatments in which the fine is equal to 1000, and the probability of detection is equal to 0.02 and to 0, respectively. The size and significance of the estimated effect of the expected fine for ANTITRUST treatments (Table 3) support this conclusion, and a more direct comparison between these two treatments confirms that the difference is significant, though weakly (p-value: 0.083).[24] This does not necessarily conflict with the finding that the difference among the average rate of communication decision almost disappears under the two LENIENCY treatments with fine equal to 1000 (p-value: 0.387). In fact, according to our general interpretation of these results, when leniency programs are introduced the probability of detection is disregarded because other factors predominate, and among them the fear of being betrayed and reported appears to be the most important one.

Result 4. *A very small probability of detection is not disregarded and rounded to zero.*

5 Conclusion

We showed that when a Prisoner's Dilemma-like Leniency program is in place, the fear and cost of being betrayed by partner wrongdoers (lack of trust) and the availability heuristic and salience bias have important effects on the deterrence of non-violent organized crime (though they are typically not taken into account in theoretical analyses). These results, obtained through an exploratory laboratory experiment, call for further, more specific experimental tests of the observed effects. If confirmed, and to the extent that they apply to real world settings, they have important policy implications.

First, they suggest that the absolute level of the sanctions should be kept higher than previously thought, as it has an own effect on deterrence, independent of its effect on the level of the expected sanction, particularly in the presence Leniency programs against organized crime (but not only, as the availability heuristic effect is likely to apply in general). This goes in the same direction of Becker (1968)'s point

[24]This comparison was obtained by means of a two levels logit regression, as explained in Appendix. In this regression, the decision to communicate when a cartel does not exist is the dependent variable, and a treatment dummy is the only regressor.

that higher sanctions, particularly monetary ones, might save law enforcement cost by allowing to reduce expenditures in policing activities, though through novel channels.

Second, they suggest that concerns voiced recently that the many applications to the antitrust leniency programs could undermine cartel deterrence by keeping competition authorities too busy to inspect industries may be misplaced, if sanctions are high and the leniency program is well designed and administered.

It would be interesting in future work to check the effects of changes in the parametrization and framing of the experiment, renaming the organized crime game 'corruption', 'fraud', o 'auditor-manager collusion', though recent work by Krajcova and Ortmann (2008) and Krajcova (2008) suggests that our results may well be robust. Another issue that appears worth studying experimentally is whether the structure of criminal organizations reacts and adapt to the introduction of novel law enforcement methods, as suggested by recent theoretical work (e.g. Garoupa 2007 , and Baccara and Bar-Isaac 2008).

More generally, the interplay of rational considerations and behavioral biases in shaping deterrence of organized criminal activities appears a promising area for future research. While substantially more evidence is needed before drawing conclusions, the glimpse that our study offers is hopefully a useful first step which will open the way for a rather new branch of experimental studies.

A 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 the observed differences across treatments. Given the rematching procedure we adopted, we need to account for correlation between two observations from the same individual, as well as correlation between two observations from different individuals who belong to the same duopoly. To this purpose, we adopted multilevel random effect models[25].

Since in our experiment a subject may take part in more than one duopoly during the game, the random effects at the subject level and at the duopoly level are not nested, which makes it difficult to estimate a model with a random effect at the duopoly level and a random effect at the subject level at the same time.

To overcome this complicacy, we hypothesized the presence of a random effect for every subject within any particular match (which accounts for the correlation among observations pertaining to the same match), nested with a random effect for every subject across different matches, which is in turn nested with a random effect at the session level.

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

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

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 β. $\eta^{(2)}_{ms}$ 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

[25]We thank Dorothea Kübler for suggesting this methodology.

distributed, with a variance that is estimated through our regression.

To estimate our model we used GLLAMM [26], a software specifically designed to provide a maximum likelihood framework for models with unobserved components, such as multilevel models, certain latent variable models, panel data models, or models with common factors.

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

B Appendix to the theoretical predictions

B.1 Changes in the expected fine

Claim 1: Both under ANTITRUST and LENIENCY, an increase in αF tightens the PC.

Proof: The claim follows immediately from an inspection of inequality (PC). QED.

Claim 2: Both under ANTITRUST and LENIENCY, an increase in αF tightens the ICC.

Proof: In the case of LENIENCY, the claim follows immediately from an inspection of inequality (ICC-Leniency). Absent leniency, the proof is (somewhat) less trivial. Let $A(\alpha) \equiv \frac{1}{1-\delta} - \frac{1}{1-(1-\alpha)\delta}$ and note that $A(\alpha) \geq 0$ and $A'(\alpha) > 0$. From inequality (ICC-Antitrust), an increase in the expected fine, $d(\alpha F) > 0$, tightens the ICC iff $A(\alpha)\alpha F$ increases. Differentiating $A(\alpha)\alpha F$ with respect to α and αF yields that

$$d(A(\alpha)\alpha F) = A(\alpha)\,d(\alpha F) + A'(\alpha)\,\alpha F d\alpha$$

An increase in the expected fine, $d(\alpha F) > 0$, thus tightens the ICC under ANTITRUST, $d(A(\alpha)\alpha F) > 0$, iff $d\alpha$ is not too negative (since $A(\alpha) \geq 0$ and $A'(\alpha)\alpha F \geq 0$). This condition is satisfied in the considered treatments since whenever αF is higher in one treatment than in another (i.e. $d(\alpha F) > 0$), then also α is higher in that treatment (i.e. $d\alpha > 0$). QED.

Claim 3: Both under ANTITRUST and LENIENCY, an increase in αF increases the minimum level of trust required to make cooperation attractive.

Proof: Recall that p_K decreases with $V_K^{ss} - V_K^{ds}$ and increases with $V_K^{dd} - V_K^{sd}$. Using the same logic as in the proof of Claim 2, note first from equations (4) and (6) that $V_A^{ss} - V_A^{ds}$ and $V_L^{ss} - V_L^{ds}$ decreases with αF. Second, $V_A^{dd} - V_A^{sd}$ is unaffected by changes in αF (by equation (5)). Third, αF does not directly affect $V_L^{dd} - V_L^{sd}$ (by equation (7)).[27] QED.

[27] Changes in αF only affect $V_L^{dd} - V_L^{sd}$ indirectly through F. Should this be discussed?

C 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 5: **Average price with and without communication.**

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