RESEARCH INSTITUTE OF
INDUSTRIAL ECONOMICS

IFN Working Paper No. 738, 2008

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Fines, Leniency and Rewards in Antitrust: an Experiment*

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6th August 2009

Abstract

This paper reports results from an experiment studying how fines, leniency programs and reward schemes for whistleblowers affect cartel formation and prices. Antitrust without leniency reduces cartel formation, but increases cartel prices: subjects use costly fines as (altruistic) punishments. Leniency further increases deterrence, but stabilizes surviving cartels: subjects appear to anticipate harsher times after defections as leniency reduces recidivism and lowers post-conviction prices. With rewards, cartels are reported systematically and prices finally fall. If a ringleader is excluded from leniency, deterrence is unaffected but prices grow. Differences between treatments in Stockholm and Rome suggest culture may affect optimal law enforcement.

JEL codes: C73, C92 and L41

Key words: Cartels, Collusion, Coordination, Competition policy, Deterrence, Desistance, Law enforcement, Price-fixing, Punishment, Recidivism, Whistleblowers.

*Many thanks to Martin Dufwenberg, Tore Ellingsen, Nisvan Erkal, Magnus Johanneson, Dorothea Kuebler, Joe Harrington, Nathan Miller, Hans-Theo Normann, Sander Onderstaal, Charles Plott, Patrick Rey, Maarten Pieter Schinkel, Adriaan Soetevent, Jean Tirole, and Julian Wright for discussions and advice related to this project, and to audiences in Alicante (IMEBE 2008), Amsterdam (ENABLE Conference), Berlin (ESMT, and WZB), Boston (IIOC 2009), Copenhagen (U. of Copenhagen), Crete (CRESSE 2009), Frankfurt, Gerzensee (ESSET 2007), Gothenburg (NWBEE 2008), Mannheim (RNIC 2007), Norwich (UEA-CCP), Rome (Tor Vergata and EIEF), Toulouse, San Francisco (IOS-ASSA Meeting 2009), Singapore, Stockholm (Ifn, Stockholm School of Economics and Konkurrensverket), and Naples (U. Federico II) for comments and suggestions. We also gratefully acknowledge research funding from Konkurrensverket (the Swedish Competition Authority) that made this research possible.

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1 Introduction

The last decades have brought a major innovation in antitrust law enforcement. In most OECD countries, leniency policies – schemes that reduce sanctions for self-reporting cartel members – are now the main tool for discovering and prosecuting cartels.[1] These policies are considered hugely successful, having increased dramatically the number of detected and convicted cartels. Yet, higher numbers of detected and convicted cartels alone are not necessarily good indicators of success.[2] Since competition policy's main objective is increasing welfare, ideally a successful policy should reduce cartel formation and prices rather than increase convictions.

Compared to many other criminal activities, the deterrence effects of antitrust policies are particularly difficult to evaluate because the population of cartels and changes in it are unobservable. Recent indirect methods developed by Miller (2009) and Harrington and Chang (forthcoming) address this problem, identifying empirically the likely effects of new antitrust policies using only changes in observables (such as the number of detected cartels or their duration).[3] Although highly valuable, these methods have limitations. They can only estimate the effects of policies actually implemented, not those of the many available alternatives, and they focus on cartel formation rather than on welfare. As argued by Whinston (2006), the relationship between communication in cartels and prices is not yet fully understood, hence the presumption that reduced cartel formation feeds back into lower prices and higher welfare cannot be taken entirely for granted.[4]

These features of antitrust law enforcement make laboratory experiments particularly valuable. Experiments have obvious limitations with firms represented by students who compete in highly stylized environments. Still, experiments allow us to observe policy induced changes, both in the population of cartels and in prices, and to test different policy designs.

This paper presents results from an experiment we designed to analyze the deterrence and price effects of different antitrust policies. Subjects play a repeated differentiated goods Bertrand duopoly game and can decide, before choosing prices, whether to form a cartel by communicating on prices. Treatments differ in the presence of a cartel prohibition with positive expected fines for infringers, and in the possibility of obtaining either

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

[2] For example, an extremely lenient policy with substantial fine reductions to all cartel members may produce many leniency applications and greatly facilitate prosecution, but harm society by encouraging cartel formation and increasing prosecution costs.

[3] See also Brenner (2009). 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 also Sproul (1993) who finds in a sample of US cases that prices increased weakly after antitrust conviction; and McCutcheon (1997) who suggests that antitrust fines may stabilize collusive agreements by preventing agreements' renegotiation, but not their formation.

leniency or a reward following a report. Most crucially – and unlike in previous works – subjects can self-report both before and after price choices become public information.

The main questions we ask are: How do monetary fines with and without leniency or rewards for self-reporting whistleblowers affect cartel formation (deterrence), stability/break down (desistance), and recidivism? What are these policies' effects on prices (welfare), both inside and outside cartels, and after cartels are dismantled? Does it matter if self-reporting is possible before price choices (and hence defections) become public, as is typically the case in reality? Are leniency applications used as opportunities to defect and abandon cartels, as instruments to punish defectors and stabilize cartels, or both? And do things improve when the ringleader is banned from leniency as under US rules?

Antitrust laws without leniency, as captured by fines following successful investigations, turn out to have a significant deterrence effect – the number of cartels is reduced. But they also produce a sizable pro-collusive effect – cartel prices increase. Leniency programs exacerbate these effects, further reducing cartel formation rates at the expense of even higher cartel prices. Contrary to previous findings, in our study prices on average do not fall with leniency, as they do in a 'laissez faire' regime in which antitrust laws are not enforced publicly (although cartel agreements are not legally enforceable). Absent leniency, the net welfare effect of antitrust even appears to be negative, since prices on average increase relative to the laissez faire regime.

The only welfare enhancing policy turns out to be giving rewards for whistleblowers, financed by the fines paid by competitors. Although cartels still form, they are reported systematically, which disrupts the subjects' ability to sustain high prices. Then prices fall substantially and approximate competitive levels.

The focus of current antitrust practice is deterring explicit cartel formation. But our results seem to give weight to the concern that deterrence may not be enough to feed back into low prices, the goal of competition policy. The results also suggest that Miller's (2009) important finding, that the US Corporate Leniency Policy probably reduced cartel formation, may not yet mean that the policy was welfare-increasing.

The higher cartel prices with antitrust enforcement call for an explanation. We explore several possible ones, including selection and coordination effects. Policies with and without leniency appear to operate quite differently. Without leniency, the possibility of using reports and fines as punishments against defectors appears to drive the high cartel prices. Indeed, the effect disappears when we run an additional treatment with fines but without the possibility of self-reporting. And when we run a treatment re-matching subjects in each period with a different opponent, the use of costly reports as punishments increases further, suggesting that the punishments are 'altruistic' in the sense of Fehr and Gächter (2002).

On the contrary, the positive effect of leniency on cartel prices cannot be driven by the use of reports as punishments. Defecting subjects simultaneously self-reported, effectively hindering the use of such punishments. Nor do we find that this effect is driven mainly by a selection of 'types' or by improved coordination. Rather it is consistent with an 'enforcement effect': subjects appear to anticipate that, after defecting (and reporting) under leniency, the opponent suffers so much that the cartel is rarely re-formed. Subjects' post-conviction behavior reveals a significant ex post deterrence (desistance) effect of antitrust enforcement, as cartels do not re-form for several periods after being dismantled. This effect becomes much stronger under leniency when the cartel is detected because one party defected and self-reported. Then, the cartel is almost never reformed, so that leniency greatly reduces recidivism in our experiment, contrary to previous findings. And post-conviction prices on average are significantly lower after conviction than before, particularly with leniency.

We also find that the deterrence effect of leniency is unaffected but prices increase if the ringleader is excluded from the leniency program, as in the US case. And that treatments in Stockholm and Rome differ substantially, suggesting that optimal law enforcement may differ across cultures.

Related Literature The theoretical literature on leniency policies in antitrust, initiated by Motta and Polo (2003) and surveyed in Rey (2003) and Spagnolo (2008), has shown that these policies can be very effective in deterring and destabilizing cartels, but also that they can be used strategically by wrongdoers, for example to punish defections and stabilize cartels. Many issues remain open therefore for empirical and experimental research. We mentioned earlier the important recent empirical studies by Miller (2009) and Brenner (forthcoming), as well as their limited ability to observe prices and to evaluate policies that have not actually been implemented. Experiments are useful in this regard, and we are not the first to use them in this area. We build in particular on the work of Apesteguia, Dufwenberg and Selten (2007) and Hinloopen and Soetevent (2008), henceforth "ADS" and "HS", extending it along several dimensions and investigating un-explored issues important to the design and implementation of antitrust policy.[5]

ADS develop and implement in the lab a stylized theoretical framework. 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 afterwards if communication took place. They test four legal frameworks: *Ideal*, in which cartels are impossible (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 self-reporting firms receive a fine reduction; and *Bonus*, in which they are rewarded with a share of the fines paid by other firms. Subgame perfect collusive equilibria (including the monopoly outcome) exist in *Standard* and *Le-*

[5]There are, of course, many previous experimental studies of price competition that do not focus on the antitrust issues we analyze. See Holt (1995) for a review.

niency, sustained by the credible threat of self-reporting after a price defection;[6] in *Ideal* and *Bonus*, 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 than without. Surprisigly, their results are inconsistent with the theoretical prediction that rewarding whistleblowers further increases deterrence. Our experiment differs from this pioneering study in many ways, including the dynamic approach, the scope for learning, the possibility to self-report both before and after price choices, and the inclusion of fines that are fixed both to account for fixed components of real antitrust fines and to eliminate uncertainty about their size. Our results confirm the observations of a perverse effect of standard antitrust on prices, and of an ambiguous effect of bonuses on deterrence. On the other hand, we find that leniency performs poorly in our dynamic experiment, and that rewarding whistleblowers is the only policy that ultimately reduces prices and improves welfare.

HS implement a repeated version of ADS's game (but for bonuses) in which subjects are matched into the same group of three throughout the experiment. They find that leniency reduces cartel formation and prices, and destabilizes non-deterred cartels (cartel members defect more often and more aggressively), but does not reduce cartel recidivism compared to standard antitrust. On these issues we find instead that leniency does not reduce prices, stabilizes surviving cartels, and substantially reduces cartel recidivism. Our experiment, besides dealing with several different issues, also differs a lot in the design, which justifies the very different results on the overlapping issues. Most crucially, in our experiment subjects can self-report both before price choices are observed by other subjects, and after. This possibility activates a deterrence channel – defections become more profitable under leniency – considered crucial by theorists and practitioners.[7] It also allows us to disentangle and quantify reports linked to defections and to punishments.[8]

We are aware of two other previous experimental studies dealing with similar issues, albeit in quite different environments. Hamaguchi et al. (forthcoming) perform an experiment where subjects are forced to collude, and look at the effects of leniency in terms of the speed with which cartels are dismantled. Such a framework cannot address the

[6]The threat of self-reporting to punish a price deviation is also credible in *Standard* because the competitors of the defecting firm face no cost of self-reporting; fines are a fraction of revenues, which equal zero in a homogeneous Bertrand game.

[7]This deterrence channel was named 'protection from fines effect' in Spagnolo (2004) and 'deviator amnesty effect' in Harrington (2008). Absent the possibility to report *before* prices are disclosed, reports are likely to work mainly as credible punishments under leniency, as highlighted by Spagnolo (2000) and Ellis and Wilson (2001).

[8]Other differences with HS are that in our set up self-reporting is possible even absent leniency; that our experiment is framed as ADS's; that fines are fixed to control for expectations; that subjects compete in duopolies rather than in triopolies so that they do not refrain from punishing defectors out of reluctance to harm a third 'innocent' party (as suggested by Holt, 1995); and that our subjects are re-matched in every period with a constant probability, so that they face a constant continuation probability (as in Dal Bó, 2005; Dal Bó and Frechette, 2008), which also allows us to study in detail the differences between ex ante and post conviction deterrence.

question of how different policies perform with respect to cartel formation and prices, the core issue in our study. Hamaguchi et al. (2007) study the effects of leniency in a repeated game but focussing on procurement, so that the stage game is an auction game in which colluding players have to decide who will win the auction. They find evidence of deterrence effects with leniency programs, and some evidence of higher prices under leniency and antitrust that seem to square well with our results for oligopolies.[9]

The paper is organized as follows. The next section describes the experimental design. Section 3 presents some theoretical predictions, which serve as a benchmark for our analysis. Section 4 discusses the empirical strategy. Section 5 presents our main results on deterrence and prices, and Section 6 tries to identify their sources. Section 7 discusses extensions, and Section 8 concludes. An appendix complements the paper, containing in particular instructions for the leniency treatment.

2 Experimental Design

In our experiment, each subject represented a firm and played in anonymous two-person groups a repeated duopoly game. In every stage game, the subjects had to take three types of decisions. First, they had to decide whether or not to form a cartel by discussing prices. Second, they had to choose a price in a discrete Bertrand price game with differentiated goods.[10] Third, the subjects could choose to self-report their cartels to a competition authority. The attractiveness of this third opportunity depended on the details of the antitrust law enforcement institution, which were the treatment variables in 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.)

[9] After our work other experimental studies have been performed in various environments, some of which confirm our finding that law enforcement policies based on leniency may have perverse effects on market prices (see e.g. Hinloopen and Onderstal 2009, again in the quite different context of auctions with different formats) or on the stability of illegal agreements (see e.g. Krajkova and Ortmann 2009a,b in a corruption framework).

[10] We adopt differentiated goods Bertrand competition because we find it more intuitive and realistic for studying price-fixing agreements than Cournot, and to avoid that leniency applications could be inflated by the strong 'revenge' incentives the homogeneous good Bertrand model may generate given the extreme costs incurred by a subject when facing any price deviation.

		your competitor's price												
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
	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
your price	**6**	0	0	0	0	53	107	160	213	267	288	288	288	288
	7	0	0	0	0	0	47	109	171	233	296	308	308	308
	8	0	0	0	0	0	0	36	107	178	249	320	320	320
	9	0	0	0	0	0	0	0	20	100	180	260	324	324
	10	0	0	0	0	0	0	0	0	0	89	178	267	320
	11	0	0	0	0	0	0	0	0	0	0	73	171	269
	12	0	0	0	0	0	0	0	0	0	0	0	53	160

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

The 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 the experiment, $a = 36$, $c = 0$ and $\gamma = 4/5$ and subjects' choice set was restricted $\{0, 2, ..., 22, 24\}$, yielding the payoff table. To simplify the table we 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 joint profit-maximizing 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 joint profit-maximizing 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 as well as associated losses for the cheated upon firm; in the range of prices $\{4, ..., 8\}$, these gains and losses are smaller than when a subject deviates unilaterally from the joint profit-maximizing 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, described in more detail below, was designed in a way to produce a common price on which to cooperate. The agreed price was non-binding so that subjects subsequently could undercut.

Whenever two subjects chose to communicate, they were considered to have formed a cartel. In this case, the subjects risked to being fined as long as the cartel had not been detected. Subjects could be fined therefore in a period even if no communication took place in that period, for example if they had communicated in the previous period without being detected. Once detected, a cartel was considered to be dismantled and in subsequent periods the former cartelists did not run risk being fined unless they communicated again.

2.3 Antitrust law enforcement (Treatments)

We ran four lead treatments corresponding to different legal frameworks and each subject participated in a single treatment, a *between subjects* design. Depending on the treatment, a competition authority could detect cartels and convict its members for price fixing. Detection could occur in two ways. First, cartel members could self-report their cartel. In this case the cartel members were convicted for price fixing with certainty and if so, the size of the fine depended on the treatment. Second, non-reported cartels were in every period detected with an exogenous probability, α, and, if detected, both cartel members had to pay an exogenous fine, F.

The lead treatments are summarized in Table 2. The baseline treatment, L-Faire, corresponded to a laissez faire regime: in this treatment, $\alpha = F = 0$ so that forming a cartel by discussing prices was legal. To simplify the instructions and to eliminate irrelevant alternatives, subjects were not allowed to report cartels. In the three other treatments, Fine, Leniency, and Reward, the expected fine (given no reporting) was strictly positive ($\alpha = 0.1$ and $F = 200$ yielding an expected fine $\alpha F = 20$) and cartel members were allowed to report their cartel. Fine corresponded to traditional antitrust laws without leniency: if a report took place, both cartel members (including the reporting one) had to pay the full fine F. Leniency corresponded to antitrust laws embedded with leniency: if the cartel was reported by one cartel member only, the reporting member paid no fine while the other paid the full fine, F; if instead both cartel members reported the cartel simultaneously, both paid a reduced fine equal to $F/2$. Finally, Reward differed from Leniency in one respect only: if only one cartel member reported the cartel, he/she paid no fine and was rewarded with the full fine, F, paid by the other cartel member.

In addition we ran three other treatments, NoReport, ReMatch and RingLeader, which we review further below.

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)
Reward	200	0.10	Yes	reward (half the fine if both report)

Figure 1: Timing of the stage game

2.4 Timing and rematching procedure

At the end of each period, subjects were rematched with the same competitor with a probability of 85%. With the remaining probability of 15%, all subjects were randomly matched into new pairs. If so, subjects could no longer be fined for cartels formed in the previous match. After the first 20 periods, if the 15% probability event took place there was no more rematch, and the experiment ended. The subjects were also informed that the experiment would end as well if it lasted for more than 2 and 1/2 hours. This latter possibility was unlikely and did not occur. This re-matching procedure minimized problems with end game effects, pinned down subjects' expectations on the duration of matches for all contingencies, and allowed us to distinguish ex ante deterrence (communication decisions prior to the first time two subjects communicated) from post conviction deterrence (communication decisions after a first cartel was convicted).

2.5 The timing of the stage game

With the exception of L-Faire, a stage game consisted of 7 steps. In L-Faire, steps 4, 5 and 6 were skipped. 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 30 seconds before pricing decisions were taken in Step 3. In all periods, subjects were also informed whether or not a re-match had taken place.

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

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

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

Step 5: Market prices and public reports. Subjects learned the competitor's price choice. If communication took place in the current period or in one of the previous periods without being discovered and no one reported it in step 4, subjects had a new opportunity to report the cartel. The crucial difference between this 'public' report and the secret one is that 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/reward.

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

Step 7: Summary of the current period. At the end of each period, all the relevant information about the stage game was displayed: the agreed upon price (if any), prices chosen by the two players, possible fines and net profits. When players were fined, they were also told how many players reported. This step lasted 20 seconds.

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). Sessions lasted on average 2 hours, including instructions and payment. The average payment was: (*i*) in Stockholm Euros 26.14, with a minimum of 12.54 and a maximum of 42.51 and (*ii*) in Rome Euros 24.22 with a minimum of 16.5 and a maximum of 31.5.[11] In every session we ran one treatment; the number of subjects per session ranged from 16 to 32, and the total number of subjects was 390. Details about each session including the number of subjects, when and where they were conducted as well as the number of periods and matches are reported in Appendix A.3.

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

The experiment was programmed and conducted using z-tree (Fischbacher, 2007). Subjects were welcomed in the lab and seated, each in front of a computer. They received a printed version of the instructions and the profit table. Instructions were read aloud to ensure common knowledge of the rules of the game. We then asked the subjects to read the instructions on their own and ask questions, which were answered privately. When everyone had read the instructions and there were no more questions (in each session, after about fifteen minutes), each subject was randomly matched with another subject for five trial periods. After these trial periods, participants had a final opportunity to ask questions. Then subjects 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, an event that never occurred. 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 (50 Swedish kronor in Stockholm). The conversion rate was 200 points for 1 Euro (10 Swedish kronor in Stockholm).

3 Theoretical predictions and hypotheses

Our experimental design implements a discounted repeated (uncertain horizon) price game embedded in different antitrust law enforcement institutions.

Much of the theory on repeated oligopoly may be interpreted to suggest that antitrust law enforcement should not matter: subjects should collude tacitly and reap the gains from collusion without running the risk of being convicted. This conclusion is invalid if pre-play communication (cartel formation in our context) enhances subjects' ability to coordinate and charge high prices, as experimental evidence strongly suggests (see e.g. Crawford 1998). The simple equilibrium analysis below, therefore, presumes cartel formation to be a prerequisite for successful collusion.

Our purpose here is to describe how the different policies in our experiment are intended to work in reality and to reach sensible testable hypothesys, not to derive the whole equilibrium set.

3.1 A simple equilibrium analysis

The joint profit-maximizing price can be supported as an equilibrium outcome in our four lead treatments (see Appendix A.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, two necessary conditions for the existence of a collusive equilibrium, provide valuable insights about the possible effects of law enforcement institutions. These constraints are tighter in some treatments, and under the standard assumption that tighter equilibrium conditions make it harder to sustain the equilibrium, they should also increase deterrence. Combined with the assumption that cartel formation pushes up prices, tighter equilibrium conditions should also reduce average prices.

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.

The IC-constraint states that sticking to an agreement is preferred over a unilateral price deviation followed by a punishment. We focus on standard punishments carried out through some form of 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) not to report on the collusive path and (iii) not to be re-formed when they have been dismantled following a price deviation. This last assumption implies that the present value in the beginning of the punishment phase (net of potential fine payments), V^p, can be viewed as being generated by optimal symmetric punishments (conditional on the restrictions imposed by the other assumptions).[12] Alternatively, V^p can be viewed as resulting from some weaker form of punishment, which by assumption is the same across treatments.

The IC-constraints can then be expressed as:

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

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

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

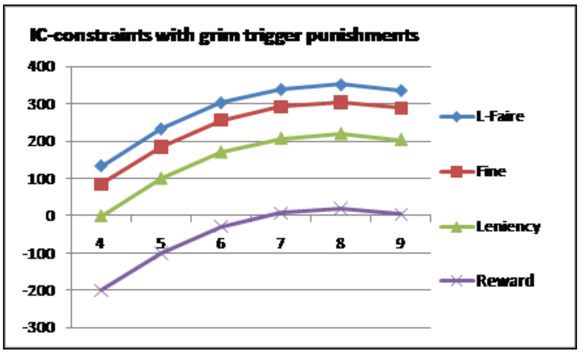
$$\frac{\pi^c - \alpha F}{1-\delta} \geq \pi^d + R + \delta V^p, \tag{IC-Reward}$$

where π^c denotes the per period profits on the collusive path, π^d the deviation profit, δ the common discount factor, α the probability of detection, F the fine, R the reward and V^p the present value in the beginning of the punishment phase (net of potential fine

[12] The assumption is not innocuous. Presumably it holds if the punishment is carried out through a grim trigger strategy. By contrast a stick and carrot type of punishment probably requires cartels to be formed during the "carrot" phase, and possibly also during the "stick" phase. Relaxing the assumption would alter the analysis in two ways. First, it would strengthen the punishment in the policy treatments (but not in L-Faire) as subjects run the risk of being fined also on the punishment path. Second, it would affect the scope for punishing defectors, particularly in Leniency and even more so in Reward, as the deviation incentives (from the punishment path) are exacerbated by the possibility to report. A formal treatment of these complicating factors is beyond the scope of this experimental paper.

payments). 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 re-formed on the punishment path. Clearly the IC-constraints are (i) tighter in REWARD than in LENIENCY (since the incentives to deviate in REWARD are stronger due to the reward, R), (ii) tighter in LENIENCY than in FINE (since a deviation combined with a secret report provides 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 the incentives to stick to the agreement more than they reduce the incentives to deviate, $\alpha F/(1-\delta) > \alpha F/(1-(1-\alpha)\delta)$).

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 collude in all treatments on the joint profit-maximizing price – the price relaxing the P-constraint the most. Alternatively, subjects may collude on the collusive price that minimizes the incentives to deviate – the price relaxing the IC-constraint the most. This price is the same across treatments provided V^p is the same across treatments, as is illustrated in Figure 3.1 where collusion is sustained through grim trigger strategies. The horizontal axis represents the collusive price and the vertical axis the IC-constraint. The figure illustrates the previous ranking of treatments: for the same collusive price, the IC-constraint is most relaxed in L-FAIRE followed in order of magnitude by FINE, LENIENCY and REWARD. It also suggests that subjects may collude in all treatments on the same price, 8, the price minimizing deviation incentives.[13]



3.2 Hypotheses

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

[13]The IC-constraints are invertly 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.

are highest in L-Faire, followed in order of magnitude by Fine, Leniency and Reward.

The previous analysis implicitly presumes subjects to be risk neutral and fully rational, perfectly able to coordinate on any proposed equilibrium when communicating, and motivated only by monetary payoffs. None of these assumptions is realistic: subjects are likely both to undercut the agreed upon price and to report, and therefore differences across treatments in terms of cartel stability, cartel detection, cartel prices and so on are likely to arise. Still, the above equilibrium analysis highlights costs and benefits associated with price deviations and reports (even though it fails to predict such actions). As such it offers a valuable starting point for stating plausible hypotheses about subjects' behaviour which, strictly speaking, is inconsistent with the analysis.

Optimal price deviations are combined with secret reports in Leniency and Reward, in effect hindering the use of public reports as a punishment against defectors. In Fine, both secret and public reports are costly. These incentives suggest the next hypothesis.

Hypothesis 2 (secret and public reports) Price deviations are combined with secret reports in Leniency and Reward, but not in Fine. Public reports are used in none of the treatments.

Tighter IC-constraints may not only affect cartel formation but also cartel stability. Since the incentives to stick to a collusive agreement are weaker 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 also may affect cartel prices: all else equal, cartel prices should be higher in treatments with low rates of price deviations. Finally, agreed upon prices also may be higher in treatments with stable cartels; if cartels are re-formed 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 magnitude by Fine, Leniency and Reward.

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 relating to cartel stability thus also suggests the following hypothesis.

Hypothesis 4 (cartel detection) Cartels are detected most frequently in Reward, followed in order of magnitude by Leniency and Fine.

Secret reports may generate distrust and thereby increase ex post deterrence. Trust destruction following secret reports motivates our final hypothesis.

Hypothesis 5 (cartel recidivism) Convicted cartels are re-formed earlier in FINE than in LENIENCY and REWARD.

Finally, note that standard equilibrium analysis fails to account for the risk of being cheated upon.[14] A perceived risk of price deviations and reports is likely to affect deterrence levels and cartel stability in all treatments. Yet this risk does not necessarily weaken the statements in Hypotheses 1, 3, 4 and 5. Due to the risk of being fined following a secret report by a rival, the cost of being cheated upon is largest in LENIENCY and REWARD. Thus one may expect higher deterrence levels primarily in LENIENCY and REWARD. Similarly, deviation incentives may be exacerbated primarily in LENIENCY and REWARD, since a price deviation combined with a secret report (at least partially) protects against the risk of being fined after a competitor's report. (In a companion paper, Bigoni et al. (2008), we attempt to quantify how this risk affects cooperation/collusion.)

4 Data and empirical methodology

In each period, subjects had to take up to four types of decisions: (i) decide whether or not to communicate, (ii) determine an agreed upon price, (iii) choose a price and (iv) decide whether or not to report a cartel. These decisions yielded individual or duopoly-level data. For example, observations of a cartel being formed or being detected are duopoly-level data because they are identical for subjects belonging to the same duopoly. An attempt to communicate or a decision to undercut an agreed upon price are examples of individual level data.

The main challenge for testing differences across treatments lies in accounting for correlations between observations from the same individual, or from different individuals belonging to the same duopoly. In addition, the tests must also account for correlations among observations that result from potential session or cultural effects. To address this issue, we adopt multilevel random effect models. The following four- and five-level models are used to account for correlations between observations generated within the same duopoly:

$$
\begin{aligned}
y_{pdsc} &= \beta_0 + \beta_1 TREAT_{pdsc} + \eta^{(2)}_{dsc} + \eta^{(3)}_{sc} + \eta^{(4)}_{c}, \\
y_{pidsc} &= \beta_0 + \beta_1 TREAT_{pidsc} + \eta^{(2)}_{idsc} + \eta^{(3)}_{dsc} + \eta^{(4)}_{sc} + \eta^{(5)}_{c}.
\end{aligned}
$$

The four-level model uses only duopoly-level data. A measurement occasion, p (one for each period), is nested in a specific duopoly, d, which in turn is nested in a session, s, and

[14] The experimental evidence by Dal Bó and Fréchette (2008) and Blonski et al. (2008) suggests that the risk of being cheated upon and its cost are important in infinitely repeated prisoners' dilemma games.

a city, c. $TREAT$ is a treatment dummy variable and equals 1 for one of the treatments and 0 for the other. $\eta^{(2)}_{dsc}$ is the second-level random intercept common to observations belonging to the same duopoly d in session s and in city c, $\eta^{(3)}_{sc}$ the third-level random intercept common to observations from the same session s in city c and $\eta^{(4)}_{c}$ the fourth-level random intercept common to observations from the same city c. Random intercepts are assumed to be independently normally distributed with a variance estimated through our regression. The five-level model uses individual level data instead, so that there are two observations per period in a specific duopoly, one for each subject i in a duopoly.[15]

This model accounts for potential correlations among observations from the same duopoly. Observations from different duopolies may also be correlated however, because subjects participated in several duopolies. To address this problem, we also run several regressions using a single observation per individual and duopoly, adopting the following-four level random effect model:

$$y_{djsc} = \beta_0 + \beta_1 TREAT_{djsc} + \eta^{(2)}_{jsc} + \eta^{(3)}_{sc} + \eta^{(4)}_{c}.$$

In this case, a measurement occasion, d (one per subject and duopoly), is nested in a specific subject, j, which in turn is nested in a session, s, and a city, c. Note that this model does not account for possible correlations among (the two) observations belonging to the same duopoly. For this reason, we use only observations within a duopoly that can (reasonably) be viewed as independent. For example, as a measure for deterrence, we use only subjects' decision to attempt to communicate in the first period in a match. Similarly, as a measure for cartel prices, we use only the prices charged in the periods when two subjects communicated for the first time. These regressions can be viewed as a robustness check. In some cases, however, they also test for something different than when more observations from the same match are used. For example, using only subjects' attempts to communicate during the first period in a match in effect tests for *ex ante* deterrence only.

We run logit regressions to analyze the decisions to communicate and deviate and to test for the rates of cartel formation and detection, adopting instead linear regressions for prices and agreed upon prices. To estimate our models we use the GLLAMM commands in Stata (see Rabe-Hesketh and Skrondal, 2004 and http://www.gllamm.org).

[15] Adding a level substantially increases the time needed to run a regression. For this reason, we transform some individual level data into duopoly-level data. Specifically, we transform the individual price data into duopoly-level data by taking the average price charged by two subjects in a given period and duopoly as a single observation.

5 Main experimental results

The success of our experiment hinges to a large extent on two factors. First, consistently with existing experimental evidence, pre-play communication enhances subjects' ability to coordinate (see the survey by Crawford, 1998), cartel formation should lead subjects to charge high prices. It is not surprising that our experiment validates this finding.

Second, the experiment works if subjects understand the incentives linked to self-reporting. Table 3 presents the rates of secret reports (given an own price deviation) and of public reports (provided only the rival deviated without reporting simultaneously) in Fine, Leniency and Reward. As expected, subjects almost never used secret reports in Fine, while in Leniency and Reward price deviations usually were optimally combined with secret reports.[16]

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 explore more about the motive behind these costly reports in Section 6.3.1. The rates of public reports in Leniency and Reward also are 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 jeopardizing future cooperation. 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

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 (actual communication) provided that subjects are not already cartel members. The requirement that cartels are not formed is important; in effect an attempt at communicating is an attempt at forming a cartel, and not merely a decision to communicate at no cost. The table also reports the rates of communication attempts during the first period in a match – a measure of *ex ante* deterrence, which also has the advantage of being insensitive to the (random) length of matches.

[16] 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 five first periods and exceeded 0.9 (equaled 1) over the five last periods.

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. (1st period)	0.925	$>^{***}$	0.684	$\approx$	0.437	$<^{*}$	0.481
Rate of reporting	–	–	0.092	$<^{***}$	0.507	$<^{***}$	0.937
Rate of reporting (1st 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 **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 a cartel was formed in that period. The **Rates of reporting** are computed provided that a cartel was formed, using a single observation per duopoly and period, indicating if a cartel was detected in that period because one or both subjects reported the cartel. The **Rates of reporting** during the first period two subjects communicated in a match are computed using the reporting decisions of each subject as a single observation. The differences across treatments are tested using multilevel random intercept logit regressions, as outlined in Section 4.

Result 1 reflects that the rates of communication attempts and of cartel formation are significantly lower in Fine, and even lower in Leniency, than in L-Faire. These deterrence effects are consistent with the experimental findings in ADS and HS. Interestingly, Leniency reduced the cartel formation rate by 47% relative to Fine, a reduction of roughly the same size as Miller's (2009) estimate of 52%.

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 ADS, 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, based either on reporting decisions in all periods a cartel was formed, or during the first period two subjects communicated. Both measures yield 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 given 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 to report, managing to collude successfully for the seven remaining periods of the match. In principle, the subjects could exploit the reward system by taking turns in reporting and cashing in the reward.[17] 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 ADS would be validated in our sample if subjects systematically combined reports with price deviations. We return to this issue when we discuss price deviation rates. Finally note that Result 2 is qualitatively consistent with Miller's (2009) empirical finding that leniency programs increase detection rates by 62%, although we observe even higher increases, and with the increased detection rate of 50% observed in ADS'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 was not formed. This pattern suggests that cartel detection may have affected subjects' decisions to re-form a cartel. Figure 2 shows for Fine, Leniency and Reward the cumulative percentage of cartels (vertical axis) re-formed by convicted subjects in the five periods following the conviction (horizontal axis). The plots underestimate this percentage number of re-formed cartels, since some matches ended before the five periods after the conviction occurred. Still, the data tells us quite a lot.

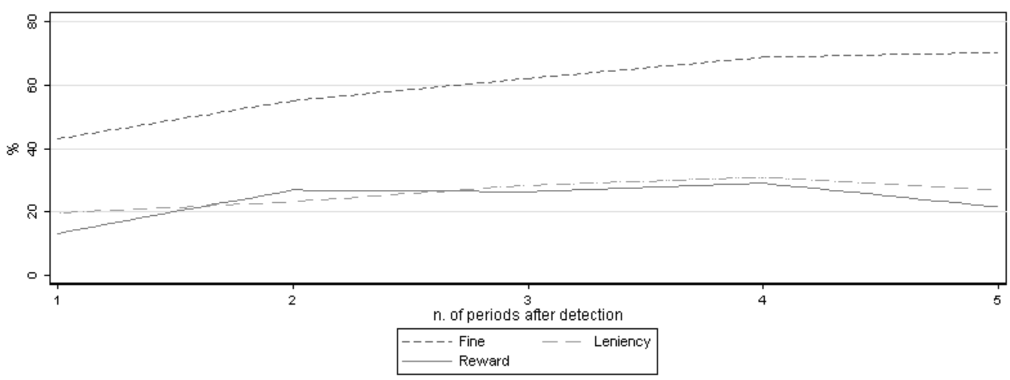


Figure 2: % of cartels re-established

First, history of play matters, since a large fraction of cartels are not re-formed after conviction even though the subjects faced the same expected fine, available actions and

[17]The reward scheme is exploitable in the sense that the expected fine is 0 if cartel members take turns in self-reporting and cashing in the reward. Some practitioners have raised concerns that reward schemes could be exploited, although it is well known that it is always possible to design them non-exploitable by keeping rewards substantially below the sum of fines paid by other wrongdoers (see e.g. Spagnolo, 2004).

payoff functions after the conviction as before the convicted cartel was formed. Second, ex post deterrence in LENIENCY and REWARD is higher than in FINE: close to 40% of convicted cartels are re-formed immediately in FINE, but not in LENIENCY and REWARD.

Result 3 (Cartel recidivism) Leniency and Reward significantly reduce cartel recidivism.

Result 3 contrasts with HS who found no reduction in cartel recidivism 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's share of convictions in LENIENCY and REWARD were due to secret reports. Such reports are likely to generate substantially more distrust than would a discovery by the competition authority, reducing subjects' willingness to re-form 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 price levels on average as well as average prices within and outside cartels and average agreed upon prices. 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, prices are higher within cartels than outside them. 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).

Result 4 (Average prices) Prices are on average highest in FINE and only REWARD reduces prices relative to L-FAIRE.

Average prices are almost the same in LENIENCY as in L-FAIRE and are significantly higher in FINE. Thus in our experiment LENIENCY does not improve welfare relative to L-FAIRE, and FINE even appears to reduce it. The only welfare enhancing policy appears to be REWARD. Interestingly, our finding that average prices in FINE are significantly higher than in LENIENCY is consistent with ADS. This may be surprising since reporting is costly in FINE, whereas in ADS's *Standard* treatment fines were costless for cheated upon subjects (since cheated upon subjects had no revenues).

The fact that average prices did not fall in FINE and LENIENCY is also surprising in view of the deterrence effects associated with these policies. The prices charged within cartels are the main explanation for why average prices did not drop in FINE and LENIENCY.

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

	L-Faire		Fine		Leniency		Reward
Average price	4.917	$<^{*}$	5.349	$>^{***}$	4.845	$>^{*}$	3.973
Cartel price	4.971	$<^{***}$	6.144	$<^{***}$	7.024	$>^{***}$	5.339
Prices outside cartels	3.5	$<^{**}$	4.233	$\approx$	4.063	$\approx$	3.567
Agreed upon price	7.689	$<^{***}$	8.242	$\approx$	8.218	$\approx$	8.512
Rate of price dev.	0.564	$>^{***}$	0.424	$\approx$	0.373	$<^{***}$	0.782
Cartel price (1^{st} comm.)	5.929	$<^{***}$	6.990	$>^{***}$	6.663	$>^{***}$	5.483
Agreed upon price (1^{st} comm.)	7.881	$<^{***}$	8.129	$>^{*}$	7.886	$\approx$	8.100
Rate of price dev. (1^{st} comm.)	0.590	$>^{***}$	0.408	$\approx$	0.443	$<^{***}$	0.717

Note: the point estimates for the different price measures are computed using the average among the prices chosen in a period by the two members of a duopoly. **Average prices** are computed using all observations, whereas **average prices within (outside) cartels** only uses observations when a cartel is formed (not formed). **Average agreed upon prices** are computed using observations when subjects actually communicated. To test for differences across treatments, we run multi-level random intercept linear regressions as outlined in Section 4. The average **cartel price** during the periods when two subjects communicated for the first time is computed and tested using individual price data. The **Rates of price deviations** are computed using the binary individual decisions to undercut the last agreed upon price, provided that no subject has not yet undercutted that price. Differences across treatments are tested using a five level random intercept logit regressions, as outlined in Section 4. We also check the robustness of our results using only observations from the first period two subjects communicated. In this case we run four level random intercept logit regressions, as outlined in Section 4.

Result 5 (Cartel prices) FINE and even more so LENIENCY significantly increase cartel prices.

Note also that the price levels for non cartel members appear to be higher in FINE and LENIENCY than in L-FAIRE. Thus the prices charged outside cartels also contributed to the high average prices in FINE and LENIENCY.[18] 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 rates of price deviations reported in Table 5.

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

The very high rate of price deviations in REWARD shows that the reward scheme was not exploited. In fact, no pair of subjects appears to have realized the opportunity to take turns in reporting.[19] Rather, subjects formed cartels with the intent of fooling the

[18] Since cartels were almost formed systematically in L-FAIRE, this is not the main explanation for the high average prices in FINE and LENIENCY.

[19] This is consistent with Dal Bo's (2005) finding that efficient asymmetric (alternating) equilibria in a repeated prisoners' dilemma game are never played in the lab. This could change, of course, if subjects had available more open forms of communication than in our experiment, an interesting subject for future work.

competitor by simultaneously undercutting the agreed upon price and reporting 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 and after conviction (conviction takes place at time 0), separately for the subjects that re-formed and did not re-form 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 rising gradually in Fine, (d) post-conviction prices are higher in Fine than in Leniency and Reward when the convicted cartel is not re-formed and finally (e) post-conviction prices are higher in Fine and Leniency than in Reward when the convicted cartel is re-formed.

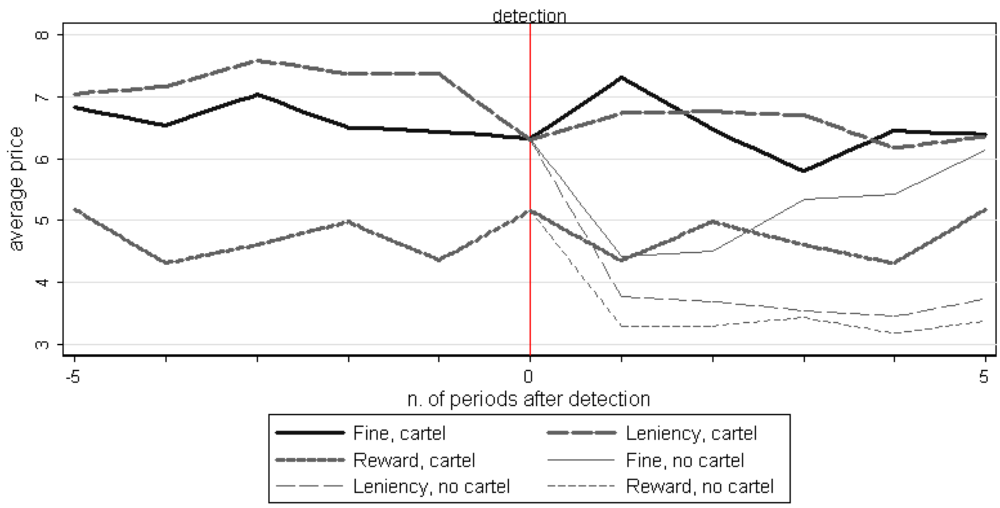


Figure 3: Price before and after detection

The difference arising between Leniency and Reward on the one hand, and Fine on the other, when convicted cartels are not reformed warrants more discussion (stylized fact d)). While the average price remains close to Bertrand in Leniency and Reward, it rises in Fine as if – after having formed an explicit cartel and having paid the fine – some of the subjects tried 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. Under Leniency the cartel is discovered because it is reported by the deviating player; therefore, post-conviction tacit collusion is more difficult to achieve.

6 Potential explanations for high cartel prices

Looking at the results, a clear picture emerges in Reward. As in ADS, most subjects formed cartels with the intent of fooling the competitor by simultaneously undercutting the agreed upon price and reporting 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 distrust. The lower level of trust reduced post-conviction cartel formation and prices, and weakened subjects' ability to collude tacitly. Reward reduced average prices relative to all other treatments emerging as the only welfare-improving policy.

Fine and Leniency did succeed in significantly lowering cartel formation rates, but were unsuccessful in reducing prices. The main reason appears to be that cartel prices increased significantly in both treatments relative to L-Faire. Several forces may have contributed to the high cartel prices in Fine and Leniency. Next we explore three potential explanations: selection, coordination and enforcement.

6.1 Selection

The jump in cartel prices in Fine and Leniency could be explained by a selection effect, whereby subjects with a preference for cheating were disproportionately more likely to be deterred when they faced a risk of being fined. To evaluate this hypothesis, subjects first must be partitioned into different categories, or types. We posit that subjects' choices during the first period they communicated (roughly) captures their preferences. Subjects are classified as Cooperators (Defectors) if they stuck to (undercut) the agreed upon price.[20] The remaining subjects (those who never formed a cartel, either because they consistently refused to communicate or were paired with subjects refusing to communicate) are classified as Non-Communicators.

This exogenous classification does not capture perfectly subjects' true preferences. Still, Table 6 suggests that it proxies these preferences in the sense that a subject's type roughly predicts decisions to stick to or to undercut agreed upon prices in periods following the one determining the subject's type. Indeed the Defectors' rates of price deviations are (almost) twice as large as the Cooperators'.[21]

A selection effect could materialize in different ways. Some Defectors may have been

[20] The more recent experimental literature on types elicits subjects' preferences (Fischbacher and Gächter, forthcoming), making a distinction between conditional and unconditional cooperators possible. We cannot accurately distinguish conditional from unconditional cooperators. Our set of Cooperators is thus likely to contain both types.

[21] These rates are computed using only observations from periods when two subjects communicated for the first time, provided these observations did not determine a subject's type (i.e. the observations from the first period a subject communicated are not used). Observations from other periods are not used, since a decision to undercut or not in periods following an initial price deviation may reflect a subjects' strategy rather than his or her preferences.

Table 6: **Price deviations across types**

	L-Faire	Fine	Leniency
Defectors	0.802	0.825	0.722
Cooperators	0.411	0.345	0.403

completely deterred, resulting in a greater proportion of Non-Communicators in Fine and Leniency relative to L-Faire at the expense of a decrease in the proportion of Defectors. Table 7 reports the proportion of Cooperators, Defectors and Non-Communicators across the three treatments. All subjects communicated at least once in L-Faire and only a few subjects were classified as Non-Communicators in Fine and Leniency. The striking difference between the treatments is rather that the proportion of Cooperators increased in both Fine and Leniency relative to L-Faire. This pattern is a first piece of evidence suggesting that a selection effect did not drive the high cartel prices in Fine and Leniency.

Alternatively, Defectors in Fine and Leniency may have formed cartels less frequently than Cooperators. Table 7 also reports the rates of communication attempts across types and treatments during the first period of a match. It reveals that Defectors were less likely to form cartels when faced by a risk of being fined. Still, the data give little support for a selection effect, since Cooperators also were less likely to form cartels. In Leniency, they were deterred (slightly) more frequently than Defectors. In Fine the data suggest the opposite, but nevertheless appear to be inconsistent with a selection effect. Defectors also were deterred more frequently than Cooperators in L-Faire and there the difference is larger.

Table 7: **Types and communication attempts**

	Fine	L-Faire	Leniency
Proportion of Cooperators	0.723	0.457	0.622
Proportion of Defectors	0.245	0.543	0.329
Proportion of Non-Communicators	0.032	0	0.049
Comm. att. by Cooperators (1^{st} per.)	0.715	0.984	0.434
Comm. att. by Defectors (1^{st} per.)	0.699	0.874	0.486

Bearing in mind the limitations of our subject classification, the above evidence suggests that the selection effect was not a main driver of the high cartel prices in Fine and Leniency.

6.2 Coordination

In experiments where subjects pay to participate in a game, e.g. in an auction, their ability to coordinate on more efficient outcomes appears substantially enhanced.[22] Offerman and Potters (2006) recently found an analogous effect in an experiment where licence auctions are followed by dynamic oligopolistic interaction. In our context, the risk of being fined in FINE and LENIENCY after communicating similarly may have worked as a coordination device, with subjects coordinating on higher collusive prices thanks to the additional expected cost of cartel formation. Alternatively, the risk of being fined may have facilitated coordination by transforming the initial communication stage from pure 'cheap talk' to possibly more effective 'costly talk'.[23]

If these kinds of coordination effects were important in our experiment, one would expect higher agreed upon prices in FINE and LENIENCY than in L-FAIRE. The agreed upon prices in Table 5, based on all observations when subjects actually communicated, provide some support for a coordination effect. Yet the low agreed upon prices in L-FAIRE may reflect only high deviation rates. Subjects perhaps attempted initially to coordinate on a high price also in L-FAIRE, then experienced frequent price deviations and, to reduce the temptation to cheat, subsequently attempted to collude on a lower price. The agreed upon prices in Table 5, based only on the periods when two subjects communicated for the first time, were less sensitive to this problem. These agreed upon prices were virtually the same in L-FAIRE and LENIENCY, suggesting that improved coordination was not driving the high cartel prices in LENIENCY. However, it may have contributed to the high cartel prices in FINE, since the agreed upon prices in that treatment were significantly higher than those in L-FAIRE.

6.3 Enforcement

The high cartel prices in FINE and LENIENCY could also be explained by some enforcement effect. Subjects may have refrained from undercutting agreed upon prices for fear of harsher punishments. The scope for punishing defectors differed in FINE and LENIENCY: since subjects in FINE had no incentives to (and did not) use secret reports, they had access to the public report as an additional instrument for punishing deviators. For this reason, we discuss potential enforcement effects separately for the two treatments.

[22] See e.g. Van Huyck and Battalio (1993) and Cachon and Camerer (1996). Crawford and Broseta (1998) showed that this effect is partly due to forward induction considerations, and partly to learning and other forces.

[23] The effects of costly communication on coordination and collusion has been investigated experimentally in Andersson et al. (2006) and Andersson and Wengstrom (2007), though with a very different take.

6.3.1 Enforcement effect in Fine

The fact that some subjects in FINE used public reports as punishments (see Table 3) suggests that the threat of such reports may have enforced high cartel prices.[24] At first glance one might dismiss public reports as non-credible, but in fact, punishments involving costly reports are optimal: any collusive price can be sustained in equilibrium for any discount factor. The reason 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 deviates unilaterally, then deviating is no longer profitable. Furthermore, 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. 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 constructed easily when the stage game is repeated infinitely (see Appendix A.2).

We ran an additional treatment, NOREPORT, to test the hypothesis that the threat of public reports enforced high cartel prices in FINE. NOREPORT was identical to FINE except for the missing reporting possibility. The cartel prices in NOREPORT should be low if the public reports enforced the high cartel prices in FINE. On average cartel prices were 5.031 in FINE and 3.553 in NOREPORT, and this difference is significant at the 1% level.[25]

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

Result 7 suggests that subjects may have perceived the public reports as a credible threat. But it does not explain us why. Were the subjects so sophisticated that they understood the structure of such optimal punishments? Or did they use public reports to punish "altruistically", as often observed in public good experiments (Fehr and Gächter; 2000, 2002) and suggested by recent findings in the field of Neuroeconomics (de Quervain et al., 2004)? To discriminate between these two hypotheses, and in line with Fehr and Gächter (2002), we ran an additional treatment, REMATCH. The only difference from FINE was that subjects were paired with a new rival in every period.[26] In REMATCH, public reports were not credible unless subjects used them altruistically. Provided that only one subject defected from the agreed upon price, the rates of public reports were higher in REMATCH (0.324) than in FINE (0.197).

[24] Dreber et al. (2009) implement experimentally a modified version of a repeated prisoners' dilemma where subjects can punish defectors. They find that "winners don't punish", i.e. subjects that fare better, do not use costly punishments. Still, the possibility to punish seems to discipline subjects.

[25] Here we use only data collected in Rome, since NOREPORT (as well as the REMATCH treatment discussed below) was conducted only in Rome.

[26] REMATCH was a perfect stranger design so that two subjects were never paired twice, and the fixed number of periods was 25. This was emphasized in the instructions.

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

Interestingly, public reports were used more frequently in ReMatch than in Fine, suggesting that some subjects perceived price wars as a cheaper punishment than the costly public reports.

6.3.2 Enforcement effect in Leniency

The high cartel prices in Leniency were probably not driven by the threat of public reports as punishments. Price deviations 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. The post-conviction behaviour documented earlier shows that price deviations combined with secret reports led to low post-conviction cartel formation rates, and thereby to long and costly price wars. As a result, subjects may have refrained from undercutting agreed-upon prices (as documented by the low rates of price deviations in Leniency) due to the threat of long and costly price wars.

7 Additional results

This section reports results from an additional treatment in which the cartel ringleader is excluded from the Leniency Program. We then summarize results from treatments with higher expected fines and discuss cultural effects in antitrust enforcement.

7.1 Ineligibility for Cartel Ringleader

Under the US Corporate Leniency Policy, and unlike in the EU since the revision of the EU Leniency Notice in 2002, the cartel instigator (the ringleader) is ineligible for amnesty. Excluding the ringleader from the leniency program may both increase deterrence – if firms wait for other firms to take the initiative of forming the cartel – and reduce it because the ringleader becomes trustworthy, so that the incentives for other firms to rush to report become weaker.

To evaluate the pros and cons of ringleader ineligibility, we ran the additional treatment Ringleader.[27] It was identical to Leniency except that the subject who first wanted to communicate (the first to push the "yes" button) was treated as the ringleader. If only one of the subjects wanted to communicate, then this subject was treated as a ringleader even if the cartel was formed in later periods. Ringleader had a small and

[27] We thank Joe Harrington for suggesting this additional treatment.

insignificant deterrence effect, as the rates of communication attempts (0.290) were insignificantly lower than in LENIENCY (0.344).[28] And yet, relative to LENIENCY, RINGLEADER increased prices on average (4.840 versus 3.926 (p-value=0.00)). As cartels were stabilized, price deviations were significantly lower in RINGLEADER, 0.230 versus 0.472 (p-value=0.00).

The US practice of excluding ringleaders thus may reduce the effectiveness of leniency programs. One important caveat should be emphasized here. Subjects competed in duopolies. This is the worst conceivable scenario for excluding the ringleader, as the ban leaves only one cartel member with the option to self-report. The incentive to "race to report" generated by the risk of being cheated upon is then eliminated. Experimental research with many cartel members is therefore needed before drawing any strong conclusion.

7.2 High expected fines

We also test the robustness of our findings by running additional treatments with higher expected fines ($\alpha = 0.2$ and $F = 300$). We find that higher expected fines increase deterrence and reduce average prices under traditional antitrust laws, but not when a leniency program is present. The reason is probably that most of the increase in expected fines occurred through a higher probability of detection. With leniency many cartels are reported regardless of this probability, so subjects are likely less sensitive to it.

As for post-conviction behavior, paid fines can be viewed as a sunk cost incurred by convicted subjects. As discussed in section 6.2 such payments could facilitate coordination on more efficient equilibria (e.g. van Huyk et al. 1993, Offerman and Potters 2006), and they could even increase prices in competitive situations (e.g. Al-Najjar et al. 2008, MacAfee et al. forthcoming). Consistently with Sproul (1993) we observe instead a negative (not always significant) correlation between the size of the fine paid and post-conviction prices, suggesting that neither of the two effects was at work in our experiment.[29]

7.3 Culture, trust and antitrust

Culture has been shown to have a direct impact on expectations and preferences, which in turn have an impact on economic outcomes (see Guiso et al. 2006 for a review). Similarly one may extrapolate that culture may have some influence on the propensity to collude and consequently on optimal antitrust enforcement. We ran our experiments in Stockholm

[28] RINGLEADER was run only in Rome and therefore we use only observations in Rome here for LENIENCY as well. The statistical tests are outlined in Section 4 but without random effects at the city and session levels, as we ran only one session in Rome for each treatment.

[29] A detailed analysis of the effects of different expected and experienced fines and probability of detection requires many additional treatments and is performed in a companion paper, Bigoni et al. (2008).

and Rome, two cities with distinct cultures.[30] Either cultural setting, one might argue, could lead to more cartels. Italians may be more successful in colluding given the framing of our experiment – cartel formation was presented as illegal – and given that Swedes often are thought of to be more law abiding than Italians. According to the World Values Survey (1999), however, other cultural differences point in a different direction. When asked whether "information to help justice should be given to the authorities", 40.2 % of the Italians strongly agreed while only 26% of Swedes did. Moreover a majority of Swedes (63.7%) thought that "people can be trusted" while only 31.8% of Italians did. These answers suggest that leniency programs may be more effective in Italy and that Swedes may be more confident in the cooperation of partners.

Table 8 reports the average price across cities and treatments as well as the rates of communication attempts and price deviations based on observations in the first period of a match and during the first period two subjects communicated. The differences across cities are consistent with the answers in the World Value Surveys: Swedes tend to collude more often and deviate less often than Italians and, as a result, Swedes appear able to sustain higher prices than do Italians. The result is also consistent with recent findings that subjects from Denmark contribute more than others to public goods games (Engelmann and Normann 2007). Nordic countries thus may be in greater need of antitrust enforcement because of their more 'cooperative' culture than their southern neighbors.

Table 8: **Cultural Effects**

		L-Faire	Fine	Leniency	Reward
	Stockholm	0.967	0.660	0.525	0.609
Rate of comm. att. (1^{st} period)		$\vee^{*}$	$\approx$	$\vee^{***}$	$\vee^{*}$
	Rome	0.875	0.708	0.219	0.395
	Stockholm	0.513	0.323	0.460	0.650
Rate of price dev. (1^{st} comm.)		$\wedge^{***}$	$\wedge^{***}$	$\vee^{*}$	$\approx$
	Rome	0.690	0.515	0.400	0.750
	Stockholm	5.404	5.960	5.418	4.011
Average price		$\approx$	$\vee^{***}$	$\vee^{***}$	$\approx$
	Rome	4.268	4.345	3.926	3.957

Note: the **rates of communication attempts** and **price deviations** are based on observations in the first period of a match and during the first period two subjects communicated so as to capture subjects' preferences rather than their strategies. The **average price** is computed across all periods, using one observation per duopoly per period, as in table 5. The statistical tests are performed using multi-level random effect models as in Section 4. The difference is that we test the significance of a dummy variable taking value one for observations gathered in Rome. Also, the regressions do not include a random effect common for observations in the same city.

[30] Ideally one would want to run the experiment in many more places (as in Roth et al., 1991) and also with other subjects than students (as in Henrich et al., 2005). Our results suggest this is an important avenue for future research.

8 Conclusions

Leniency policies and rewards for whistleblowers are being introduced in more and more areas of law enforcement, though their effects on cartel formation and prices are 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' decisions to form cartels (cartel deterrence) and on their price choices (welfare).

In the experiment traditional antitrust law enforcement without leniency has a significant deterrence effect (fewer cartels form), but also a strong pro-collusive effect (cartel prices grow) so that overall prices do not fall. This effect appears to be driven by agents' use of self-reporting and fines as punishment devices. Leniency programs further increase cartel deterrence but also stabilize surviving cartels, pushing up cartel prices even more. The reason for the higher prices here, however, is that subjects appear to anticipate that after a defection including self-reporting a cartel is much less likely to be re-formed. When fines are used as rewards for self-reporting agents, cartels are still formed, but they are reported systematically. Only then do prices fall and antitrust can be said to improve welfare.

To the extent that we can rely on laboratory experiments, our results suggest that well designed rewards are likely to be more effective than simple leniency programs in fighting cartels and similar forms of organized crime. They also suggest that we should continue to evaluate the deterrence effects of antitrust policies, because prices may not always react to these policies as intended. More experimental and empirical work in this area is clearly needed.

A Appendix

A.1 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

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

where π^b denotes the profits in the competitive Bertrand equilibrium. The first inequality is the P-constraint in L-Faire and the second inequality is 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 greater 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 joint profit-maximizing 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 joint profit-maximizing price is sustainable in all treatments.

A.2 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, either on the collusive, or 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 if and only if the other player deviated. Then the cheated upon player has no incentive to report if δ is sufficiently small, since the avoidable immediate cost of reporting outweighs the future benefit of returning to the collusive path.

A.3 Experimental sessions

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

Treatment and date	City	N. Subjects	N. of Periods	N. of Matches
L-FAIRE				
26/03/2007	Stockholm	16	29	4
30/05/2007	Rome	32	23	4
07/11/2007	Stockholm	22	23	4
FINE				
26/03/2007	Stockholm	16	22	2
31/05/2007	Rome	32	26	6
09/11/2007	Stockholm	24	21	4
09/11/2007	Stockholm	22	23	3
LENIENCY				
28/03/2007	Stockholm	18	26	1
04/06/2007	Rome	32	25	2
08/11/2007	Stockholm	18	24	4
08/11/2007	Stockholm	14	27	5
REWARD				
29/03/2007	Stockholm	16	23	4
12/12/2007	Rome	32	23	3
RINGLEADER				
08/06/2007	Rome	32	22	3
REMATCH				
13/12/2007	Rome	32	25	25
NOREPORT				
14/12/2007	Rome	32	27	5

A.4 Instructions for Leniency

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Step 1: Pairing information and price communication decision Every period starts by informing you whether or not you will play against the same competitor as in the previous period.

Remember that if you are paired with a new competitor, you cannot be fined anymore for cartels that you formed with your previous competitors.

In this step you will also be asked if you want to communicate with your competitor to discuss prices. A communication screen will open only if BOTH you and your competitor choose the "YES" button within 15 seconds. Otherwise you will have to wait for an additional 30 seconds until pricing decisions starts in Step 3.

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

Step 3: Pricing decision You and your competitor must choose one of the following prices: 0, 1, 2, ... , 12. When you choose your price, your competitor will not observe your choice nor will you observe his or her price choice. This information is only revealed in Step 5. The experiment proceeds after 30 seconds have passed. If you fail to choose a price within 30 seconds, then your price is chosen so high that your profits will be 0.

The experiment proceeds to the first reporting decision in Step 4 if you communicated in Step 2 or if in previous periods you formed a cartel not yet discovered or reported. Otherwise you have to wait for 10 seconds until market prices are revealed in Step 5.

Step 4: First (secret) reporting decision By choosing to push the "REPORT" button, you can report that you have been communicating in the past. As described above, if you are the only one to report, you will not pay the fine; the opposite happens if only your competitor reports; and if both of you report, you will both pay 50% of the fine.

If you do not wish to report, push instead the "DO NOT REPORT" button.

When you decide whether or not to report, your competitor will not observe your choice, nor will you observe his or her choice. This information is only revealed when market prices are revealed in Step 5.

If you do not reach a decision within 10 seconds, your default decision will be "DO NOT REPORT".

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

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

Step 7: Summary In this step you learn the choices made in the previous steps: your and your competitor's price choices and profits, your eventual fine, and your earnings.

If you paid a fine in this period, you will also know whether your competitor reported the cartel or the government discovered it.

In case a cartel was detected or reported in this period, you will not run any risk of being fined in future periods, unless you and your competitor discuss prices again.

Step 7 will last for 20 seconds.

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

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

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

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

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

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