Fines, Leniency, Rewards and Antitrust: an Antitrust Experiments*

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Abstract

This paper reports results from an experiment studying how fines, leniency programs and reward schemes for whistleblowers affect cartel formation and prices. Subjects play a repeated differentiated goods Bertrand game choosing whether to communicate (form cartels). Treatments differ in the presence of fines and in the possibility of obtaining leniency or rewards by self-reporting, before and after prices become public. Antitrust without leniency reduces cartel formation but increases cartel prices: subjects use fines as 'altruistic punishments'. Leniency further increase deterrence but stabilizes surviving cartels, as subjects anticipate harsher times after defections. With rewards, cartels are systematically reported and prices finally fall. Leniency reduces recidivism as well as post-conviction prices. Subjects do not exploit the possibility to manipulate rewards taking turn to report. If the ringleader is excluded from leniency, deterrence falls and prices grow. Differences between treatments in Stockholm and Rome suggest a possible 'cultural effect' on deterrence.

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1 Introduction

The last decades have witnessed major innovations in antitrust law enforcement around the world. Following the US example, leniency policies that reduce sanctions for cartel members that self-report have been adopted by competition authorities of most OECD countries, and have become the main tool for cartel discovery and prosecution.[1] Following these innovations, the number of cartels detected and convicted increased dramatically, which is why they are considered a tremendous success. A higher number of detected and convicted cartel, however, is not a good indicator of the effectiveness of Antitrust policies.[2] Law enforcement's main objective is deterrence, prevention, and a successful antitrust policy against cartels is one that reduces cartel formation and market prices, not necessarily by increasing convictions.

In this paper, we present results from a laboratory experiment designed to analyze the deterrence and price effects of different antitrust policies. In particular, we focus on how monetary fines, leniency programs, and reward schemes for self-reporting whistleblowers affect market participants' decision to form cartels (deterrence), cartel stability and breakdown (desistance), and firm price choices, in and outside cartels (welfare).

It is hard to evaluate the deterrence and price effects of antitrust policies, because contrary to many other crimes, we cannot observe the total population of cartels and how this changes with policy changes. Miller (2008) and Harrington and Chang (forthcoming) recently developed sophisticated indirect methods to empirically identify the likely effects of changes in antitrust policy using only changes in observables, like the number of detected cartels or their duration.[3] However, even these skillful methods have limits, as they only allow to estimate the effects of policies actually introduced, not of the many available alternatives.

Also, these methods focus on the rate of cartel formation, while the welfare effect of an antitrust policy depends on its final effect on industry prices. As forcefully argued by Whinston (2006), there is still a lot that we don't know about the relationship between communication in cartels and actual prices, so we cannot be sure that reduced cartel formation actually feeds into lower prices and higher welfare.[4]

These special features of antitrust law enforcement make laboratory experiments particularly valuable, as within their own limitations these allow us to observe changes in the total population of cartels, and to test many different designs of antitrust policy.

In our experiment, subjects play a repeated differentiated goods Bertrand duopoly game, and can decide whether to communicate on price, thereby forming a cartel, before choosing prices. We consider several treatments differing in terms of the presence of a prohibition with positive expected fines for infringers and, most crucially (and differently from previous work), in the possibility to self-report before price choices become public information and after, thereby obtaining either leniency or a reward.

The main questions we ask are: What are the effects of different law enforcement policies, expected fines with and without leniency and rewards for self-reporting whistleblowers, on cartel formation and stability? What are their effects on pricing behavior, in and outside the formed cartels, and after cartels are dismantled? Does it make a difference if self-reporting is possible before price choices (hence defections) become public as is typically the case in reality? Is the possibility of obtaining leniency used as an opportunity to defect and abandon the cartel, as an instrument to punish defectors and stabilize cartels, or both? And do things improve when the ringleader is banned from leniency as in the US?

We find that traditional antitrust law enforcement, fines following successful investigations by the competition authority but no leniency, has a significant deterrence effect (it reduces the number of cartels formed),

[1] Some jurisdictions (e.g. Korea, the UK) also introduced rewards for whistle-blowers that report a cartel, following their successful use in the fight of government fraud (US False Claim Act) and tax evasion. See Spagnolo (2008) for an overview.

[2] For example, an extremely lenient policy that substantially reduces fines to all members of a cartel that collaborate will induce many cartels to self-reports and greatly facilitate prosecution, but harm society by encouraging cartel formation and increasing prosecution costs.

[3] See also Brenner (forthcoming). Brenner and Miller bring these methods to the data and find, respectively, no significant increase in deterrence following the 1996 introduction of the EU Leniency program, and a positive and significant increase in deterrence following the 1993 changes in the US Leniency policy.

[4] See e.g. Sprouls (1993), who finds that in a sample of US cases prices weakly increased after antitrust conviction; and McCoutcheon (1997), which suggests that the antitrust fines may actually stabilize collusive agreements by preventing agreements' renegotiation, but not their formation.

but it also has a sizable pro-collusive effect (it increases cartel prices), so that average industry prices do not fall because of this policy.

Perhaps more surprisingly, in our experiment the introduction of leniency programs deters a significantly higher fraction of cartels from forming, but it also induces significantly higher prices in those cartels that are not deterred. Contrary to previous findings, average industry prices do not fall with leniency compared to a 'lassez faire' regime, in which cartel agreements are not legally enforceable but antitrust laws are not publicly enforced.

When fines paid by other parties are used as rewards for the party that self-reports, cartels are still formed, but are systematically reported, disrupting completely subjects' ability to form cartels and to sustain high prices. Then, industry price fall substantially and approximate competitive levels, so that with rewards antitrust finally improves welfare.

This first set of results appears to confirm Whinston's (2006) concern that deterring explicit cartel formation, the focus of current antitrust practice, may not be sufficient to achieve the real goal of competition policy, low price levels. They also suggest that Miller's finding that the introduction of the Corporate Leniency Policy has probably reduced the rate of cartel formation in the US, though important, may not warrant yet the conclusion that the policy was successful in increasing welfare.

When we try to identify why cartel prices go up with antitrust enforcement, whether because of a selection effect, of improved coordination or of other forces, we find that what happens with standard antitrust is quite different than what happens with leniency. With standard antitrust, the effect appears mainly driven by the ability to use reporting and fines as a punishment device. Indeed, when we run an additional treatment without the possibility of self-reporting the effect disappears; and when we run a further treatment re-matching agents each period with a different opponent, agents' use of reporting to punish defections increases further, suggesting that these punishments are 'altruistic' in the sense of Fehr and Gaechter (2002).

On the contrary, the positive effect of leniency on cartel prices cannot be driven by the use of self-reporting as a punishment, since then defecting subjects simultaneously self-report, removing such punishment possibility. We find that this effect is also not driven by selection of 'types' or by improved coordination, but rather that it is consistent with what we call an 'enforcement effect': subjects appear to anticipate that, after defecting (and reporting) under leniency, the opponent suffers so much that a new cartel can hardly be formed in the rest of the match. Indeed, when we turn to post-conviction behavior, we find that there is a significant ex post deterrence (desistance) effect of antitrust enforcement, as cartels do not re-form for several periods after being dismantled, but that this effect becomes much stronger when leniency is present and the cartel is detected because one party defected and self-reported. Then, a new cartel is almost never formed, so that - contrary to previous findings - in our experiment leniency greatly reduces recidivism. Consistently, we find that post-conviction prices are on average significantly lower than before, but much more so when leniency is present.

Additional results are that subjects do not seem to recognize the possibility to manipulate the reward scheme by taking turn to self-reporting (a result in line with recent experiments in other fields, like Dal Bo, 2005); that if the ringleader is excluded from the leniency program, as under the US leniency policy, the deterrence effect of leniency falls and prices are higher; and that there is a substantial difference between treatments run in Stockholm and in Rome, suggesting a possible 'cultural effect' that would imply that optimal law enforcement differ in different cultures.

Related Literature. Our paper is related to the theoretical literature that, starting with the seminal contributions of Motta and Polo (2003), Harrington (2004, 2008), Aubert et al. (2006) and Spagnolo (2000, 2004), tries to shed light on the effects and optimal design of antitrust policy against cartels.[5] We are not the first to look at these issues experimentally. Apesteguia, Dufwemberg and Selten (2007) and Hinloopen and Soetevent (2008) have already produced important pieces of work in this direction. We build on their work extending it along several important dimensions, confirming some of their results and conjectures but not others, and exploring several questions crucial to the design and implementation of antitrust policy that were not explored before.

[5] See Rey (2003) and Spagnolo (2008) for surveys of this litrature.

Apesteguia et al. (2007) develop a stylized theoretical framework capturing several points made in the literature and use it for experimental analysis. They augment a one-shot homogeneous goods discrete Bertrand triopoly game with the possibility to communicate before the price choice and to be convicted by an antitrust authority after it (if communication took place). They test four legal frameworks: *Ideal*, in which firms face no fines and explicit cartels are not possible (communication is not allowed); *Standard* where communicating firms face fines equal to 10% of their revenue with positive probability and no fine reduction if they self-report; *Leniency* in which firms that self-report receive a reduction in their fine; and *Bonus* in which they receive part of the fines paid by other firms as a reward. Subgame perfect collusive equilibria (including the monopoly outcome) exist in *Standard* and *Leniency*, sustained by the credible threat of self-reporting after a price defection;[6] in *Ideal* and *Bonus* instead the Bertrand outcome is the only equilibrium. They find *Leniency* to have a significant deterrence effect relative to *Standard*, although prices are higher with antitrust enforcement (in *Standard* more than in *Leniency*) than without (in *Ideal*). Surprisingly, their experimental results are inconsistent with the theoretical prediction that rewarding self-reporting firms with a bonus should further increase deterrence. They conjecture that this puzzling result might disappear in a dynamic set up that allows subject to play repeatedly and learn better the underlying game.

We extend their set up by having a stochastically repeated game; five initial rounds of practice; fixed levels for the fines to account for fixed components of antitrust fines and control subjects' expectation on them; and, most crucially, the possibility to self-report both before and after the choice of prices becomes public, so that a subject that decides to undercut the cartel can also self-report to obtain leniency before competitors become aware of the defection. This last feature captures a deterrence channel (defections become more profitable) considered important by both theorists and practitioners.[7] Our experiment shows that their result that standard antitrust (without leniency) may have perverse effects survives in a repeated environment; and confirms their conjecture that the puzzling result on bonuses disappears when subjects can play the game repeatedly. On the other hand, as mentioned earlier in our dynamic experiment leniency performed much less brilliantly than in their one.

Hinloopen and Soetevent (2008) implement a repeated version of Apesteguia et al.'s game in which subjects are matched in groups of three at the beginning of each session and play without re-matchings for at least 20 rounds, after which the continuation probability falls to 80%. They consider four treatments: *Benchmark*, where subjects cannot communicate; *Communication*, where subjects can communicate before choosing prices; *Antitrust*, where subjects that communicate are exposed to a positive expected fined; and *Leniency*, where in addition they can self-report after the choice of price, obtaining a discount on the fine larger for the first reporting party. Their results differ substantially from ours. They find, as we do, that leniency increases cartel deterrence (fewer cartels are formed); however, contrary to us, they find that leniency destabilizes cartels that are not deterred (agents that form a cartel defect more often and more aggressively) and does not reduce cartel recidivism compared to standard antitrust.

The different results are justified, as our experiment differs substantially from their one. Most crucially, as already mentioned, in our set up subjects can both set prices and self-report before these choices are observed by other subjects, so that the 'protection from fines' effect is present; in addition, they also have the possibility to self-report after observing price choices, provided nobody reported before prices were disclosed. This feature of our design also allows us to disentangle and quantify reports linked to defections and reports made instead to punish defections.[8] Other differences are that we allow for self-reporting even when there is no leniency; we follow Apesteguia et al. (2007) in framing the experiment as a cartel/antitrust game; we adopt a differentiated product Bertrand game; subjects are re-matched with constant probability along

[6] The reason why the threat of self-reporting to punish a price deviation is credible also in *Standard* is that if a firm defects in an homogeneous Bertrand game, its opponent has zero revenue and - being fines a fraction of revenue - faces no cost of self-reporting, even in the absence of leniency.

[7] See Spagnolo (2008). This deterrence channel was named 'protection from fines effect' in Spagnolo (2004) and 'deviator amnesty effect' in Harrington (2008).

[8] Spagnolo (2000b) for auctions and Buccirossi and Spagnolo (1999, 2006) for corruption showed that when self-reporting becomes attractive thanks to leniency programs, the *threat* of self-reporting to punish an agent that did not behave as agreed upon may also become credible, and may be exploited to enforce cartels or other illegal agreements that would not be sustainable otherwise. Ellis and Wilson (2001) applied this idea in a dynamic oligopoly setting showing that, even when leniency has deterrence effects, it may reinforce/stabilize cartels that are not deterred by strengthening the punishment for defections of an amount equal to antitrust fines.

the treatments to have a constant continuation probability (see e.g. Dal Bó, 2005; Dal Bó and Frechette, 2008; Blonski et al., 2008); we fix fines to have control on expected fines; and we use duopolies rather than triopolies to avoid that agents refrain from punishing defections to avoid harming a third 'innocent' party (as suggested by Holt, 1995).

We are aware of two other previous experimental studies dealing with related issues, though in quite different environments. Hamaguchi and Kawagoe (2005) perform an experiment where subjects are forced to collude, looking at the effects of leniency in terms of the speed with which cartels are dismantled. In such a framework they cannot address how different policies perform in terms of cartel formation and deterrence, however, a core question in our study. Hamaguchi et al. (2007) adapt the setup of Hinloopen and Soetevent to a repeated procurement auction in which, when players collude, they have to decide who will win the auction. They find evidence of deterrence effects with leniency programs, as well as of higher prices under leniency and antitrust than under communication, which seem to square well with our results for oligopolies.

Finally, after our work other experimental studies have been performed in various different environments, some of them confirming our finding that law enforcement policies based on leniency might have perverse effects on market prices (see e.g. Hinloopen and Onderstal 2009, in the context of different auction formats) or on the stability of illegal agreements (see e.g. Krajkova and Ortmann 2009 in a corruption framework).

The remainder of this paper is organized as follows. The next section discusses in depth related literature, theoretical and experimental. Section 2 describes the experimental design. Section 3 presents the theoretical predictions that form the benchmark for our analysis. Section 4 discusses the empirical strategy. Section 5 presents our main results in terms of deterrence and prices, and tries to identify their sources. Section 6 discusses extensions, and Section 7 concludes. An appendix contains the instructions for the experiment.

2 Experimental Design

In our experiment, each subject represented a firm and played in anonymous two-persons groups a repeated duopoly game. In every stage game, the subjects had to take three types of decisions. First, they had to choose a price in a discrete Bertrand price game with differentiated goods. Second, they had to decide whether or not to form a cartel by discussing prices. 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, the subjects had to choose a price from the choice set $\{0, 1, ..., 11, 12\}$. The resulting profits depended on their own price choice and on the price chosen by their competitor and were reported in a profit table distributed to the subjects (see Table 1). This table was derived from the following standard linear Bertrand game. (The details of the Bertrand game were not described to the subjects.)

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 (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 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

		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**

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 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, and 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. In this case, the subjects risked to be fined as long as the competition authority had not yet detected the cartel. 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 had communicated in the previous period and the competition authority had not detected 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 Antitrust law enforcement (Treatments)

Whenever two subjects had 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, the cartel members could self-report the cartel, in which case the cartel members 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 five types of treatments and we adopted a *between subjects* design, so that every subject only played the game under a single treatment. Each treatment corresponded to a specific type of antitrust law,

that is our treatment variables were the different law enforcement institutions. The differences between the treatments are summarized in Table 2.

Table 2: **Treatments**

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

*Only for the player who's the last to decide to communicate.

Our baseline treatment denoted L-Faire corresponds to a laisser faire regime: 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 four other treatments, denoted Fine, Leniency, Ringleader and Reward, the expected fine (given that no reports took place) was strictly positive ($\alpha = 0.1$ and $F = 200$ yielding an expected fine $\alpha F = 20$) and cartel members were allowed to report cartels in which they participated. The Fine treatment corresponds to traditional antitrust laws without any leniency program: in case a report took place, both cartel members (including the reporting one) had to pay the full fine F. The Leniency treatment corresponds to current antitrust laws embedded 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 $F/2$. The treatment Ringleader was identical to Leniency except that the first subject attempting to communicate was treated as the cartel's initiator - the so-called ringleader - and, as a result, was not eligible for the leniency program. (The way the ringleader was identified is described in more detail below). Finally, the Reward treatment differed from Leniency in one respect only: if only one cartel member reported the cartel, his/her fine was not only reduced to 0; in addition, he was rewarded with the full fine, F, paid by the other cartel member.

In addition to these five treatments, we also ran a number of other treatments to check the robustness of our results to changes in α and F. First, we ran two additional fine and leniency treatments with higher expected fines equal to 60 ($\alpha = 0.2$ and $F = 300$). These treatments were denoted FineHEF and LeniencyHEF respectively. Second, we ran two additional reward treatments, both with an expected fine equal to 0 ($\alpha = 0$) but with different fines. The treatment denoted RewardLF had a relatively low fine ($F = 200$) while RewardHF had a high fine ($F = 1000$).

2.4 The experiment's timing and the 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, the history in the previous match did no longer matter; for example, a subject could no longer be fined for a cartel formed in a previous match. The subjects were also informed that the experiment would end if more than 20 periods had passed and the 15% probability event took place or if the experiment lasted for more than 2 hours and 30 minutes. This latter possibility was so unlikely that it never happened.

This re-matching procedure had several advantages. First, the subjects were playing truly *infinitely repeated games* without problems associated with end effects. Second, each subject played several repeated games against different competitors. Thereby we observed the subjects' behavior in a larger number of repeated games.

Before the experiment started, the subjects were paired with the same competitor for five practice periods. During these practice periods, subjects were assigned to different competitors than those that they faced in the first period of the 'true' (i.e. remunerated) experiment. Participants were informed about this.

Figure 1: Timing of the stage game

2.5 The timing of the stage game

With the exception of the L-Faire treatment, a stage game consisted of 7 steps. In L-Faire, steps 4,5 and 6 were skipped. An overview of the steps is given in Figure 1.

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 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.

In the treatment Ringleader, the first subject to push the button within the time window of 15 seconds was treated as the ringleader. If instead only one of the subjects pushed the yes button, then this subject was treated as a ringleader even if the cartel was formed in later periods. In either case, both subjects were informed at the end of Step 1 about the identity of the (possibly only potential) ringleader.

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 so high that their profits became 0.

Step 4: First Reporting Decision. If communication took place in the current period or in one of the previous periods and had not yet been discovered by the competition authority, subjects had a first opportunity to report the cartel.

Step 5: Market prices and second reporting decision. Subjects learned the prices set by their opponent. If communication took place in the current period or in one of the previous periods and was not yet discovered by the competition authority and nobody had reported it in step 4, subjects had again the opportunity to report the cartel. The crucial difference between this second reporting opportunity and the first one is that the subjects knew the price chosen by the 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 was 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. This step lasted 20 seconds

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 March, April, May and December 2007 at the Stockholm School of Economics (Sweden) and at Tor Vergata university (Rome, Italy). Session lasted on average 2 hours, including instructions and payment. The average payment was: (*i*) in Stockholm Euros 26.49, with a minimum of 15.3 and a maximum of 36 and (*ii*) in Rome Euros 24.45 with a minimum of 16.5 and a maximum of 31.5.[9] We ran a treatment for every session; the number of subjects per session ranged from 16 to 32, and the total number of subjects was 194.

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 again 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 play started.

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

3 Theoretical predictions and hypotheses

The above experimental design implements a repeated price game embedded in different law enforcement institutions. Much of the theory on repeated oligopoly may be interpreted to suggest that law enforcement institutions should not matter; subjects should collude tacitly and reap the gains from collusion without running the risk of being fined. This conclusion is of course invalid if pre-play communication - cartel formation in our context - enhances subjects' ability to charge high prices. The discussion below, therefore, presumes cartel formation to be a prerequisite to successful collusion.

Section 3.1 provides a simple equilibrium analysis. Section 3.2 discusses non-standard equilibrium (or dis-equilibium) behaviour.

3.1 A simple equilibrium analysis

The monopoly price can be supported as an equilibrium outcome in our four lead treatments, L-Faire, Fine, Leniency and Reward (see Appendix 1). 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 - the two conditions for the existence of a collusive equilibium - provide valuable insights on possible effects of law enforcement institutions. These constraints are tighter in some treatments and to the extent tighter equilibrium conditions increase the perceived risk of cartel formation, they should also increase deterrence. Combined with the assumption that cartel formation increases prices, tighter equilibrium conditions should also reduce average prices.

The participation constraints The P-constraint states that the gains from collusion should be larger than the expected cost. Assuming that cartels never report on the collusive path and charge the same collusive price across periods and treatments, the P-constraints show that the gains from collusion are highest in L-Faire, since the expected cost - the risk of being fined - is 0 in that treatment.

[9] The subjects in Stockholm were paid in Swedish kronor (SEK). At the time of the experiment, 1 SEK=0.109 Euros.

The incentive compatibility constraints The IC-constraint states that sticking to an agreement is preferred over a unilateral price deviation followed by a punishment. We start by restricting attention to punishments carried out through some form of price war - reports are not used on the punishment path. In addition, cartels are assumed (i) to charge the same collusive price across treatments and periods, (ii) to never report on the collusive path and (iii) not to be reformed whenever they have been dismantled following a price deviation. This last assumption is not innocuous.[10] It implies that V^p - the present value in the beginning of the punishment phase (net of potential fine payments) - can be viewed as being generated by optimal symmetric punishments (conditional on the restrictions imposed by the other assumptions). Alternatively, V^p can be viewed as resulting from some weaker form of punishment, which by assumption is the same across treatments. Using standard notation,[11] the IC-constraints can then be expressed as

$$\frac{\pi^c}{1-\delta} \geq \pi^d + \delta V^p, \tag{IC-L-Faire}$$

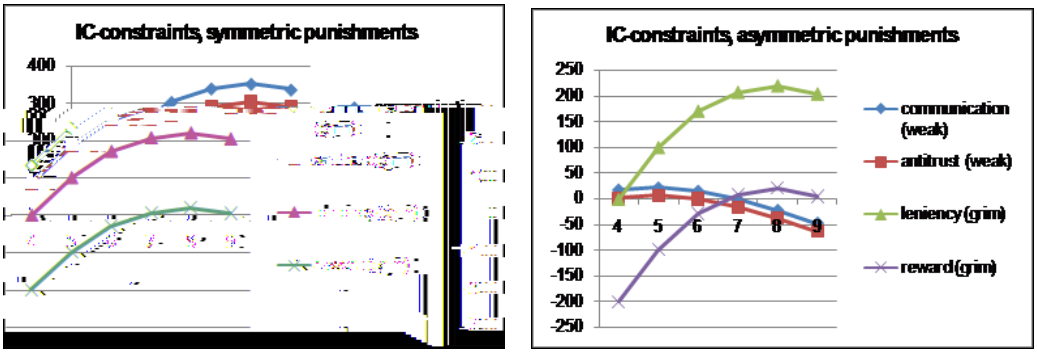
$$\frac{\pi^c - \alpha F}{1-\delta} \geq \pi^d - \frac{\alpha F}{1-(1-\alpha)\delta} + \delta V^p, \tag{IC-Fine}$$

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

$$\frac{\pi^c - \alpha F}{1-\delta} \geq \pi^d + R + \delta V^p. \tag{IC-Reward}$$

Following a deviation, a player risks to be fined in FINE only. The reason is that an optimal deviation in LENIENCY and REWARD is combined with a simultaneous secret report. Note also that $\alpha F/(1-\delta) > \alpha F/(1-(1-\alpha)\delta)$, since dismantled cartels are assumed not to be reformed on the punishment path. Clearly the IC-constraints are (i) tighter in REWARD than in LENIENCY (since the incentives to deviate in REWARD are higher due to the reward, R), (ii) tighter in LENIENCY than in FINE (since a deviation combined with a secret report provides a protection against the fine, $\alpha F/(1-(1-\alpha)\delta)$) and (iii) tighter in FINE than in L-FAIRE (since in FINE, expected fines reduce more the incentives to stick to the agreement than the incentives to deviate, $\alpha F/(1-\delta) > \alpha F/(1-(1-\alpha)\delta)$). Under the assumption that tighter P- and IC-constraints increase deterrence and thereby reduce prices on average, this equilibrium analysis leads to our first hypothesis.

Hypothesis 1 (cartel deterrence and prices): Cartel deterrence is lowest and prices are highest in L-FAIRE followed in order of importance by FINE, LENIENCY and REWARD.



The assumption that collusive prices (or equivalently π^c and π^d) are the same across treatments can be motivated in at least two ways. Subjects may in all treatments collude on the monopoly price - the price relaxing the P-constraint the most. Alternatively, subjects may collude on the collusive price minimizing the incentives to deviate - the price relaxing the IC-constraint the most. This price is the same across

[10] Presumably the assumption 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. As argued in Appendix 1, however, relaxing the assumption should not alter our Hypotheses.

[11] The notation is explained in Appendix 1.

treatments provided V^p is the same across treatments. This is illustrated in panel a of Figure X where collusion is sustained through grim trigger strategies. The horizontal axis represents the collusive price and the vertical axis the IC-constraint. Besides illustrating the ranking in Hypothesis 1 - for the same collusive price, the IC-constraint is most relaxed in L-Faire followed in order of importance by Fine, Leniency and Reward - panel a also suggests that subjects may in all treatments collude on the same price, 8 - the price minimizing the incentives to deviate.[12]

Different punishments across treatments The previous analysis presumes identical punishments across treatments. The possibility to report affects however the scope for punishing a deviator. In fact, punishments through costly public reports are optimal in Fine: any collusive price can be sustained in equilibrium for any $\delta > 0$. The key behind this finding is that collusion is a subgame perfect equilibrium in the stage game. If *both* players' strategies stipulate that they report the cartel whenever one of them unilaterally deviates, then deviating is no longer profitable. Furthermore, the costly public reports are credible. Since both players (including the deviating one) report the cartel following a deviation, both players are indifferent between reporting and not reporting and thus reporting is an equilibrium in the reporting subgame. The weakness of this subgame perfect equilibrium is that the Nash equilibrium in the reporting subgame is in weakly dominated strategies. Yet undominated strategies with the same flavor are easily constructed when the stage game is infinitely repeated (see Appendix 1).

Punishments through reports are less relevant in Leniency and Reward; in those treatments optimal price deviations are combined with secret reports, effectively hindering the use of public reports as punishments. Punishments may nevertheless be tuffer in Leniency and Reward, particularly if secret reports reduce trust, leading subjects to coordinate on equilibria sustained by punishments with low expost cartel formation and long and costly price wars. Both secret and public reports may thus enforce cartel stability by strengthening the punishments following a price deviation. Thereby the ranking of the treatments in terms of deterrence and prices may change, leading to a rejection of Hypothesis 1.[13]

Different punishments may also result in different collusive prices across treatments. In line with the previous reasoning, assume punishments to be harsher in Leniency and Reward. Specifically, assume grim trigger strategies in Leniency and Reward while a weak form of a stick and carrot punishment sustains collusion in L-Faire and Fine. The stick is a one period punishment on the bertrand outcome and the carrot a reversion to the collusive path in the subsequent period. Panel b of Figure X illustrates the IC-contraints in this case and suggests that collusive prices may be lower in the treatments with weak punishments, since the price minimizing the incentives to deviate is lower in those treatments. Intuitively, higher collusive prices do not only affect the incentives to stick to the agreement and the short run deviation gain; they also increase the carrot and thereby the incentives to deviate.[14]

3.2 Non-standard equilibrium behaviour

The previous analysis implicitly presumes subjects to be rational, perfectly able to coordinate on any proposed equilibrium and to be risk neutral as well as to be motivated by monetary payoffs only. None of these assumptions is realistic and therefore subjects are likely both to undercut agreed upon prices and to report, implying potential differences across treatments in terms of cartel stability, cartel detection, cartel prices and so on. While unpredicted price deviations and reports underscore the limitations of the above equilibrium analysis, it still highlights costs and benefits associated with price deviations and reports. As such it constitutes a valuable starting point for stating hypotheses also in terms of behaviour which is inconsistent with the analysis.

[12] The IC-constraints are invertely u-shaped in the collusive price. A (marginal) increase in the collusive price increases both π^c and π^d while V^p is unaffected with grim trigger strategies. The effect on π^c (π^d) is decreasing (increasing) in the collusive price (see the payoff table). For $\delta = 0.85$, the effect on π^d dominates when the collusive price reaches 8.

[13] Deterrence levels may be lowest in L-Faire regardless of whether or not the IC-constraint holds; subjects may form cartels even if they systematically deviate since cartel formation is costless in that treatment. If so, prices may be lowest in L-Faire even if cartel formation rates are highest.

[14] The figure also illustrates that different punishments may motivate a rejection of Hypothesis 1: for sufficiently high collusive prices, the IC-constraints are tighter in Communication and Fine than in Leniency and in Reward.

Secret and public reports The success of our experiment hinges to a large extent on whether or not subjects understand the incentives linked to reports. These incentives motivates the two next hypotheses.
Hypothesis 2a (secret reports): Price deviations are combined with secret reports in LENIENCY and REWARD but not in FINE.

If Hypothesis 2 is true, public reports should be observed rarely in LENIENCY and REWARD. The same may be expected in FINE, since reporting is costly in that treatment.
Hypothesis 2b (public reports): Public reports are used in none of the treatments.

Hypotheses 2a and 2b may be rejected if subjects do not combine price deviations with secret reports in LENIENCY and REWARD; public reports can then be used as a costless punishment. They may also be rejected if subjects use costly public reports in FINE as suggested by the optimal punishments in that treatment. Experimental evidence on public good games shows that subjects frequently punish free riders even though punishments are costly (Fehr and Gächter, 2002). Subjects may thus also use public reports as an altruistic punishment, raising the question of the motive behind eventual public reports in FINE.
Hypothesis 2c (altruistic public reports): Public reports are used in FINE as altruistic rather than optimal punishments.[15]

Cartel stability, cartel detection, cartel prices and agreed upon prices Tighter IC-constraints may not only affect cartel formation but also cartel stability: since the incentives to stick to a collusive agreement are smaller when IC-constraints are tight, one may expect price deviations to occur more frequently in treatments with tight IC-constraints. By affecting cartel stability, tighter IC-constraints may also affect cartel prices: all else equal, cartel prices should be higher in treatments with low rates of price deviations. Finally, agreed upon prices may also be higher in treatments with stable cartels; if cartels are reformed after price deviations, subjects may attempt to collude on lower prices in order to relax the IC-constraint. The ranking in Hypothesis 1 thus suggests the following hypothesis.
Hypothesis 3 (cartel stability, cartel prices and agreed upon prices): Cartel stability, cartel prices and agreed upon prices are highest in L-FAIRE followed in order of importance by FINE, LENIENCY and REWARD.

Hypothesis 3 may be rejected for the same reasons as Hypothesis 1. Subjects in FINE, LENIENCY and/or REWARD may refrain from undercutting agreed upon prices if they expect tuff punishments, leading to higher cartel stability, cartel prices and agreed upon prices in those treatments than in L-FAIRE. In addition cartel prices and agreed upon prices may be higher in treatments with harsher punishments if subjects choose collusive prices so as to minimize the incentives to deviate (as panel b in Figure X suggests).

Cartel stability is also likely to affect the frequency of cartel detections, since optimal price deviations are combined with secret reports in LENIENCY and REWARD but not in FINE. The ranking in Hypothesis 3 in terms of cartel stability thus also suggests the following hypothesis.
Hypothesis 4 (cartel detection): Cartels are detected most frequently in REWARD followed in order of importance by LENIENCY and FINE.

Hypothesis 4 may be rejected if punishments differ across treatments. Detection rates being highest in FINE may be viewed as unlikely, however, particularly if Hypotheses 2a and 2b are true. In that case, price deviations will frequently be combined with (secret) reports in LENIENCY and/or REWARD while cartels are reported rarely in FINE. Thus price deviations would need to be much more frequent in FINE in order to generate higher detection rates in that treatment.

Strategic risk Standard equilibrium analysis fails to account for strategic risk - the risk of being cheated upon.[16] Yet strategic risk does not necessarily weaken the statements in Hypotheses 1, 3 and 4. A perceived risk of price deviations and reports is likely to affect deterrence levels and cartel stability in all treatments. The effects should however be largest in LENIENCY and REWARD. Due to secret reports, cheated upon subjects in those treatments are likely to pay fines, suggesting even higher deterrence levels. Similarly,

[15] We test Hypothesis 2c by running an additional treatment, REMATCH, where subjects were rematched in every period with a new competitor.

[16] Refer to and discuss Harsanyi and Selten (199x), Blonski and Spagnolo (200x), Blonski, Ockenfels and Spagnolo (200x) and Dal Bo and Fréchette (200x)?

deviation incentives should be exacerbated in LENIENCY and REWARD, since a price deviation combined with a secret report (at least partially) protects a subject against the risk of being fined due to a report by the competitor.

Strategic risk may also provide an additional motive for subjects to choose the collusive price minimizing deviation incentives rather than maximizing collusive gains. Thereby rivals' incentives to deviate (and the risk of being cheated upon) should be minimized. In case punishments differ across punishments, strategic risk may then contribute to a rejection of the previous hypotheses in terms of average prices (in Hypothesis 1) and cartel prices and agreed upon prices (in Hypothesis 3).

4 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. Before explaining more in detail the procedure we adopted, note that we have two types of data. Individual-level pertains to individual decisions by subjects and duopoly-level data refers to variables that always have the same value for the two members of a duopoly. For example, the presence of a cartel within a duopoly in a given period, or the fact that a given cartel is detected by the antitrust authority, are duopoly-level data, while the decision to communicate or not in a given period or the decision to unilaterally deviate from a collusive agreement are individual level data.

Given the structure of our game, 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. Moreover, since we have run the experiment in two different cities, we must also control for the possible correlation among observations collected in the same city. For this purpose, we adopted a multilevel random effect models.

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, making it difficult to estimate a model with a random effect both at the duopoly and individual level. To overcome this difficulty, we assume in our analysis of individual-level data, that there is a random effect for every subject within any particular match – which accounts for the correlation among observations belonging to the same match. To account the possible correlation among observations relative to the same subject in different matches, we hypothesize that there is a second random effect for every subject across different matches. Finally, we conjecture a third random effect at the city level.

To analyze duopoly-level data we make the assumption that correlation between observations belonging to the same subject but to different duopolies can be disregarded. We therefore hypothesize to have only a random effect at the duopoly level, nested with a random effect at the city level.

The only independent variable of our simple regressions is the treatment, as a dummy. To analyze individual-level data, we adopt a four-levels model of the following form:

$$y_{hijk} = \beta_0 + \beta_1 TREAT_{hijk} + \eta^{(2)}_{ijk} + \eta^{(3)}_{jk} + \eta^{(4)}_{k}$$

where *h, i , j* and *k* are indices for measurement occasions, subjects in matches, subjects across matches and cities, respectively. *TREAT* is the dummy variable for the treatment. Since we always compare only two treatments at a time, this variable takes value 1 in correspondence of one of the two treatments, and value 0 in correspondence of the other one. $\eta^{(2)}_{ijk}$ represents the random intercept for subject j in match i, and in city k (second level), $\eta^{(3)}_{jk}$ represents the random intercept for subject j in city k (third level) and $\eta^{(4)}_{k}$ represents the random intercept for city k (fourth level). Random intercepts are assumed to be independently normally distributed, with a variance that is estimated through our regression.

The general three-levels model we adopt when looking at duopoly-level data has the following form:

$$y_{hlk} = \beta_0 + \beta_1 TREAT_{hlk} + \eta^{(2)}_{lk} + \eta^{(3)}_{k}$$

As above, h and k are indices for measurement occasions and cities, while l is the index for duopolies. $\eta^{(2)}_{lk}$ and $\eta^{(3)}_{k}$ represent random intercepts at the duopoly and city levels.

We ran logit regressions to analyze the decision to communicate, the decision to deviate, and the rates of cartel formation and of cartel detection; we adopted instead linear regressions for prices and agreed upon prices. To estimate our model we used an ordinary panel regression with random effect, when the number of considered levels was equal to 2, while we used GLLAMM (see Rabe-Hesketh and Skrondal, 2004 and http://www.gllamm.org) when the number of considered levels was equal or higher than three.

5 Main experimental results

The success of our experiment hinges to a large extent on two factors. First, cartel formation should help subjects to charge high prices. In view of the large experimental evidence showing in various settings that pre-play communication enhances subjects' ability to cooperate (references), it is not surprising that also our experiment validates this finding. This will become clear below when we report price levels across treatments.

Second, subjects should understand the incentives linked to reports. Table 3 reports the rates of secret reports (given an own price deviation) and public reports (provided only the rival deviated) in FINE, LENIENCY and REWARD. As expected, subjects almost never used secret reports in FINE while in LENIENCY and REWARD, price deviations were usually optimally combined with secret reports.[17] The rates of public reports are more intriguing. Although public reports were costly in FINE, subjects used them as punishments against price deviators in almost one third of the cases. We further explore the motive behind these costly reports in Section XXX. The rates of public reports in LENIENCY are also intriguing, since public reports were not used systematically as a costless punishment against defectors that did not combine their price deviation with a secret report. One may hypothesize that subjects in this case were reluctant to use the public report for fear of reducing trust and jeopardize future cooperation.[18] Overall we view the rates reported in Table 3 as evidence that the subjects understood fairly well the incentives linked to reports.

Table 3: **Self reporting**

	Fine	Leniency	Reward
Rate of Secret Reports (given own price deviation)	0.002	0.704	.905
Rate of Public Reports (given only rival deviated)	0.286	0.481	0.333

The two next sections report our main experimental findings, assessing the performance of traditional (FINE), modern (LENIENCY) and possibly optimal (REWARD)[19] antitrust laws relative to a laissez faire regime (L-FAIRE) and to each other. The aim is to document how these policies perform in terms of deterrence and prices.

5.1 Cartel deterrence, detection and recidivism

Cartel deterrence Table 4 reports the two main measures for evaluating the success of the different policies in terms of deterrence: the rates of communication attempts and of cartel formation provided that subjects are not already cartel members. The requirement that cartels are not formed is important; in effect an attempt at communicating is then an attempt at forming a cartel, not merely a decision to communicate at no cost.[20] The table also report the rates of communication attempts during the first period in a match

[17] As subjects gained experience, the rates of secret reports rose gradually in both LENIENCY and REWARD. In LENIENCY (REWARD) these rates were approximately 0.6 (0.8) over the 5 first periods and exceeded 0.9 (equaled 1) over the 5 last periods.

[18] In REWARD price deviations not combined with secret reports only occured at three occasions. With so few observations, no conclusion can be drawn from the fact that in two of these occasions, the cheated upon subject did not use the public report to punish the defector.

[19] Korea is the only country we are aware of that have implemented this kind of reward schemes for whistleblowers in antitrust; analogous schemes are however used in other fields of law enforcement, particularly in the US.

[20] Hinloopen and Soetevent (2006) report the rate of communication for all periods and therefore our results are not perfectly comparable with theirs.

- a measure of *ex ante* deterrence, which also has the advantage of being insensitive to the (random) length of matches.[21]

Result 1 (Cartel deterrence) FINE and even more so LENIENCY are effective at deterring cartel formation while REWARD reduces deterrence relative to LENIENCY.

Table 4: **Cartel deterrence and detection**

	L-Faire		**Fine**		**Leniency**		Reward
Rate of comm. att.	0.835	$>^{**}$	0.566	$>^{***}$	0.377	$<^{***}$	0.484
Rate of cartel formation	0.716	$>^{***}$	0.315	$>^{***}$	0.178	$\approx$	0.220
Rate of comm. att. (1^{st} period)	0.925	$>^{***}$	0.684	$\approx$	0.437	$<^{*}$	0.481
Rate of reporting	–	–	0.092	$<^{***}$	0.507	$<^{***}$	0.937
Rate of reporting (1^{st} comm.)	–	–	0.136	$<^{***}$	0.761	$<^{***}$	0.983

Note: In this and the following table, ***, ** and * indicate significance at the 1%, 5% and 10% levels.
The tests are clustered at the city (session and city) level(s) when all obs (single obs per match) are used.

The first part in Result 1 reflects that the rates of communication attempts and of cartel formation are significantly lower in FINE and even more so in LENIENCY than in L-FAIRE. Relative to L-FAIRE, the rates of individual communication attempts decreased by 31% in FINE and by 56% in LENIENCY. These differences are even more striking for the rates of cartel formation, with decreases of 55% in FINE and 77% in LENIENCY. Note also that FINE and LENIENCY increase ex ante deterrence according to the rates of communication attempts during the first period in a match. Interestingly, the reduction of 47% in cartel formation rates in LENIENCY relative to FINE is rougly comparable to Miller's (2007) estimate of 52%. Result 1 is also (partly) consistent with previous experimental results. Hinloopen and Soetevent find a similar pattern concerning cartel formation rates but observe no significant difference in terms of rates of communication attempts between their antitrust (i.e fine) and leniency treatments while Apesteguja et al. (2006) do find a reduction in the percentage of formed cartels (from 67% to 50%).

The deterrence effects of FINE and LENIENCY are thus consistent with Hypothesis 1. By contrast, the reduced deterrence in REWARD relative to LENIENCY contradicts Hypothesis 1. For the moment we note that this finding is similar to the one by Apesteguja et al. (2006), albeit a bit weaker; the rates of cartel formation in their bonus (i.e. reward) treatment were higher than in their standard (i.e fine) treatment.

Cartel detection Table 4 also reports two measures of cartel detection: the rates of detection due to self-reporting, either based on reporting decisions in all periods a cartel was formed or during the first period two subjects communicated.[22] Both measures yield the same ranking of the three policy treatments, a ranking consistent with Hypothesis 4:

Result 2 (Cartel detection) LENIENCY and even more so REWARD substantially and significantly increase cartel detection due to self reporting.

Result 2 is not surprising in view of the high rates of secret reports in LENIENCY and REWARD reported in Table 3. The rates of detection are particularly spectacular in REWARD where almost systematically at least one cartel member reported: in 118 out of the 120 cases a cartel was formed, it was reported in the first period. One of the remaining cartels was reported in the subsequent period, while only the subjects in the last cartel resisted the temptation of reporting, managing to collude successfully for the seven remaining

[21] The **Rates of communication attempts** are computed using the binary individual decisions to communicate in all periods a cartel was not already formed (or in the first period in a match). The **Rates of cartel formation** are computed using a single observation per duopoly and period, indicating if subjects formed a cartel in that period. The differences across treatments are evaluated using a multilevel random intercept model. With individual (duopoly)-level data, we ran a four (three)-level random intercept logistic regression per each couple of treatments.

[22] Describe the rates of reporting.

periods of the match. In principle, the subjects could exploit the reward system by taking turns in reporting and cashing in the reward.[23] Alternatively they may have formed a cartel with the hope of fooling their competitor by undercutting the agreed-upon price and by reporting the cartel in order to cash in the reward. This latter hypothesis initially proposed by Apesteguja et al (2006) would also be validated in our sample if subjects systematically combined reports with price deviations. We return to this issue when we discuss price deviations rates. Finally note that Result 2 is qualitatively consistent with Miller's (2007) empirical finding that leniency programs increase detection rates by 62% although we observe even higher rate increases. Similarly it is consistent with the increased detection rate of 50% observed in Apesteguja et al. (2006)s' experiment.

Cartel recidivism The rates of communication attempts in the first period of a match are higher in FINE and LENIENCY than the rates of communication based on observations from all periods when a cartel a cartel was not formed. This pattern suggests that cartel detection may have affected subjects' decisions to reform a cartel. Figure 2 shows for FINE, LENIENCY and REWARD the cumulative percentage of cartels (vertical axis) reformed by convicted subjects in the five periods following the conviction (horizontal axis). The plots underestimate this percentage number of reformed cartels, since some matches ended before the five periods after the conviction occurred. Still, the data tells us quite a lot.

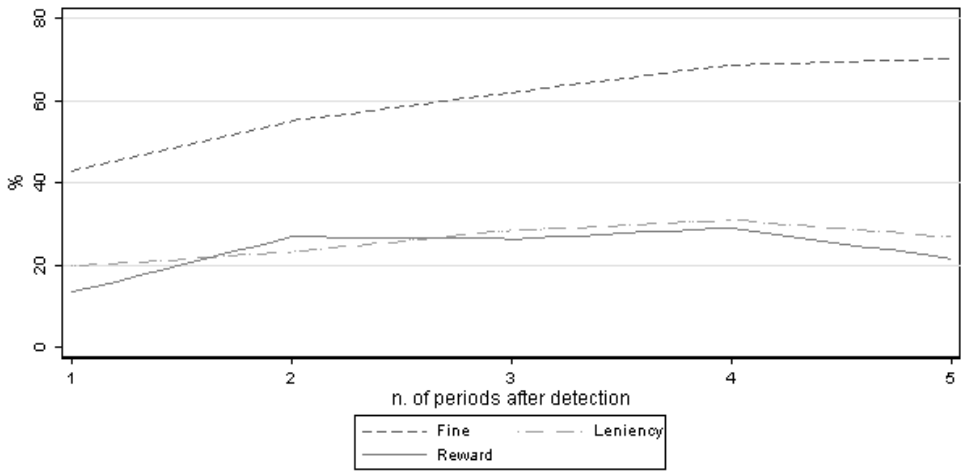


Figure 2: % of cartels re-established

First, history of play matters, since a large fraction of cartels are not reformed after conviction even though the subjects faced the same expected fine, available actions and payoff functions after the conviction as before the convicted cartel was formed. Second, ex post deterrence in LENIENCY and REWARD than in FINE: close to 40% of convicted cartels are reformed immediately in FINE but not in LENIENCY and REWARD.

Result 3 (Cartel recidivism) LENIENCY and REWARD produces a strong increase in desistance.

Result 3 is in stark contrast with Hinloopen and Soetevent (2006); they found no improvement in desistance linked to the introduction of leniency policies. The reason is probably that price deviations could not be combined with simultaneous secret reports in their experiment whereas the lion share of convictions in LENIENCY and REWARD were due to secret reports. Such reports are likely to generate substantially more

[23] We designed an exploitable reward scheme in the sense that the expected fine is 0 if cartel members take turns in self-reporting and cashing in the reward. Spagnolo (2004; 2006) shows that in optimal schemes, rewards should always be strictly smaller than the sum of fines paid by the other wrongdoers.

distrust than a discovery by the competition authority, thereby reducing subjects' willingness to reform a cartel.

5.2 Prices, price deviations and post-conviction pricing

Prices The ultimate objective of antitrust law enforcement is to generate low prices. Table 5 presents the average price, the average cartel price, the average agreed upon price and the average price given that subjects do not communicate.[24] The Table also reports the average cartel and agreed upon prices based on observations from periods when two subjects communicated for the first time. The first lesson to be drawn from this table is that cartel deterrence is desirable, since it reduces prices; in all treatments, cartel prices are higher than the prices without communication. (Although not reported, these differences are statistically significant.) This finding combined with the high cartel formation rates in L-Faire suggests that prices should be highest in that treatment. Except for Reward, our data contradicts this conjecture (and Hypothesis 1).

Table 5: **Prices, agreed upon prices and price deviations**

	L-Faire		Fine		Leniency		Reward
Average price	4.913	$\approx$	5.348	$>^{***}$	4.844	$\approx$	3.975
Cartel price	4.971	$<^{***}$	6.114	$<^{**}$	7.024	$>^{***}$	5.339
Cartel price (1^{st} comm.)	5.929	$<^{***}$	6.990	$>^{***}$	6.663	$>^{***}$	5.483
Agreed upon price	7.689	$<^{***}$	8.242	$\approx$	8.218	$\approx$	8.512
Agreed upon price (1^{st} comm.)	7.881	$<^{***}$	8.129	$>^{*}$	7.886	$\approx$	8.100
Price without communication	3.227	$\approx$	3.890	$\approx$	4.013	$\approx$	3.565
Rate of price dev.	0.564	$>^{***}$	0.424	$\approx$	0.373	$<^{***}$	0.781
Rate of price dev. (1^{st} comm.)	0.590	$>^{***}$	0.408	$\approx$	0.443	$<^{***}$	0.717

Note: In this and the following table, ***, ** and * indicate significance at the 1%, 5% and 10% levels. The tests are clustered at the city (session and city) level(s) when all obs (single obs per match) are used.

Result 4 (Average prices) Only Reward appears to reduce prices on average relative to L-Faire.

Result 4 suggests that rewarding whistleblowers is the only welfare enhancing policy. The systematic secret reports probably undermined trust and, as a result, both prices within explicit cartels and outside cartels were reduced, contributing to the drop in average prices.[25].

Equally interesting, average prices are not lower in Fine and Leniency than in L-Faire. In fact average prices are almost the same in Leniency as in L-Faire and somewhat higher in Fine. As already mentioned above, this is surprising in view of the deterrence effects associated with these policies. The prices charged within cartels constitutes the main explanation for why average prices do not drop in Fine and Leniency.

Result 5 (Cartel prices) Fine and Leniency increase cartel prices significantly.

[24] For the Average price, a single observation is represented by the average among the prices chosen in a period by the two members of a duopoly. The same is true for the cartel prices, but here we only consider the cases in which the members of a duopoly have formed a cartel which has not been detected or reported yet. For Agreed upon prices we only consider the cases in which the subjects have communicated and found an agreement on the price to set. A single observation is given by the agreed upon price per duopoly, per period. For Prices without communication we restrict our analysis to the cases in which no communication has taken place in the present period, and any possible previous agreement on prices has already been broken. A single observation is represented by the average among the prices chosen by the two members of a duopoly, in every single period. As explained above, we used a three-level random intercept linear model to compare the results across treatments since the analysis here concerns duopoly-level data. We ran a regression per each couple of treatments.

[25] Average prices are only insignificantly lower in Reward (see Table 5). The reason is that the tests use observations clustered at the city level only, not at the session level. A likelihood ratio test suggests however that clustering at the session level is to be preferred and in that case average prices are significantly lower in Reward.

Interestingly, note also that the price levels for non cartel members appear to be higher (although insignificantly so) in FINE and LENIENCY than in L-FAIRE. Thus the prices charged outside cartels do also contribute to the surprisingly high average prices in FINE and LENIENCY. One possible interpretation of this pattern is that a refusal to communicate when it is costly to do so, does not clearly signal an unwillingness to cooperate. Thereby antitrust policies may facilitate tacit collusion.

Price deviations The high cartel prices in FINE and LENIENCY and the low ones in REWARD are also consistent with the rate of price deviations reported in Table 5.

Result 6 (Price deviations) Both FINE and LENIENCY significantly reduces the frequency of price deviations whereas REWARD significantly increases that frequency.

The very high rates of price deviations in REWARD show that the reward scheme was not exploited. In fact, no pair of subjects appears to have realized the opportunity to take turns in reporting.[26] Rather subjects formed cartels with the intent of fooling the competitor by simultaneaously undercutting the agreed upon price and report the cartel so as to cash in the reward. By contrast FINE and LENIENCY reduced the rates of price deviations and thereby stabilized cartels.

Post-conviction prices Figure 3 shows for FINE, LENIENCY and REWARD the price choices in cartels before conviction (conviction takes place at time 0) and after conviction, separately for the subjects that reformed and did not reform the convicted cartel. The stylized facts emerging from the figure are (a) prices after conviction are on average lower than in cartels before conviction, (b) when cartels are re-established after conviction, prices stabilize at levels close to those prevailing in the period when the cartel was convicted, (c) when cartels are not re-established, prices fall substantially relative to the cartel price prevailing at the time of conviction, remaining low in LENIENCY and REWARD and raising gradually in FINE, (d) post-conviction prices are higher in FINE than in LENIENCY and REWARD when the convicted cartel is not reformed and finally (e) post-conviction prices are higher in FINE and LENIENCY than in REWARD when the convicted cartel is reformed.

The difference arising between LENIENCY and REWARD on the one hand and FINE on the other when convicted cartels are not reformed is particularly interesting (stylized fact d)). While under LENIENCY and REWARD the average price remains close to Bertrand, under FINE average non-collusive prices after detection rise as if – after having formed an explicit cartel and having experienced the fine – some of the subjects try to reach a tacit agreement on prices. A possible interpretation of this effect is that under FINE detection does not affect trust between cartelists, while under LENIENCY detection and defection are often simultaneous, and the cartel is discovered because it is reported by the deviating player; therefore, post-conviction tacit collusion is more difficult to achieve under LENIENCY.

5.3 Preliminary summary

The picture emerging in REWARD is clear. As in Apesteguja et al (2006), most subjects formed cartels with the intent of fooling the competitor by simultaneaously undercutting the agreed upon price and report the cartel so as to cash in the reward. The frequent price deviations substantially reduced cartel prices and together with the systematic secret reports generated substantial distrust. The reduced trust had both the effect of substantially reducing post-conviction cartel formation and prices as well as subjects' ability to collude tacitly. As a result REWARD reduced average prices relative to all other treatments and appears to be the only welfare improving policy.

The patterns in FINE and LENIENCY are more intriguing. Both policies significantly reduced cartel formation rates but nevertheless appeared unsuccessful in reducing prices. The main reason appears to be

[26] This casts doubts on the concern raised by some legal scholars that reward schemes could be exploited, particularly so given that our reward scheme was inappropriately designed and that the subjects nevertheless failed to seize the opportunity. This result is also consistent with Dal Bo's (2005) finding that efficient asymmetric (alternating) equilibria in repeated prisoners' dilemma game are never played in the lab.

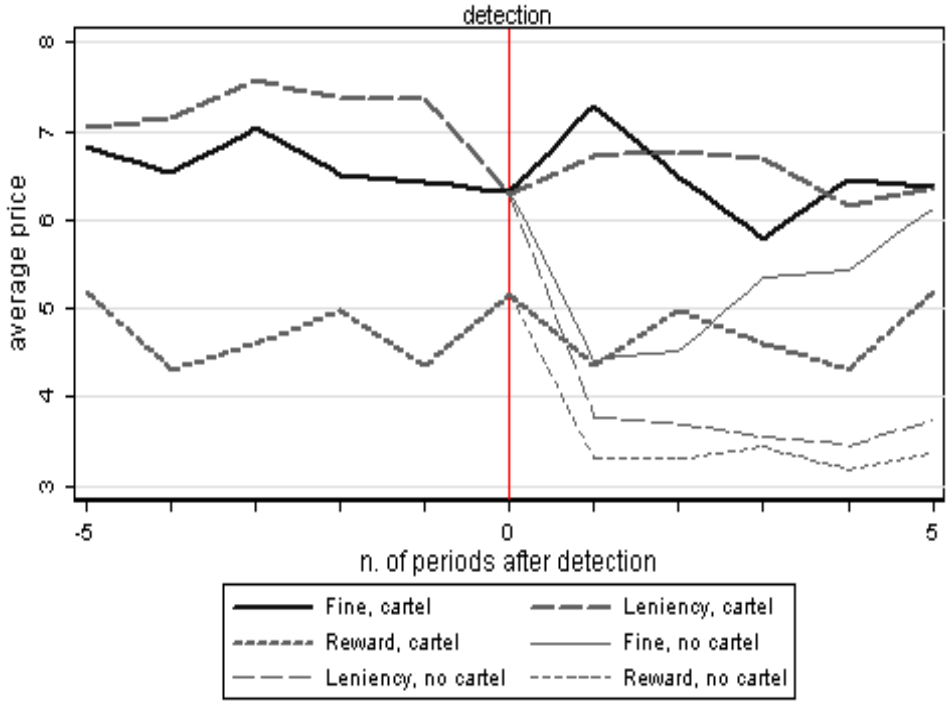


Figure 3: Price before and after detection

that cartel prices increased significantly in both treatments relative to L-Faire. These findings call for an explanation. The next section explores several potential explanations for the high cartel prices in Fine and Leniency.[27]

6 Why cartel prices are high in Fine and Leniency

Several potential explanations may contribute at explaining the high cartel prices in Fine and Leniency. An enforcement effect may have been at work whereby subjects refrained from undercutting agreed upon prices for fear of tuff punishments. Alternatively a selection effect may explain the data if subjects with a tendency to deviate - defectors - were deterred from forming cartels rather than cooperative subjects. Finally, a coordination effect may also help us understand the puzzle if subjects in the policy treatments coordinated on equilibria with higher collusive prices so as to compensate for the expected cost of cartel formation. Below we attempt to assess the importance of these different explanations.

6.1 Enforcement effects

Although the high cartel prices in both Fine and Leniency may be driven by an enforcement effect, its exact form may differ between the two treatments. Since price devations usually were optimally combined with secret reports in Leniency but not in Fine (see Table 3), the subjects in the latter treatment in effect

[27] Spagnolo (2000b), Buccirossi and Spagnolo (2001, 2006) and Ellis and Wilson (2001) suggest that antitrust policies embedded with a leniency program could stabilize non-deterred cartels. The idea is that reporting can be used as a punishment against deviators, since reporting is less costly with a leniency program. This potential explanation for the high cartel prices in Leniency is not convincing in the present context; since defectors could, and usually did combine price deviations with secret reports, they could in effect protect themselves against such punishments. In fact, reports as threats against deviators are in our experiment more relevant in Fine.

had an additional instrument for punishing a deviator - the public report. This raises the question whether the risk of being punished through a public report may have enforced high cartel stability and as a result high cartel prices in FINE. This question is particularly relevant in view of the fact that some subjects indeed used the public reports to punish defectors. The next subsection is devoted to this question and we therefore postpone our discussion of the presence of an enforcement effect in LENIENCY.

6.1.1 Enforcement effect in Fine

To test whether the public reports explains the high cartel prices in FINE, we ran an additional treatment, NOREPORT. This treatment was identical to FINE except for the possibility to report. If access to public reports were the main driving force behind the high cartel prices in Fine, one would expect significantly lower cartel prices in NOREPORT. Because we only ran one session of the NOREPORT treatment in Rome, we only use the data collected in Rome, also for the FINE treatment. The cartel prices on average 6.109 in FINE and 4.403 in NOREPORT. The difference is significant at the 1 % percent level (p-value=0.00).

Result 7 (Cartel prices and public reports) The opportunity in FINE to punish defectors significantly increase cartel prices.

Result 7 suggests that public reports enforced higher cartel prices. Yet Result 1 does not tell us the reason why subjects perceived the public reports as a credible threats. There are at least two potential explanations for why subjects may have perceived the costly public reports as credible. First, optimal punishments in FINE involve public reports. Second, subjects may use public reports as an altruistic punishment as suggested by experimental evidence from public good games (Fehr and Gächter, 2002). To discriminate between the two hypotheses, and in line with Fehr and Gächter (2002), we ran an additional (fine) treatment in Rome, REMATCH, where subjects were rematched in every period. In this treatment, public reports were not credible unless subjects used them altruistically. Since we only ran REMATCH in Rome, we only use the Rome data also in FINE. Provided that only one subject defected from the agreed upon price, the rates of public reports were higher in REMATCH (0.197) than in FINE (0.324).

Result 8 (Public reports as altruistic punishments) Subjects used public reports as altruistic punishments rather than optimal punishments.

6.1.2 Enforcement effect in Leniency

The high cartel prices in LENIENCY were probably not driven by the threat of public reports as punishments, since price devations mostly were combined with simultaneous secret reports (See Table 3), effectively hindering the use of public reports as punishments. Yet our previous results are consistent with an enforcement effect. Subjects appear to anticipate that price deviations optimally combined with secret reports will generate so much distrust, that the convicted cartel hardly can be reformed. The post-conviction behaviour documented earlier shows that such deviations implies a strong desistance effect associated with low post-conviction prices. As a result, subjects may have refrained from undercutting agreed-upon prices (as documented by the rates of price deviations in Leniency) due to the threat of long and costly price wars.

6.2 Selection effect

(Incomplete section) To explore the relevance of a selection effect whereby antitrust policies would have deterred disproportionately many subjects with a tendency to defect (and possibly report), we posit that subjects can be classified into three types: Non-communicators (subjects that always refuse to communicate and to form cartels), cooperators (subjects that cooperates, either systematically or conditionally on whether or not also the rival cooperates) and defectors (subjects which tend to or systematically deviate). A pattern consistent with a selection effect would be that we would observe a larger proportion of non-communicators and a lower proportion of defectors after an introduction of antitrust policies.

Before testing for a selection effect we first need to posit a procedure for partitioning subjects into one of the three categories and, second, we need to document that the resulting partioning is relevant, i.e. subjects

identified as e.g. defectors should on average defect more frequently than subjects identified as cooperators. We follow the early literature on types (references) by defining subjects as cooperators (deviators) if they sticked to (undercutted) the agreed upon price during the first period they had the occasion to communicate. The remaining subjects are Non-communicators, i.e. subjects that systematically refused to communicate throughout the experiment. This partition turns out to be satisfactory in the sense that the decision whether or not to deviate in the first period a subject communicated is a fairly good predictor for subsequent decisions to deviate or not.

In L-Faire, no subject was classified as a Non-communicator while only a few subjects were classified as Non-communicators in Fine and Leniency. The striking difference between the treatments is instead that the proportion of cooperators increased in both Fine and Leniency relative to L-Faire. If anything, this pattern rejects the hypothesis that the high cartel prices in Fine and Leniency were driven by a selection effect.

6.3 Coordination effect

(Incomplete section) To explore the relevance of a coordination effect whereby antitrust policies would improve subjects' ability to coordinate on higher collusive prices, we use the data on agreed upon prices. If the coordination effect is important for explaing the high cartel prices in Fine and Leniency, we should observe higher agreed upon prices in those treatments than in L-Faire. The agreed upon prices in Table 5 based on all observations when subjects actually communicated gives some support for a coordination effect.

Yet these high agreed upon prices do not necessarily imply that the coordination effect is at work. The reason is that the high agreed upon prices may be a consequence of the lower rates of deviations in Fine and Leniency. Indeed, the subjects may initially have attempted to coordinate on a high price and may have experienced frequent price deviations. Thereby they may have learned that it is too tempting to deviate from a high agreed upon price. In subsequent periods, the subjects may therefore have attempted to collude on a lower price in order to relax the IC-constraint and reduce strategic risk.

To control for this problem and assess the importance of the coordination effect, we focus instead on the prices agreed upon during the first period of communication in each match. From Table 5, these agreed upon prices are virtually the same in L-Faire and Leniency, while they are significantly higher in Fine. We conclude that a coordination effect probably is unimportant for explaining the high cartel prices in Leniency but may have contributed to increase cartel prices in Fine.

7 Additional Results

This section discusses the impact of the level of the fine for our result on cartel deterrence and price formation. We first check the robustness of our findings by running additional treatments with high expected fines. We then discuss whether the size of the fine affects our results.

7.1 Higher expected fines

We test the robustness of our findings by running two additional treatments with higher expected fines of 60 ($\alpha = 0.2$ and $F = 300$), FineHEF and LeniencyHEF. Table 6 reports the rates of communication attempts and of cartel formation as well as average prices and prices within and outside cartels. These figures are compared with those for our original treatments, Fine and Leniency.[28] The first lesson from this table is that higher expected fines increase deterrence and reduce average prices under traditional antitrust laws but not under modern laws embedded with a leniency program. The reason is probably that the expected fine mostly increased through an increase in the probability of detection - this probability was doubled while the size of the fine increased by 50 % only - and that under leniency, many cartels are reported irrespective of the probability of detection, thereby reducing subjects sensitivity to changes in that probability. Note also that the prices within cartels increased in the leniency treatment but not in the Fine treatment.

[28] The treatments FineHEF and LeniencyHEF were run in Rome only. For sake of consistency, we only consider observations gathered in Rome for the treatments Fine and Leniency as well.

Table 6: **High expected fines**

	Fine		**FineHEF**		**LeniencyHEF**		**Leniency**
Rate of comm. dec.	0.590	$>^{**}$	0.452	$\approx$	0.435	$\approx$	0.344
Rate of cartel form.	0.316	$>^{***}$	0.195	$\approx$	0.163	$\approx$	0.146
Average price	4.34	$>^{*}$	4.00	$>^{*}$	3.65	$\approx$	3.93
Price within cartels	5.03	$\approx$	5.22	$<^{**}$	6.21	$>^{*}$	5.49
Price without communication	3.32	$\approx$	3.20	$\approx$	3.17	$\approx$	3.46

Higher level of fine. Antitrust fines can be viewed as sunk costs incurred by convicted subjects. Recently, the literature has discussed the possible coordination role of sunk costs (e.g. Offerman and Potters 2006) and the existence of a 'sunk cost bias' in decision making, whereby agents try to recover sunk costs by increasing their mark ups (Baliga et al. 2004). To distinguish the two effects, we hypothesized that the first effect should imply improved coordination in general. That is, following an increase in fines, coordination on higher prices should improve both when formerly convicted cartels did and did not reestablish the cartel. By contrast, if subjects are driven by a sunk cost bias, then an increased fine should only increase post conviction prices when the former cartellists do not reform the cartel. Table 7 reports post conviction prices from our experiment, both within and outside cartels, and the level of the fines levied on convicted agents. Consistently with one of Sproul's finding, we observe a negative (although not always significant) correlation between the size of the fine and post-conviction prices. In our experiment this effect is somehow puzzling, since even before getting fined our subjects were informed about the size of the fine and the probability of detection, so if they were fully rational they should not change their behavior after detection. A deeper analysis is required to understand the reasons that lead to this finding.[29]

Table 7: Size of the fine and post-conviction pricing

Treatment	**Fine**	**Prices outside cartels**	**Prices within cartels**
Fine	200	4.418	7.297
		$\approx$	$\vee^{*}$
FineHEF	300	3.310	5.750
Leniency	200	3.776	6.732
		$\approx$	$\approx$
LeniencyHEF	300	3.181	4.700

We also observe that post conviction prices are generally lower when the fine (and the expected fine) is higher, both within cartels and outside cartels, whether leniency is granted to the "whistleblowers" or not. Consequently, our evidence seems to contradict the hypothesis of a sunk cost bias, which would affect prices of firms that choose not to re-establish a cartel after being fined; our results also contradict the hypothesis of a coordination effect of the fine for cartels restored right after their detection.

To test the significance of the observed difference in post conviction prices between FINE and FINEHEF, and between LENIENCY and LENIENCYHEF, we estimated a three level random effect linear model using GLLAMM, following the procedure explained in section 2.6. As mentioned above, this procedure allows us to keep into account the correlation between observations from the same duopoly, and also the correlation between observations from the same city. We notice that the differences we observe are economically, but not statistically significant in most of the cases. According to our results, the difference in post conviction prices between LENIENCY and LENIENCYHEF is not significant, neither within cartels nor outside cartels. On the other hand, the difference between prices observed in FINE and FINEHEF is significant, but only within cartels. This lack of statistical significance may be due to the sample size, which is very small since we restrict our analysis only to the cases in which a cartel was discovered and dismantled in the previous period.

[29] To investigate this matter, we ran some other related experiments' whose results will be presented in a companion paper.

7.2 Ineligibility for Cartel Ringleader[30]

Under the US Corporate Leniency Policy, a firm is ineligible for amnesty if it is the instigator of the cartel - the so called ringleader. In order to qualify for amnesty, the policy requires that the "corporation did not coerce another party to participate in the illegal activity and clearly was not the leader in, or the originator of, the activity" (Corporate Leniency Policy, *supra* note 58). By contrast, and following the revision of the EU Leniency Notice in 2002, also the ringleader is eligible for amnesty in the EU. Excluding the ringleader from the leniency program may increase deterrence if each firm wait for some other firm to take the initiative of forming the cartel. As noted by Leslie (2006), however, extending amnesty to the ringleader may increase deterrence as well by ensuring that even the ringleader cannot be completely trusted, as it may also loose confidence and rush to report under the leniency program.

Table 8: **Deterrence effects**

	Leniency		**Ringleader**
Rate of communication attempts	0.344	$\approx$	0.290
Rate of cartel formation	0.146	$\approx$	0.135
Rate of individual deviation	0.472	$>^{***}$	0.230
Rate of reporting	0.646	$>^{***}$	0.289

To evaluate the pros and cons of ringleader ineligibility, we ran the additional treatment, RINGLEADER. Tables 8 and 9 compare the effects on deterrence and on price levels of eliminating the possibility of amnesty for the ringleader. Three features are striking in these tables. First, the RINGLEADER treatment has no significant effect on cartel deterrence relative to the Leniency treatment. Second, cartels appear to become more stable and third the RINGLEADER treatment increase prices significantly according to all our price measures. These findings are summarized in the next result [31].

Result 7 (Ringleader) If the ringleader is excluded from the leniency program, the deterrence effect of leniency falls and prices are higher than otherwise.

Result 7 thus suggests that the US practice of excluding the ringleader from the leniency program is unambiguously bad in our set up. While we find this result an interesting first step, that confirms some observers' concerns that excluding ringleaders may reduce the effectiveness of the leniency program, we should also emphasize one important caveat. In our experiment subjects were matched pairwise into duopolies to avoid social preferences effects towards non-defecting third parties.

Table 9: **Price levels**

	Leniency		**Ringleader**
Average price	3.926	$<^{***}$	4.847
Price within cartels	5.494	$<^{***}$	7.284
Agreed upon price	7.099	$\approx$	7.833
Price without communication	3.457	$<^{***}$	3.912

This, however, is the worst conceivable situation for the US policy of excluding ringleaders, as the ban leaves only one cartel member with the option to self-report obtaining leniency, eliminating the incentives to "race to report" generated by the risk that another cartel member could do it before. With more than two firms, therefore, it is likely that RINGLEADER treatment will show more desirable properties. Therefore, further experimental research with many cartel members is needed before attempting to draw any policy implication.

[30] We thank Joe Harrington for suggesting this treatment.

[31] RINGLEADER was run only in Rome. For sake of consistency, in tables 8 and 9 we only consider observations gathered in Rome for LENIENCY as well.

7.3 Culture, Trust and Antitrust

We ran our experiments in Stockholm and in Rome, two towns with quite distinct cultures. It is not obvious that one or the other culture should lead to more cartels. On the one hand, one may expect Italians to be more successful in colluding, given the framing of our experiment - cartel formation was presented as illegal - and given that Swedes often are thought to be more law abiding than Italians, . On the other hand, according to the World Values Survey (1999), there are important differences between Sweden and Italy that may point in a different direction. In particular, when they were asked whether "information to help justice should be given to the authorities", 40.2 % of the Italians strongly agreed when only 26% of Swedes do. Moreover a majority of Swedes (63.7%) think that "people can be trusted" while only 31.8% Italian agreed. The difference in the answers to the first question suggests that leniency programs could be more effective in Italy. The difference in the answers to the second question suggest that Swedes are more confident in the cooperation of partners, so that they are more likely to coordinate on collusive/cooperative equilibria.

Separating treatments according to location we found results consistent with the differences in answers to the World Value Surveys: Swedes collude more often, coordinate on higher prices, and deviate much less often than Italians. In all treatments prices were lower and cartels less frequent in Italy than in Sweden, and defection and applications to leniency are much more frequent in Italy. According to our results, Nordic countries may be in more need of antitrust enforcement because of their 'cooperative' culture than southern ones.

8 Conclusions

Leniency policies and rewards for whistleblowers are being introduced in ever more fields of law enforcement, though their effects are often hard to observe. This paper reports results from a laboratory experiment designed to examine the effects of fines, leniency programs, and reward schemes for whistleblowers on firms' decision to form cartels (cartel deterrence) and on their price choices (welfare). Our subjects play a repeated Bertrand price game with differentiated goods and uncertain duration choosing whether to communicate on prices (form cartels). We ran several treatments differing in the possibility of being convicted and fined, of self-reporting to obtain leniency before and after prices become public, and of cashing a reward for self-reporting.

In our experiment antitrust law enforcement without leniency has a significant deterrence effect (fewer cartels form), but also a sizable pro-collusive effect (cartel prices grow) so that overall prices do not fall. This effect appears driven by agents' use of self-reporting and fines as a 'altruistic' punishment devices. Leniency programs further increase cartel deterrence but also stabilizes surviving cartels, as subjects appear to anticipate that after defections including self-reporting cartels can hardly form again. When fines are used as rewards for self-reporting agents, cartels are still formed, but they are systematically reported. Only then prices fall and antitrust improves welfare.

To the extent that we can rely on laboratory experiments, these results suggest that rewards are likely to be a more effective deterrence instruments that simple leniency programs in the fight of cartels and similar forms of organized crime. They also suggest that we should not stop with checking deterrence effects, because prices may not react in the way one could expect. Further experimental and empirical work appears therefore badly needed.

9 Appendix 1: Theoretical predictions

9.1 Notation

π^b and π^c denote the profits in the competitive bertrand equilibrium and on the collusive path respectively and π^d the deviation profit. δ denotes the discount factor, α the probability of detection, F the fine and R the reward. V^p denotes the present value in the beginning of the punishment phase net of expected fine payments and EF_A, EF_L and EF_R denote the present values of expected fine payments in FINE, LENIENCY and REWARD respectively.

9.2 Existence of collusive equilibria

Collusive equilibria exist if the P- and IC-constraints hold. Assuming that cartels never report on the collusive path and charge the same collusive price across periods and treatments, the P-constraints can be expressed as

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

The first inequality is the P-constraint in L-FAIRE and the second inequality the P-constraint common to the policy treatments. Clearly the P-constraints hold in all treatments, since $\pi^c - \pi^b > \alpha F = 20$ for all collusive prices larger than 3.

Note also from the IC-constraints that a collusive price is sustainable in all treatments if it is sustainable in REWARD. Consider a collusive equilibrium sustained through grim trigger strategies where the collusive price equals the monopoly price. The rematching procedure implies for risk neutral subjects that $\delta = 0.85$. Moreover, $\pi^b = 100$, $\pi^c = 180$, $\pi^d = 296$, $\alpha = 0.1$ and $R = F = 200$. Then $\alpha F/(1-\delta) = 20/0.15$ and $V^p = \pi^b/(1-\delta) = 100/0.15$ so that (IC-REWARD) holds with strict inequality. Thus the monopoly price is sustainable in all treatments.

9.3 Cartel formation on the punishment path

The IC-constraints were stated assuming that cartels are not reformed on the punishment. This assumption is not innocuous because cartel formation on the punishment path affects the incentives to deviate both from the collusive path and from the punishment path. Relaxing this assumption should however not alter the statement in Hypothesis 1.

Consider a punishment which is credible absent cartel formation on the punishment path and assume first that the punishment remains credible even if cartels are formed on the punishment path. Then the IC-constraints (for not deviating from the collusive path) can be expressed as

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

$$\frac{\pi^c - \alpha F}{1-\delta} \geq \pi^d - \alpha F + \delta\left(V^p - EF_F\right), \qquad \text{(IC-Antitrust-A)}$$

$$\frac{\pi^c - \alpha F}{1-\delta} \geq \pi^d + \delta\left(V^p - EF_L\right), \qquad \text{(IC-Leniency-A)}$$

$$\frac{\pi^c - \alpha F}{1-\delta} \geq \pi^d + R + \delta\left(V^p - EF_R\right). \qquad \text{(IC-Reward-A)}$$

The difference with the IC-constraints stated in the body of the text is that the present values at the start of the punishment phase are reduced by the expected fine payments EF_F, EF_L and EF_R. The size of these expected fine payments depends on how often and how far in the future cartels are formed. In FINE, $EF_F \in [(1-\alpha)\alpha F/(1-(1-\alpha)\delta), \alpha F/(1-\delta)]$. The strictly positive lower bound on EF_F reflects that following a deviation a cartel is not dismantled with certainty and thus fines are paid with positive probability

on the punishment path;[32] the upper bound reflects that at most a cartel is formed with certainty in every period on the punishment path. In LENIENCY and REWARD, the expected fine payments are the same when the punishment is carried out through a price war, $EF_L = EF_R$. Moreover $EF_L \in [0, \alpha F/(1-\delta)]$. The lower bound equals 0, since an optimal price deviation in LENIENCY and REWARD is combined with a simultaneous report and since cartels may never be reformed on the punishment path. Finally, note that $EF_F \geq EF_L$. Since punishments in the form of price wars may not require cartels to be formed in certain periods, fine payments may in LENIENCY and REWARD be avoided with certainty in those periods.[33] This is not true in FINE, since a cartel is not detected with certainty during the deviation period. Finally note that the statement in Hypothesis 1 remains valid even if cartels must be formed on the punishment path since $\alpha F/(1-\delta) \geq \alpha F + \delta EF_F$ and $EF_F \geq EF_L = EF_R$.

Next, assume instead that the punishment may not remain credible in all treatments if cartel formation is needed to carry it out. The question is in which treatments the punishments may become non-credible. Clearly, cartel formation on the punishment path cannot affect a punishment's credibility in L-FAIRE. Matters are different in the policy treatments. In those treatments, cartel formation should tighten the conditions for not deviating from the punishment path exactly for the same reasons that cartel formation tightens the condition for not deviating from the collusive path. That is, the scope for punishing a price deviator should be largest in L-FAIRE followed in order of importance by FINE, LENIENCY and REWARD.[34] This conclusion reinforces the statement in Hypothesis 1.

9.4 Optimal Punishments through reports in Fine

Consider the following strategy in FINE. 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 $\delta > 0$. That is, no player has an incentive to deviate, neither on the collusive, nor on the punishment path. Two properties of this strategy are worth emphasizing. First, reporting is no longer a weakly dominated strategy, since not reporting implies foregone future profits due to the punishment through grim trigger strategies. Second, it is essential that both players report the cartel. Otherwise it would not be optimal to report the cartel for all $\delta > 0$. To see this, assume instead that the strategy stipulates that a player reports immediately iff the other player deviated. Then the cheated upon player has no incentives to report if δ is sufficiently small, since the avoidable immediate cost of reporting outweighs the future benefit of returning to the collusive path.

Appendix 2: Instructions for the Leniency 1 treatment

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 7 Euros for your participation. On top of that you can earn more than 30 Euros if you make good decisions.

We will first read the instructions aloud. Then you will have time to read them on your own. If you then have questions, raise your hand and you will be helped privately.

In summary, the situation you will face is the following. You and one other participant referred to as your competitor produce similar goods and sell them in a common market. As in most markets, the higher the price you charge, the more you earn on each sold good, but the fewer goods you sell. And, as in many markets, the lower the price charged by your competitor, the more customers he or she will take away from you and the less you will sell and earn. It is possible, however, to form a cartel with your competitor, that is, you will have the possibility to communicate and try to agree on prices at which to sell the goods. In

[32] The expression for the lower bound is computed assuming that once the cartel is dismantled, it is never reformed. Note also that when EF_A is equal to the lower bound, then $\alpha F + \delta EF_A$ equals the expected fine payment in (IC-Antitrust).

[33] In particular, fines can be avoided with certainty in the beginning of the punishment phase if the punishment does not require the cartel to be formed in these periods.

[34] A formal proof of this conjecture is beyond the scope of this experimental paper and is left for future research.

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 you want to know your profit 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 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.

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 meeting 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 or plus an eventual reward. 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, ... , 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, f 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, your eventual reward 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.

The following time line summarizes the seven steps of each round.

Figure 4: Timing of the stage game

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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