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Trust and recidivism; the partial success of corporate leniency programs in the laboratory

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Abstract

An experiment is conducted were subjects interact repeatedly to examine the effect of a particular leniency program on cartel formation, cartel stability and cartel recidivism. The program leads to lower prices for three reasons. First, non-cooperators are more persistent in their behavior which effectively blocks cartel formation in their respective groups. Second, members of groups that do form a cartel defect more often thus reducing the average cartel lifetime. Third, the difference between the agreed-upon price and the undercutting price is larger. The leniency program does not however affect the probability that a dismantled cartel is re-established.

Key words: cartels, corporate leniency programs, Bertrand competition, experiment.

JEL Classification: C92, D43, L41

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1 Introduction

Corporate leniency programs have become an increasingly important tool for antitrust authorities to break cartels. These programs provide for fine reductions and/or rewards for reporting a cartel to antitrust authorities by one of the cartel members. The first such program was initiated by the US Department of Justice in 1978. Meanwhile they are part of antitrust legislation in the US, the EU and other countries (OECD (2002), Ghosal (2004), Spagnolo, 2006).

Next to the enhanced incentive to cheat upon a cartel while simultaneously reporting it, leniency programs can also strengthen internal cartel stability. This occurs when cartel profits net of reduced fine payments exceed defection profits. When this happens too many cartel members are given (too large) fine reductions upon reporting, and cartels are formed and reported continuously. Indeed, since the introduction of leniency programs the number of cartels that is detected has increased quite dramatically, but "in principle [this] could be due to an increase in cartel activity" (Spagnolo, 2004).[1]

For obtaining a better understanding of the effects of leniency programs, empirical evidence on their workings would be most welcome. This evidence is hard to collect however since information on cartels not yet disclosed is typically not available. Moreover, as it is not feasible to adjust legislation too often and because all empirical findings are contingent on the particular leniency program in place, natural experiments do not present themselves.[2] This paper therefore reports on an experiment that assesses the effects of a particular leniency program on cartel formation, cartel duration, and cartel recidivism.

Leniency programs differ in the size of fine reduction for reporting a cartel, to what extent leniency is still an option if the antitrust authorities have started an investigation into the particular cartel before a member reports it, whether it is public information which and how many firms have applied for leniency, and whether fine reductions are available to reporting cartel

[1] Leniency programs carrying this feature are called exploitable (Spagnolo, 2004). Motta and Polo (2003) are the first to identify this possible pro-collusive effect of leniency programs. They show further that when resources of antitrust authorities are limited the use of leniency programs does improve welfare in that average price levels are reduced. In their model the optimal leniency program is one in which firms that corroborate with the antitrust authorities should not pay any fine.

[2] One possibility would be to compare cartel behavior between jurisdictions with different types of corporate leniency programs enacted. Yet, additional factors that affect individual firm behavior are likely to differ between jurisdictions, including the institutional environment, the ruling legal system, and cultural norms.

members that are not the first to report the cartel.[3] The leniency program we investigate resembles the current practice in many jurisdictions; the first applicant receives full amnesty, the second is given a 50 percent fine reduction, the third to come forward has to pay the full fine, and applicants remain anonymous.

In our experiment, subjects repeatedly play a discrete homogeneous-goods Bertrand pricing game in groups of three. Four different treatments are considered. The BENCHMARK case is the standard game where subjects cannot discuss prices. In the COMMUNICATION treatment subjects have the possibility to form a cartel, which means that group members unanimously agree to discuss prices before they post their individual ask-price. In the COMMUNICATION treatment fines are absent. This is the crucial difference with the ANTITRUST treatment, where groups that discuss prices face in each period a probability of 15% of being detected.[4] When caught, group members have to pay a fine equal to ten percent of their turnover in that period. The fourth treatment, LENIENCY, in turn resembles the ANTITRUST treatment, except that subjects who participate in a cartel now have the possibility to report the cartel in exchange for a fine reduction.

Our main finding is that leniency programs lead to lower prices. The reason for this are threefold. First, non-cooperators are more persistent in their behavior, which effectively blocks cartel formation in their respective groups. That is, given the number of subjects that wants to form a cartel, in LENIENCY 47% less cartels are established than can be expected based on a random assignment of subjects to groups. For COMMUNICATION and ANTITRUST this number is -1% and 1% respectively. Second, cartel members defect more often. In COMMUNICATION and ANTITRUST about half of all cartel members deviates from the agreed-upon price; in LENIENCY this fraction is 72%. As a result in LENIENCY the average cartel lifetime (1.0 periods) is lower than the observed cartel lifetime (1.3 periods) in both COMMUNICATION and ANTITRUST. Third, the average difference between the agreed-upon price and the undercutting price in LENIENCY is 66% of the price-cost margin, which is significantly higher than in both ANTITRUST

[3] For example, in the Netherlands complete exemption from fine payments is available to cartel members that are the first to report a cartel, that are not the cartel's ringleader, and provided that no investigation into the particular cartel is ongoing. In case the antitrust authorities already investigate the particular cartel the fine reduction is reduced with 0-50 percentage points. For the second, third and fourth reporting cartel member fine reductions in the range of 10-50% are available. As a rule, information as to which firms applied for leniency is not made public.

[4] This probability reflects the much-cited empirical finding by Bryant and Eckard (1991) that in a given given year 13-17% of the existing price fixing cartels are detected.

(54%) and COMMUNICATION (52%). We interpret these findings as all indicating that the leniency program induces a breakdown of trust among cartel members.

On the other hand the leniency program does not affect cartel recidivism; the probability that a dismantled cartel is re-established is reduced due to introduction of a detection probability, but it is not influenced further by the introduction of a leniency program.

Our experiment is related to that of Apesteguia, Dufwenberg and Selten (2006). They find that leniency programs that provide for fine reductions to whistle-blowers bring down prices close to the level obtained in a setting where cartel formation is not possible. This is because the leniency program induces less cartels to be formed. Apesteguia *et al.* (2006) observe at the same time that more cartels are established under a generous leniency program that gives a bonus (i.e. a negative fine) to cartel members that report the cartel.

The design of our experiment differs in several crucial aspects from that of Apesteguia *et al.* (2006) however. First, subjects play the stage game with the same opponents for at least 20 periods, as opposed to the one-shot setting of Apesteguia *et al.* (2006). In a one-shot game, the positive effects of leniency programs are likely to be overstated since, by definition, there is no negative backlash of whistle-blowing for future cooperation. Second, we explicitly take into account the moment at which cartel members apply for leniency. In this way, we allow for the possibility to "race to report" by giving early applicants larger fine reductions. Third our communication phase is shorter and more structured, for subjects can only communicate about prices and only for one rather than 10 minutes. This tighter time constraint is due to the repeated nature of our setup. Fourth, and finally, we restrict attention to a leniency program that is labelled "moderate" (Spagnolo, 2004) in the sense that rewards for whistle-blowers are not considered.

At present a debate is running as to which theoretical approach is most appropriate for understanding the workings of leniency programs.[5] Most studies are rooted in the stick-and-carrot tradition initiated by Becker (1968) and Friedman (1971). However, as observed by Harrington (2005): "these theories produce the counterfactual that a cartel will never use the leniency program." The reason is that in a fixed environment, cartel formation re-

[5]This debate is complicated by the fact that in several countries, notably the US, antitrust legislation includes the possibility to prosecute individuals. Aubert *et al.* (2006) therefore distinguish between leniency given to individuals and to corporations. They show that for some parameter configurations leniency provisions to corporations or to individuals alone would not suffice to break a cartel while corporate leniency in combination with reduced personal sentences would induce cartel reporting.

quires that it is not optimal for firms to apply for leniency now nor in any future period. In practice however cartels exist for a limited number of years (Bryant and Eckard, 1991) and individual cartel members do apply for leniency. Harrington (2005) brings theory closer to practice by allowing the detection probability to vary over time; it may be optimal to collude today, even when it turns out to be optimal to defect and to report tomorrow. Within this setting Chen and Harrington (2006) analyze corporate leniency programs and confirm the findings of Motta and Polo (2003): collusion is more difficult to sustain due to the introduction of a leniency program but too generous such programs can facilitate cartel formation. Despite all these much-welcomed contributions, a theoretical analysis has yet to appear that captures the increased persistency in behavior that we have observed for the non-cooperators in case a leniency program is introduced.

2 Experiment design

The design of the experiment for the LENIENCY treatment is explained as the other three treatments are nested versions of that. The Appendix contains the instructions subjects received in the LENIENCY treatment. Note that in these instructions, a neutral language is adopted that avoids the mentioning of words like "cartel," "fine," etc.

Upon arrival in the laboratory, participants were explained first some general rules regarding the experiment. Next, each subject was randomly assigned a cubicle equipped with a computer, a calculator, a pencil and an empty sheet of paper. When all participants were seated, the instructions were put onto their computer screens. These were followed by a number of questions to test whether subjects had understood the game. Individuals with questions were answered in private. Only in case all participants answered all questions correctly would the experiment continue. The experiment was preceded by five practice periods to train subjects in playing the game. In these practice periods, subjects were assigned different group members than those with which they formed a group in the 'true' experiment. Participants were informed about this. During play every screen was divided into two parts: an upper part relating to the current step in each period, and a lower part containing the values of all key variables for each previous period (scrollable).

In all treatments, subjects play in groups of three persons a repeated discrete Bertrand pricing game. In this game – a variation of the games played in Dufwenberg and Gneezy (2000) and Apesteguia *et al.* (2006) – each of the subjects has to choose an integer in the range 101-110. Player(s)

who choose(s) the lowest number p receive(s) net earnings of:

$$\pi = (p - 100)/L,$$

with L equal to the number of players choosing the lowest number. The 100 can be interpreted as a fixed marginal cost. The other players earn nothing. All treatments last for at least 20 periods. To attenuate possible end-round effects, subjects were informed that after period 19 each next period will be the last one with probability 20%.[6]

2.1 Stage games

In LENIENCY, each stage game consists of seven steps.

Step 1: Communication decision Each subject has to decide whether she wants to discuss prices or not by pressing the appropriate button; a communication window opens only in case *all* subjects within a group choose to discuss price. Throughout the analysis we refer to this situation as 'a cartel being established'. Indeed, it is the unanimously agreed-upon act of price discussion that triggers the positive detection probability and the possibility to apply for leniency. This approach is related to Aubert *et al.* (2006) in that we assume that communication generates hard evidence of collusion. Note further that the unanimity condition corresponds to practice; it is hardly conceivable that firms would be forced to join a cartel, and if not all firms in an industry would join an agreement to quote a high price, cartel pricing would simply lead to a loss of market share. Subjects only learn the joint communication decision in their group, not the individual willingness to communicate nor the possible cartel formation in other groups.

Step 2: Communication In case all subjects agree to communicate a communication window opens that allows each cartel member to indicate its acceptable price range. All group members simultaneously supply a minimum and maximum price from the choice set {101, 102,..., 110}. If a subject insists on one particular price, she can articulate this by choosing that price both as her minimum and maximum price. The intersection of all three price ranges becomes the choice set of a second round of price negotiations.

[6] Note that this does not make our setting stationary. Mason and Phillips (2002) provide an example of how a finitely repeated game with an uncertain ending period can be made stationary by adjusting over time the exchange between experimental tokens and cash. This approach however carries the disadvantage of small monetary incentives in early periods.

In case the intersection is empty the common choice set is not adjusted. This updating process continues until either a unique price is obtained or when a minute has passed (and the communication window closes).

Although this communication scheme is not used elsewhere, it is rooted in the related literature. In having a communication window of one minute we are in line with Cason and Davis (1995) who allow for a two minute communication phase. Indeed, limiting the negotiation time is desirable in a setting of repeated play. We observed that having a communication phase of one minute in most cases is more than enough to allow subjects to reach an agreement. In COMMUNICATION, ANTITRUST and LENIENCY, the fraction of all price communications that did not yield a unique agreed-upon price is, respectively, 7.3%, 7.0%, and 2.7%. The design is further related to that in Holt and Davis (1990) with the difference that our subjects submit their preferred asking price range simultaneously (rather than respond to rivals' proposal), and that they continuously have access to the entire history of the game's play (see also Step 7 below).[7]

Step 3: Pricing decision Each subject chooses her price from the choice set $\{101, 102, \ldots, 110\}$. Possible price agreements reached in Step 2 are not binding. Again, this conforms to practice; leaving aside legal cartels, price agreements are not enforceable.

Step 4: Market price Subjects learn the market price, being equal to the lowest of all three prices submitted.

Step 5: Reporting decision In case a cartel was established subjects have to decide whether or not to report the cartel. Each cartel member has to push either the REPORT-button or the NON REPORT-button. We explicitly introduced these two buttons in order to force subjects to make their reporting decision consciously. In this step no information is given about the reporting decision of other cartel members.[8]

The reporting window opens if a price discussion has taken place in the current period. It also opens in case in one or more of the previous periods price discussions have taken place that are not yet reported or detected by the antitrust authorities (Step 6). In particular, group members can report

[7] As mentioned earlier, our communication design differs most notably from that in Apesteguia *et al.* (2006); in particular, we allow subjects to communicate only about price and not, for example, about their disposition towards the leniency program.

[8] Aubert *et al.* (2006) instead assume that reports to the antitrust authority are made public. That assumption is at odds with practice in most jurisdictions (OECD, 2002).

price discussions from previous periods that have not led to the dismantling of the concomitant cartel, even if no price discussion took place in the current period.

The decision to report costs one point, irrespective of whether or not leniency is granted. This cost can be interpreted as an intrinsic cost of whistle-blowing; time spent on collecting relevant information, costs of legal advice, etc. Levying a small reporting cost also precludes a cartelist who has been undercut to punish defectors for free. Such is possible in Apesteguia *et al.* (2006), which probably leads to an overestimation of the effect of leniency programs on cartel reporting.[9]

In case the cartel is reported, all group members' earnings are reduced as follows (the same earnings deduction applies in case the cartel is not reported but discovered by the antitrust authorities):

Earnings' deduction = 10% gross earnings in the current period.

Subjects can thus realize negative earnings. For instance, if price negotiations resulted in an agreed-upon price of 107, one member undercuts by quoting a price of 106, the cartel is subsequently reported, and the undercutting cartel member did not apply for leniency, its net earnings in this period would be: $(106-100)-106/10 = -4.6$. In the experiment this corresponds to -€1.15.[10]

The leniency program considered here provides for the following fine reductions: the first group member that pushes the REPORT-button receives full leniency; the second group member that pushes the REPORT-button receives a 50% reduction in its earnings' deduction; the third group member that pushes the REPORT-button does not receive any reduction.[11] This program is much in line with those currently implemented (OECD, 2002). In the example above, if the undercutting cartel member would be second in reporting the cartel, its net earnings in this period would be: $(106-100)-50\%$ of $106/10 = 0.7$. These earnings exceed single-stage Nash equilibrium earnings (0.333) but fall short of the expected collusive earnings $(0.85 \times (107-100)/3 = 1.983)$.

Step 6: Earnings deduction In case all group members have chosen not to report in Step 5, nature will decide in Step 6 whether a group is detected by the antitrust authorities. This probability is set at 15%. Applying for

[9] We readily admit however that our choice of a reporting cost of one point is fairly *ad hoc*.

[10] In none of the sessions subjects ended up with negative cumulative earnings.

[11] In Apesteguia *et al.* (2006) this time dimension is absent; if more than one cartel member applies for leniency the fine reduction is evenly split among those who report.

Treatment	Benchmark	Communication	Antitrust	Leniency
Communication	No	Yes	Yes	Yes
Detection probability	0%	0%	15%	15%
Reporting possibility	No	No	No	Yes
Sessions	2 and 8	1 and 6	3 and 7	4 and 5
# subjects	36	39	39	42

Table 1: Treatments.

leniency is then, of course, not possible anymore and all cartel members are confronted with the full earnings' deduction.

Step 7: Period ending Finally, all relevant information of the stage game is displayed; submitted price, market price, earnings gross of possible earnings' deduction, earnings' deduction, reporting costs, and net earnings. The value of participants' total earnings is also updated. This value is visible during every step in each period.

2.2 Treatments

Table 1 summarizes the four different treatments. Starting from BENCHMARK additional features are subsequently included, thereby building towards the LENIENCY treatment. The results of the leniency experiment can thus be related to these added features.

In particular, in BENCHMARK, subjects are not offered the possibility to communicate about prices; steps 1, 2, 5 and 6 are absent and overt collusion is not possible (nevertheless, because of the repeated setting, prices above the single stage Nash equilibrium price can be observed). In COMMUNICATION, subjects are offered the possibility to discuss prices, i.e. form a cartel, at no costs; steps 5 and 6 are absent. In ANTITRUST subjects can discuss prices but communicating groups face in each period a 15% probability of being detected by the antitrust authorities; Step 5 is absent: Subjects cannot themselves report the cartel. This also holds if communication that took place in one or more of the previous periods, but that has not yet been followed by detection.

In all treatments any price from the set {101,...,110} can be sustained as a subgame perfect Nash equilibrium, provided that the individual discount rates of future earnings are 'high enough' (see Appendix B). In experimental settings these typically are close to one, so in all settings we should expect cartels to be formed. The communication phase would then serve to establish

	COMMUNICATION	ANTITRUST	LENIENCY
Cartel intention	78.08	64.74	62.26
Always	30.77	20.51	23.81
Never	0.00	0.00	9.52
Cartel formation	47.31	27.31	12.86

Table 2: Fraction of subject-decisions in favor of forming a cartel, in particular those that (i) always want to form a cartel and (ii) never want to form a cartel, and the fraction of cartels actually formed.

a focal price. As we do not observe this widespread cartel formation, factors not included in standard theory should be responsible for these observations.

3 Experiment results

The experiment was conducted at the CREED-lab of the University of Amsterdam in the period June 13-17, 2005. We ran two sessions of each treatment and the total number of subjects is 156, see Table 1. Subjects were drawn from a large pool of undergraduate students that comprises all subject fields. Earnings were recorded as points and after the experiment these were converted to euros whereby one point equals €0.25. Average earnings were €14.40 and the maximum and minimum payments were €41.40 and €6.80, respectively. The length of the sessions was between one hour and one hour and 40 minutes.

3.1 Cartel formation

A cartel is said to be created whenever communication is established. The experiment design yields information on subjects' intention towards cartel formation. Table 2 summarizes these intentions. In COMMUNICATION, 78% of all subject-decisions are in favor of starting a price discussion and some 30% of all subjects indicated in each period that a price discussion should take place. There are no subjects who in all periods answer NO when asked to start a price discussion.[12]

The development over time of the fraction of subjects wanting to engage in price discussions is depicted in Figure 1. In COMMUNICATION, initially almost all subjects want to form cartels. This does not come as a surprise as there is no penalty for entering price discussions. Over time this fraction

[12] An analysis of the questionnaires filled out by the subjects shows that the propensity to communicate is not related to the subject's age or gender.

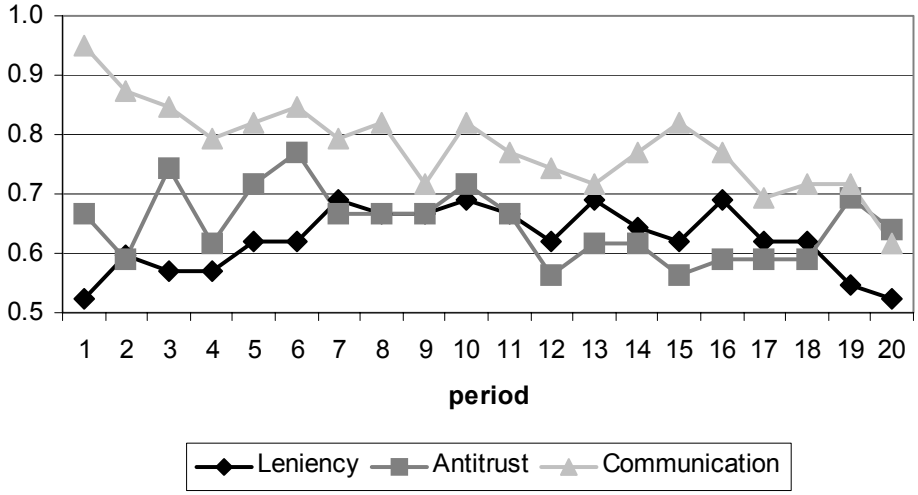

Figure 1: Average fraction of subjects that wants to discuss price.

drops gradually, either because the discussions are considered to be of no use (the agreed-upon price is not related to the market price), or because subjects can collude tacitly (after several periods the focal price is known to all group members). The average number of cartels established displays a comparable pattern (see Figure 2).

Introducing a per-period detection probability of 15% has two effects. First, the fraction of subject-decisions in favor of price discussions drops to about 65%. This drop is statistically significant according to a standard t-test ($t = 6.3$) and implies a reduction in the number of cartels being established. Second, in ANTITRUST the average fraction of subjects that wants to discuss prices is much more stable over time; the variance reduces about 35%, a reduction that is statistically significant using the Levene test based on sample medians (see Brown and Forsythe, 1974). This suggests that introduction of a detection probability induces subjects to make their communication decision more consciously.[13]

In LENIENCY the average fraction of subjects wanting to form a cartel is again significantly more stable over time compared to COMMUNICATION, and the fraction of positive cartel decisions is with 62.2% not different from that in ANTITRUST in a statistical sense ($t = 1.4$). In contrast to the two other

[13] On the other hand, we did not observe any significant difference in switching behaviour between all three treatments; the distribution of the number of switches from round to round regarding the decision to communicate are comparable.

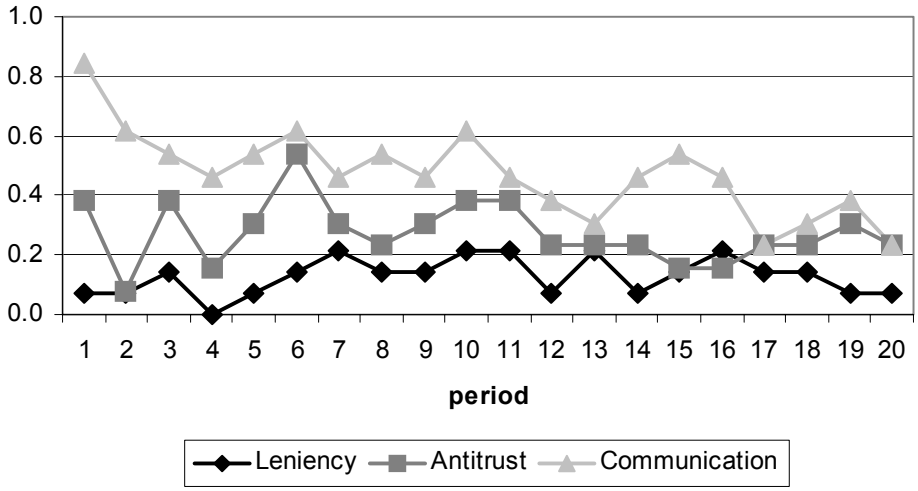

Figure 2: Average fraction of established cartels.

treatments, there is now a substantial fraction of subjects that never wants to engage in price discussions. This suggests that in LENIENCY subjects who do not want to discuss price are relatively more persistent in this choice.

To give further weight to this observed persistency we examine to what extent it is statistically significant. As it takes all subjects within a group to form a cartel, the number of cartels that actually forms as a fraction of the number of groups, is lower than the number of subjects that wants to communicate as a fraction of the total number of subjects. Yet, on the basis of the latter we can make a prediction of the former assuming that subjects wanting to form a cartel are randomly assigned to a group.

Suppose that one has S subjects who are divided into G groups of 3 subjects each. Further suppose that K out of S subjects want to form a cartel. Define $Y \in \{0, \ldots, G\}$ as the number of cartels that is established and

$$x_{i,j} = \begin{cases} 1 & \text{if subject } i \text{ in group } j \text{ wants to form a cartel} \\ 0 & \text{otherwise,} \end{cases}$$

and let $\mathbf{x} \equiv (x_{1,1}, x_{2,1}, x_{3,1}, x_{1,2}, \ldots, x_{2,G}, x_{3,G})$. Note that a cartel is formed in group j if and only if $\sum_{i=1}^{3} x_{i,j} = 3$. Denote the number of groups with m

ones as N_m, that is

$$N_m(\mathbf{x}) = \sum_{j=1}^{G} I\left(\sum_{i=1}^{3} x_{i,j} = m\right) \qquad m = 0, 1, 2, 3,$$

with $I(\cdot)$ an indicator function. $N_3(\mathbf{x})$ thus gives the total number of cartels formed. Let Ω_K be the set of all possible configurations of $\mathbf{x}$ for which $\sum_{j=1}^{G}\sum_{i=1}^{3} x_{i,j} = K$, that is, Ω_K is the set of all $\mathbf{x}$ with K subjects wanting to communicate.

For assessing the observed number of cartels we need to know how many cartels are expected given that K out of S subjects want to form a cartel and assuming that subjects are assigned to groups randomly. This asks for the probability of observing each possible configuration $\mathbf{x} \in \Omega_K$:

$$P(X = \mathbf{x}) = \frac{G!}{\prod_{j=0}^{3} N_j(\mathbf{x})!} \cdot \frac{\prod_{j=0}^{3} \binom{3}{j}^{N_j(\mathbf{x})}}{\binom{G}{K}}.$$

The first nominator states that there are $G!$ possible permutations of the G groups; the second nominator indicates that there are $\binom{3}{m}$ permutations possible such that a group ends up with m ones; the term $\binom{G}{K}$ reflects the fact that all permutations of zeros and all permutations of ones are observationally equivalent. Similarly, the first denominator accounts for the fact that permutations of groups with the same number of ones are interchangeable. Based on these probabilities, the expected number of cartels as a function of the number of K subjects that want to form a cartel is calculated as[14]

$$\hat{Y}(K) = \sum_{\mathbf{x}\in\Omega_K} N_3(\mathbf{x}) P(X = \mathbf{x}).$$

Next we relate this expected value to the number of cartels Y that was actually established. That is, for each period of each treatment, we calculate

$$Z = \frac{Y - \hat{Y}(K)}{\hat{Y}(K)}.$$

Z is an indicator of the extent to which cooperators ("ones") are randomly distributed across groups. Positive values of Z indicate that there are more clusters of three ones (a cartel) than one would expect on the basis of random assignment and negative values imply that there are more groups with at least one non-cooperator ("zero") as compared to the benchmark case of random assignment.

[14] The concomitant GAUSS-code is available from the authors upon request.

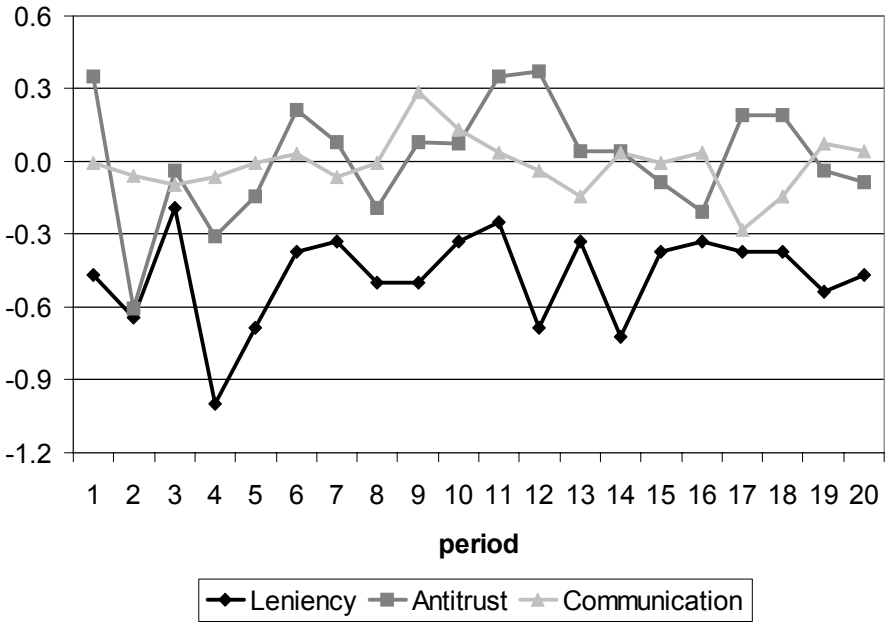

Figure 3: Per-period values of the Z indicator

For COMMUNICATION and ANTITRUST figure 3 provides some evidence that between periods 6 and 13 most non-random clusters of ones occur. Yet, for both COMMUNICATION and ANTITRUST the average value of Z does not differ significantly from zero (respective $t - values$: -0.4 and 0.3).

Quite a different picture emerges when we consider LENIENCY, as the average value of Z is with -0.47 significantly below zero ($t = -10.8$). That is, the number of cartels that is being formed is significantly below the number that is expected to be formed based on the observed willingness to communicate and assuming a random distribution of types across groups. Given that for COMMUNICATION and ANTITRUST the prediction of the number of established cartels is accurate, this lower-than-expected number of formed cartels must be due entirely to the observed persistency of non-communicators. And because the fraction of subjects that wants to discuss price in LENIENCY statistically does not differ from that in ANTITRUST, it must be that this observed persistency in turn is entirely due to the possibility of reporting the cartel. That is, in LENIENCY those that are in (slight) doubt of engaging in price discussions are (much) more difficult to entice in forming a cartel. We interpret this finding as the first of three significant indications that the leniency program triggers a breakdown of trust among cartel members.

	Mean	Median	Minimum	Maximum
COMMUNICATION	109.40	110	102	110
ANTITRUST	109.12	110	103	110
LENIENCY	109.60	110	105	110

Table 3: Agreed-upon prices

3.2 Communication

For comparing the results across treatments it is necessary that once communication is established the ensuing communication process does not evolve differently under the three different treatments. The average number of communication rounds in COMMUNICATION, ANTITRUST and LENIENCY is, respectively, 1.9, 2.0 and 1.7. A one-way ANOVA test shows that these values do not differ in a statistical sense ($F = 0.3$). In 3% of the price discussions in LENIENCY they were not conclusive in the sense that communication did not yield an unique price before the communication period ended. This happened in 7% of the cases in both COMMUNICATION and ANTITRUST.

Table 3 shows the average agreed-upon price for the three treatments. The price established in COMMUNICATION does not differ significantly from that in either ANTITRUST or LENIENCY (respective $t-values$: 1.2 and 0.9), while under LENIENCY a weakly significant higher price is coordinated upon than under ANTITRUST ($t = 1.8$). In all cases the focal price is about equal to 110, the monopoly price. In some cases the agreed-upon price was very low, with a minimum of 102 for one group in COMMUNICATION.

From these findings we conclude that the price coordination process took place in a comparable manner across treatments.

3.3 Cartel duration

Depending on the treatment considered, a cartel can break up due to defection, detection, and/or applying for leniency. Defection is recorded if at least one cartel member charges a price below the agreed-upon price. Contrary to detection and applying for leniency, with defection the detection probability does not disappear. If a cartel does not break up it carries over to the next period, independent of the communication decisions in that period.

Table 4 shows that the fraction of cartel members that defects in both ANTITRUST and COMMUNICATION is about 50% (the respective fractions do not differ in a statistical sense; $t = 0.3$). That is, introducing a detection probability only does not have any effect on members' propensity to defect. In LENIENCY however the fraction of defectors is substantially higher than

	Fraction of cartels			Fraction of cartel members	
	Defection	Detection	Reporting	Defection	Reporting
COMMUNICATION	0.67	*	*	0.52	*
ANTITRUST	0.68	0.17	*	0.50	*
LENIENCY	0.94	0.03	0.78	0.72	0.40

Table 4: Cartel breakdown

	Defect		Not defect	
	Win	Not win	Win	Not win
not report	0.49	0.71	0.67	0.63
report	0.51	0.29	0.33	0.37
1^{st}	*0.67*	*0.67*	*1.00*	*0.56*
2^{nd}	*0.25*	*0.22*	*0.00*	*0.33*
3^{rd}	*0.08*	*0.11*	*0.00*	*0.11*
observations	47	31	3	24

Table 5: Reporting decisions under the leniency program.

in ANTITRUST ($t = 6.9$). This we consider as the second indication of the breakdown in trust induced by the leniency program.

Spagnolo (2004) identifies a protection-from-fines motive for applying for leniency. This means that defectors secure their earnings by reporting the cartel as well.[15] Table 5 specifies the defection and reporting details of LENIENCY. In 35% of all defection cases did the defector also apply for leniency. The marked difference here is whether the defector quoted the lowest price or not. If it did, in about 50% of all cases (s)he subsequently applies for leniency; if it did not, an application for leniency was filed only in 29% of all cases. In either case the fraction of defectors being the first, second or third to report is about equal; there is no evidence that winning defectors are able to outsmart their competitors. We accordingly treat the high fraction of winning defectors that also report as evidence for the protection-from-fines motive.

The other motive for applying for leniency, to punish defectors, is indeed observed less strongly; both non-winning defectors and non-defectors apply for leniency in about one third of all related cases only.

Considering then the resulting cartel duration (Table 6) shows that the

[15] Recall that if doing this in every period would yield higher expected profits than adhering to the collusive agreement, the leniency program is labelled exploitable (Spagnolo (2004); see also Motta and Polo, 2003). Appendix B shows that the leniency program considered here is not exploitable.

	Mean	Median	Minimum	Maximum
COMMUNICATION	1.34	1	1	20
ANTITRUST	1.33	1	1	12
LENIENCY	1.00	1	1	1

Table 6: Average cartel lifetime

	BENCHMARK	COMMUNICATION	ANTITRUST	LENIENCY
All	103.24	103.31	103.04	101.38
Cartels	*	105.43	104.82	103.39
Non-cartels	103.24	101.40	102.38	101.08

Table 7: Average market prices.

average cartel lifetime of 1.3 periods is not affected by the introduction of a detection probability ($t = 0.0$). Indeed, only 2 out of all 75 cartels in ANTITRUST were detected while no cartel member defected. The average lifetime of a cartel in LENIENCY is with one period statistically weakly below that in ANTITRUST ($t = 1.7$). No cartel was detected that not also was reported or defected upon.

3.4 Cartel pricing

The average prices quoted for all scenarios are in Table 7. In both COMMUNICATION and ANTITRUST this average price does not differ significantly from the average price obtained in BENCHMARK (respective $t - values$: 0.2 and 0.7). Compared to ANTITRUST the leniency program brings about a statistically significant reduction in average market price however ($t = 8.3$). These patterns not only apply to average prices, they are also confirmed by the price developments over time (see Figure 4).

But communication matters. If we distinguish between the market price in case a cartel exist and in case it does not, we observe that in all three scenarios price communications yield statistically significant higher prices (respective $t - values$: 13.0, 5.6 and 6.8). The communication structure as implemented in this experiment thus enables subjects to raise price. Moreover, for non-cartel groups, the average market price is for all treatments lower than in BENCHMARK (respective $t - values$: 8.2, 2.9, and 10.0). One explanation for this finding is that the choice to discuss price signals one's willingness to cooperate: in groups where at least one group member has indicated that (s)he does not want to communicate, expectations about coordination towards supramarginal prices are tempered.

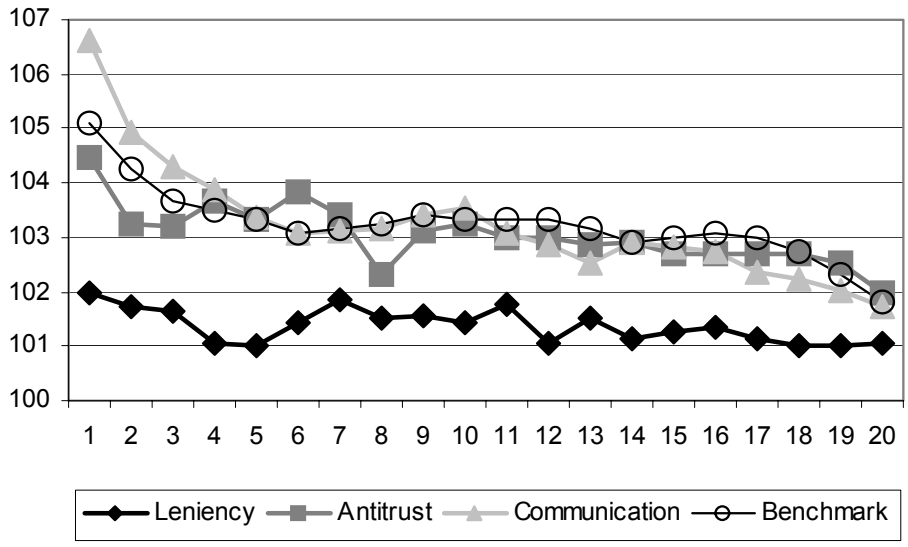

Figure 4: Average market price

The introduction of an exogenous detection probability of 15% makes price discussions more risky. This could lead to less collusion and, consequently, to lower average prices. Recall however that the average price in ANTITRUST does not differ significantly from those in both COMMUNICATION and BENCHMARK. Put differently, introduction of an antitrust authority alone is not sufficient to direct prices towards the competitive level. And although the average market price in case a cartel exists is lower in ANTITRUST than in COMMUNICATION, this difference is not significant in a statistical sense ($t = 1.3$). Moreover, the average market price for non-cartel members shows a statistically significant increase compared to COMMUNICATION ($t = 4.6$). We thus find support for the hypothesis put forward by McCutcheon (1997) that increased renegotiation costs in the form of a detection probability triggers tacit collusion.

In LENIENCY the average market price is fairly close to the competitive level although equality cannot be accepted ($t = 5.7$). This is because less cartels are established compared to ANTITRUST (Section 3.1), and because the average market price in case cartels are formed, is significantly lower ($t = 2.8$). Yet, the agreed-upon prices do not differ significantly between treatments (Section 3.2). Considering then the average defection size (that is, the difference between the agreed-upon price and the market price) shows that for COMMUNICATION, ANTITRUST and LENIENCY these are, re-

spectively, 4.65, 4.89, and 5.92. In a statistical sense the former two are equal ($t = 0.9$), whereas the average defection size in LENIENCY is significantly higher than that in both COMMUNICATION ($t = 4.6$) and ANTITRUST ($t = 3.5$). That is, subjects in LENIENCY want to be more certain that defection yields the capturing of the entire market. We consider this to be the third significant finding that trust among cartel members is reduced if there is a possibility to report the cartel.

3.5 Price dynamics

To examine prices further, the question is how market price p_{it} established in group i at time t depends on: a group-specific effect (α_i), the market price in the previous period, the presence of a cartel this period (K_{it}), defection by one or more cartel members in the previous period ($C_{i,t-1}$), whether the cartel was detected in the previous period ($D_{i,t-1}$), and whether one or more cartel members applied for leniency in the previous period ($L_{i,t-1}$). Thus we have the following regression equation:

$$p_{i,t} = \alpha_i + \beta_1 p_{i,t-1} + \beta_2 K_{i,t} + \beta_3 C_{i,t-1} + \beta_4 D_{i,t-1} + \beta_5 L_{i,t-1} + \varepsilon_{i,t}.$$

The problem with estimating this equation is however that $p_{i,t-1}$ depends on α_i, which leads to biased estimates. We solve this problem by looking at first differences instead:

$$\begin{aligned} p_{i,t} - p_{i,t-1} &= \beta_1 (p_{i,t-1} - p_{i,t-2}) + \beta_2 (K_{i,t} - K_{i,t-1}) + \beta_3 (C_{i,t-1} - C_{i,t-2}) \\ &\quad + \beta_4 (D_{i,t-1} - D_{i,t-2}) + \beta_5 (L_{i,t-1} - L_{i,t-2}) + \varepsilon_{i,t} - \varepsilon_{i,t-1}. \end{aligned}$$

In this latter equation $p_{i,t-1}$ is correlated with $\varepsilon_{i,t-1}$, which is readily restored however by using $p_{i,t-2}$ as an instrument for $p_{i,t-1} - p_{i,t-2}$ (see e.g. Verbeek, 2000).

The regression results are in Table 8. Quite obviously, communication has a positive effect on price, whereby the effect is the largest in LENIENCY, and the smallest in COMMUNICATION. Further, if defection in the previous period has an effect on price, as in ANTITRUST and to a lesser extent in LENIENCY, it reduces market price. We interpret the positive detection effect on price in ANTITRUST as a selection effect; cartels that last longest charge on average the highest price; it is precisely these cartels that, on average, will be detected.[16] Finally, no effect on current prices is observed in case a cartel has been reported in the previous period, nor is that observed if we condition on a cartel being established in the current period.

[16] Note that in LENIENCY no cartel is detected that was not also reported.

	Benchmark	Communication	Antitrust	Leniency
$p_{t-2} - p_{t-1}$	0.83	0.34	0.36	-0.04
	(12.73)	(4.09)	(1.83)	(-1.20)
Communication		1.41	1.99	2.23
		(6.46)	(3.59)	(9.29)
defection_{t-1}		0.05	-0.59	-0.99
		(0.36)	(-1.96)	(-1.63)
detection_{t-1}			0.57	—
			(1.99)	(—)
leniency_{t-1}				0.84
				(1.47)
$\text{comm}_t \times \text{leniency}_{t-1}$				1.00
				(0.85)
period 1 - 5	-0.32	0.25	0.04	-0.56
	(-0.79)	(0.71)	(0.06)	(-1.15)
period 6 - 10	0.08	0.13	-0.07	-0.35
	(0.30)	(0.41)	(-0.20)	(-0.92)
period 11 - 15	0.11	0.11	0.06	-0.15
	(0.61)	(0.25)	(-1.14)	(-1.03)
constant	-0.02	-0.04	-0.03	-0.06
	(-0.72)	(-1.08)	(-0.70)	(-1.93)
# obs.	216	234	234	252
# groups	12	13	13	14

Table 8: Estimates panel data regression, t-values within parentheses (dependent variable: first difference of the market price)

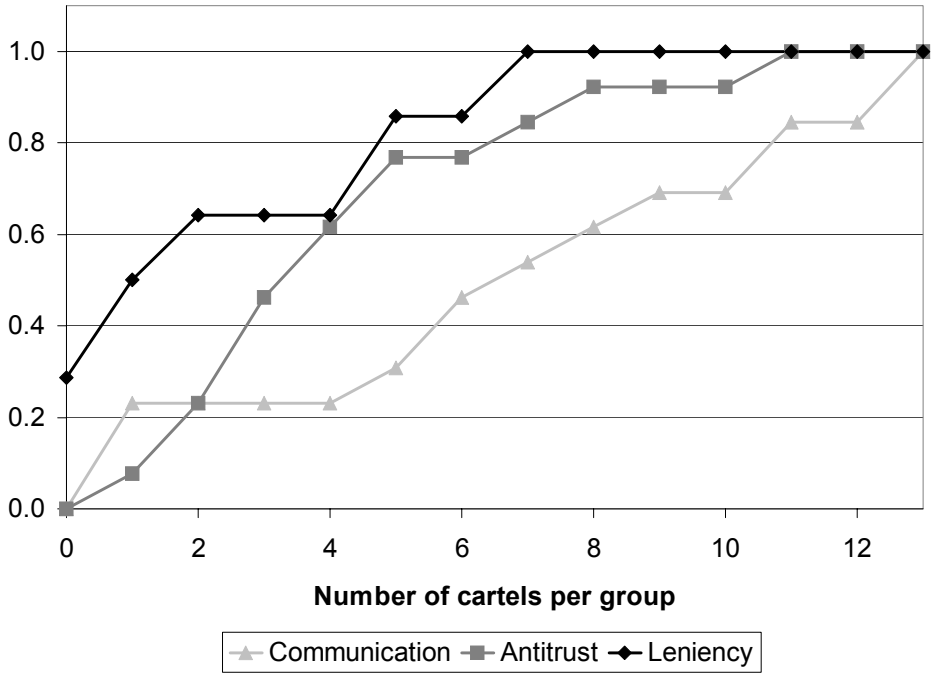

Figure 5: CDF number of cartels established per group

3.6 Cartel recidivism

Repeated offenders are common in all treatments; the average number of cartels established per group decreases from 7.08 in COMMUNICATION to 4.46 in ANTITRUST ($t = 1.8$) and to 2.57 in LENIENCY ($t = 1.8$). Connor (2003) finds that more than 50 out of 167 discovered international cartels participated in two or more cartels and 13 of them in five or more (reported in Connor, 2004). He concedes that "there [are] a few instances of true recidivism, but most of the cases concern companies colluding in overlapping cartels in multiple product lines."

Figure 5 plots for each treatment the cumulative distribution function of the number of cartels established by each group. The jump at zero for LENIENCY is caused by the fact that about one quarter of all groups never form a cartel. In COMMUNICATION and ANTITRUST all subjects join a cartel at least once. Except for this difference, the shape of the LENIENCY curve is very similar to that for ANTITRUST whereas the COMMUNICATION curve is more flat. Estimating these slopes (with a two-sided Tobit estimator) reveals indeed that equality of these estimates for LENIENCY and ANTITRUST (0.088

and 0.093 respectively) cannot be rejected while that for COMMUNICATION (0.070) is significantly lower. That is, introduction of a detection probability significantly reduces the probability of cartel recidivism; this probability is not reduced any further by the leniency program.

4 Conclusions

The experimental evidence reported in this paper shows that introduction of a particular leniency program leads to lower prices. This is because (i) non-cooperators are more persistent in their behavior such that cartel formation effectively is blocked, (ii) defection happens more often in cartels that are being formed (and hence, the average lifetime of cartels is reduced), and (iii) defection is more severe in the sense that the difference between the agreed-upon price and the undercutting price increases. These findings indicate that leniency programs undermine the trust among potential colluders.

On the other hand, the data do not provide evidence that leniency programs have an impact on cartel recidivism. The average number of follow-up cartels is reduced if a detection probability is introduced; the leniency program considered here does not affect this number any further.

As noted by Spagnolo (2006), "...more empirical and experimental evidence would be extremely welcome on all aspects of leniency and whistle-blower programs...". Although this paper responds to this wish there are still a number of important theoretical results that have to be scrutinized. For example, although the leniency program we considered here complies to the current practice in most jurisdictions, Spagnolo (2004) stresses that the most effective leniency programs are those that give a (more than) full fine reduction to the first applicant and none to subsequent ones. Another important direction for future experiments would be to incorporate endogenous detection probabilities and to confront the subsequent findings with those predicted by theory (e.g. Harrington (2005), and Chen and Harrington, 2006).

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A Appendix: Instructions Leniency Treatment (translation)

Introduction

You are going to participate in an experiment on decision-making in a market. The experiment lasts for 20 periods at least. Each period consists of 7 steps. These steps are the same in every period.

You will form a group with two randomly chosen other persons. You will not know who the two other players are. In each period, you will play with the same two group members. All groups of three persons act independently of each other.

In each treatment you can earn points. The number of points you earn depends on the decisions made by you and those made by the two other players in your group. Moreover, at the beginning of the experiment, you receive an endowment of 25 points. At the end of each period, the points that you earned in that period will be added to your endowment. In case you earn a negative number of points in a period, this number of points will be deducted from your endowment. At the end of the experiment your total earnings in points will be converted to euros, where one point has the value of €0.25.

Instruction

In this market you and the two other players in your group will compete in prices for a number of periods. In every period you have to pick your price from the set {101,102,103,104,1055,106,107,108,109,110}. The number of periods is at least 20. Each periods consists of 7 *steps*.
In every period your earnings are equal to:

$$earnings = \begin{cases} your\ price\ -\ 100 & \text{if your price is the lowest price, and } \mathbf{0} \text{ other players set the same price} \\ (your\ price\ -\ 100)/\,2 & \text{if your price is the lowest price, and } \mathbf{1} \text{ other player sets the same price} \\ (your\ price\ -\ 100)/\,3 & \text{if your price is the lowest price, and } \mathbf{2} \text{ other players set the same price} \\ 0 & \text{your price is } \mathbf{not} \text{ the lowest price} \end{cases}$$

Step 1: Communication decision

Every period starts with the question if you want to communicate with the other players about the price you want to set. You can choose YES by pressing the "YES" button, otherwise you push the "NO" button. Only if all group members press the "YES" button, a communication screen will open. If not, Step 3: Pricing decision starts.

Step 2: Communication

After the communication screen has opened you can communicate by choosing a minimum and maximum price out of the range {101,102,..., 110}. In this way you can indicate to the other players the range of prices that are acceptable to you. When all players have indicated their acceptable range of prices, the intersection of the three price ranges is displayed. You can then again choose a minimum and maximum price but now these should be within the allowed for price range. This procedure repeats until the price range is a unique integer. This is the "agreed upon price", although you and the other players do not have an obligation to actually set this price in Step 3. After reaching an agreement, the communication screen closes and Step 3 starts. If in any round, the intersection is empty, the price range in the next round will be the same as in the previous round.
If no "agreed upon price" is reached after 1 minute, the communication screen closes automatically.

Example 1 You choose a minimum price $p_{min} = 101$ and a maximum price $p_{max} = 110$; player 2 sets $p_{min} = 105$ and $p_{max} = 110$; and player 3 sets $p_{min} = 101$ and $p_{max} = 108$. The intersection of these three ranges is $105 - 108$.

Thus, in the second communication round all players can choose a minimum and maximum within this range. For example, you choose $p_{min} = 107$ and $p_{max} = 108$; player 2 sets $p_{min} = 105$ and $p_{max} = 107$; and player 3 sets $p_{min} = 106$ and $p_{max} = 108$. Then the agreed upon price is $p = 107$.

Example 2 You choose a minimum price $p_{min} = 110$ and a maximum price $p_{max} = 110$; player 2 sets $p_{min} = 107$ and $p_{max} = 110$; and player 3 sets $p_{min} = 106$ and $p_{max} = 108$. The intersection of these three ranges is empty. For this reason, the second communication round starts with the same price set {101,102,. . . , 110} to choose from.

Step 3: Pricing decision

Each person in your group must choose one of the following prices:

$$101, 102, 103, 104, 105, 106, 107, 108, 109, 110$$

The player(s) who choose the lowest price have **gross earnings** (in points) equal to their price, divided by the number of players who choose the lowest price. The other players earn zero points.

Your **net earnings** is the number of points earned after the costs (100) have been subtracted.

Example Suppose you choose a price equal to 105, player 2 chooses a prices of 107 and player 3 chooses a price of 105. In this case, player 2 earns zero points, and player 3 and you each have net earnings of $(105 - 100)/2 = 2.5$ points.

Step 4: Market price

In this phase you learn the equilibrium price obtained in your group. The market price equals the lowest price asked by a member in your group.

Step 5: Reporting decision

When communication has taken place, you must decide in this step whether or not you want to report the communication. You report by pushing the "REPORT" button, otherwise you push the "NOT REPORT" button. All other group members have to make a similar decision.

Reporting will always cost you one point, irrespective of receiving a reduction in point deduction.

Step 5 only takes place when:

1. Communication between the group members has occurred in the current period, or
2. Communication between the group members has taken place in one or more of the previous periods for which no point deduction has occurred afterwards due to chance or due to one or more of the group members pushing the "REPORT" button.

Whenever chance or one or more of the group members report, the possibility to report in future periods disappears, unless group members communicate again. The possibility of a report in future periods by chance also disappears until group members communicate again.
In case one or more group members report, each group member receives a point deduction equal to:

$$\text{Point deduction} = 10\% \text{ of your gross earnings in this period.}$$

In case you report, you receive the following reduction in point deduction:

100%	reduction, if you are the 1st to push the REPORT-button;
50%	reduction, if you are the 2nd to push the REPORT-button;
0%	reduction, if you are the 3rd to push the REPORT-button;
No	reduction, if you do not report.

Your **net point deduction** is the number of points that is deducted after having accounted for the reporting decisions of all group members.

For example, if all group members chose $p = 102$ in Step 2 and you are the second person that pushes the REPORT-button, your net point deduction equals

$$50\% \times 0.10 \times \ (102/3) = 1.7 \text{ points.}$$

The period continues with Step 6 (Point deduction) if all group members have pushed the NOT REPORT-button, otherwise the period continues with Step 7 (Closing)

Step 6: Point deduction

In this step nature randomly decides whether your group is reported. The probability that your group is reported is 15%.

Step 7: Closing

In this step you will see your **proceeds** in this period and your total endowment. Your earnings in this period are equal to the number of points that is left after the eventual net point deduction is subtracted from your net earnings. The proceeds of each group member are calculated in the same way. Your proceeds will be added to your endowment at the end of each period.

In case there was an opportunity to report in this period, you will also see whether a reporting decision has been made and how many group members pushed the REPORT-button.
Each person's earnings will be calculated by subtracting Phase 4's point deductions, if any, from Phase 3's revenues, if any. Your earnings in this period will be shown to you on your screen. After some time Phase 1 of the next period will start.

End of the experiment

In the first 19 periods, Step 7 is automatically followed by Step 1 of the next period. From period 20 onwards, the experiments ends with 20% probability at the end of each period. With a probability of 80%, Step 1 of a next period starts.

You receive a message on your screen if no further period will take place. The experiment then ends and your endowment will be exchanged in euro's where one point = €0.25

B Appendix: Incentive compatibility constraints

Here we show that in all four treatments a tacitly collusive agreement can be sustained by a trigger strategy, provided that the discount factor for future earnings is high enough. We also show that the leniency program considered here is not exploitable.

Benchmark and Communication

The value of collusion is:

$$V^C = \pi^M(1+\delta+\delta^2+...) = \frac{\pi^M}{1-\delta} = \frac{(110-100)/3}{1-\delta} = \frac{10}{3(1-\delta)},$$

whereby π^M refers to collusive profits and $\delta \in [0,1)$ is the discount factor for future earnings. In case all cartel members act according to a trigger strategy profile, maximum defection profits equal:

$$V^D = \pi^D + \pi^N(\delta+\delta^2+...) = (109-100) + \frac{101-100}{3}\frac{\delta}{1-\delta} = \frac{27-26\delta}{3(1-\delta)},$$

whereby single-stage defection and Nash profits are indicated by, respectively, π^D and π^N. The ICC for internal cartel stability then follows:

$$V^C > V^D \Longleftrightarrow \delta > \delta_1^* \approx 0.66.$$

Antitrust

The value of collusion is:

$$\begin{aligned} V^C &= \frac{\pi^M}{1-\delta} - pF\left(R^M\right)\left(1+\delta(1-p)+\delta^2(1-p)^2+...\right) \\ &= \frac{\pi^M}{1-\delta} - \frac{pF\left(R^M\right)}{1-\delta(1-p)} = \frac{10}{3(1-\delta)} - \frac{0.15\frac{110}{30}}{1-\delta(1-0.15)} \\ &= \frac{10}{3(1-\delta)} - \frac{11}{20-17\delta}, \end{aligned}$$

whereby $p \in (0,1)$ is the per-period detection probability, R refers to revenue, and $F(\cdot)$ is the fine to be paid after detection as a function of revenue. The value of defection is:

$$\begin{aligned} V^D &= \pi^D + \pi^N(\delta+\delta^2+...) - pF\left(R^D\right) - pF\left(R^N\right)\left(\delta(1-p)+\delta^2(1-p)^2+...\right) \\ &= \frac{27-26\delta}{3(1-\delta)} - 0.15\frac{109}{10} - 0.15\frac{101}{30}\frac{0.85\delta}{1-0.85\delta} = \frac{27-26\delta}{3(1-\delta)} - \frac{3270-1921\delta}{100(20-17\delta)}, \end{aligned}$$

The ICC for internal cartel stability than reads as:

$$V^C > V^D \iff \delta > \delta_2^* \approx 0.61.$$

Leniency

The value of collusion is:

$$\begin{aligned} V^C &= \frac{\pi^M}{1-\delta} - pF\left(R^M\right)\left(1+\delta(1-p)+\delta^2(1-p)^2+...\right) \\ &= \frac{\pi^M}{1-\delta} - \frac{pF\left(R^M\right)}{1-\delta(1-p)} = \frac{10}{3(1-\delta)} - \frac{0.15\frac{110}{30}}{1-\delta(1-0.15)} \\ &= \frac{10}{3(1-\delta)} - \frac{11}{20-17\delta}. \end{aligned}$$

The value of defection and applying for leniency is:

$$\begin{aligned} V^{DR} &= \pi^D + \pi^N(\delta+\delta^2+...) - \frac{1}{2}F(\pi^D) - C_L \\ &= (109-100) + \frac{101-100}{3}\frac{\delta}{1-\delta} - \frac{1}{2}\frac{109}{10} - 1 = \frac{153-133\delta}{60(1-\delta)}, \end{aligned}$$

where C_L are the cost of applying for leniency. The ICC for internal cartel stability than boils down to:

$$V^C > V^{DR} \iff \delta > \delta_3^* \approx -0.1.$$

Finally note that the leniency program considered here is not exploitable. Colluding and reporting in every period yields expected earnings of:

$$V^{CR} = \frac{1}{1-\delta}\left(\pi^M - \frac{1}{2}F(\pi^M) - C_L\right) = \frac{1}{1-\delta}\left(\frac{10}{3} - \frac{1}{2}\frac{110}{30} - 1\right) = \frac{1}{2(1-\delta)}.$$

For the leniency program to be exploitable the following must hold:

$$V^{CR} > V^D > V^C.$$

There is however no $\delta \in [0,1]$ for which this condition is satisfied.