From overt to tacit collusion: Experimental evidence on the adverse effects of corporate leniency programs

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From overt to tacit collusion: experimental evidence on the adverse effects of corporate leniency programs

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Most of recent laboratory experiments support the popular view that the introduction of corporate leniency programs has significantly decreased cartel activity. The design of these repeated game experiments however is such that engaging in illegal price discussions is the only way for subjects to avoid the one-shot competitive equilibrium. Subjects in the experiment of this paper have multiple feasible Nash equilibrium strategies to avoid the competitive equilibrium. These strategies differ in the difficulty of the coordination problem they have to solve. The experimental results show that if the efforts of the antitrust authority and the leniency program is directed exclusively to the most straightforward collusive scheme, subjects manage to switch to a more intricate form of coordination. This shift from overt collusion to tacit collusion questions the acclaimed success of corporate leniency programs.

JEL Codes: C72, C92, L41.

Keywords: overt collusion, tacit collusion, corporate leniency program, antitrust policy

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1 Introduction

An important tool for antitrust law enforcement is the corporate leniency program in Europe, and the amnesty plus program in the US. These programs allow for fine reductions to be given to former cartel members that report the cartel to the antitrust authorities. The reduction depends on the extent to which the self-reporting firm cooperates with the antitrust authorities, whether or not it has been convicted in the past for participating in a cartel, if it is the ring leader of the cartel, and so on. In some cases full amnesty is awarded whereby the self-reporting firm does not have to pay any fine at all.[1]

Antitrust authorities consider leniency programs to be an efficient tool for fighting cartel behavior. Some of the experimental studies that have appeared (Apesteguia *et al.*, 2007; Hinloopen and Soetevent, 2008) support this view in showing that implementation of a leniency program reduces market prices as well as cartel activity.[2] On the other hand, an experiment by Bigoni (2008a, 2008b) finds that leniency programs are ineffective and do not reduce average market prices. Higher cartel stability under leniency, leading to higher prices within cartels, is identified as the main driving force; in non-cartel groups, average market prices are not significantly different across treatments.

The design of most of these experiments is such that it is difficult for subjects to coordinate on supra-competitive prices other than through explicit price discussions; tacit collusion is made difficult because groups consist of three members or because subjects have a considerable range of prices to coordinate upon. Thus by design, these experiments tend not to be too informative on the extent to which the introduction of leniency programs induce cartel members to go underground in order to avoid creating evidence of illegal price discussions. One exception to this is possibly the experiment by Bigoni *et al.*(2008a, 2008b) where groups consist of two members only and non-cartel groups are able to reach average prices higher than the competitive level in all treatments considered. The objective of the experiment in this paper is to test the effects of different leniency programs in a setting where it is less difficult for cartel members to collude tacitly.

A related problem is that leniency programs might induce firms to collude and report in each period if that is more profitable in an expected sense than either colluding and not reporting or not colluding at all (Motta and Polo, 2003). Programs that carry this feature are called exploitable. To the best of our knowledge, the experimental literature so far has focused exclusively on non-exploitable leniency programs. In our experiment we consider and compare the effects of both an exploitable and a non-exploitable leniency program.

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[1] Some differences exist between the US and EU program (Roux and von Ungern-Sternberg, 2007, Spagnolo, 2008). But these are not the focus of this paper and we henceforth refer to leniency programs.

[2] For example, Hinloopen and Soetevent (2008, p. 612) show that in all treatments, market prices in non-cartel groups are significantly lower than those in cartel groups and that with a leniency program in place, the market prices in non-cartel groups almost never exceed the competitive price.

We conducted a pen-and-paper experiment that is an extension of Holt and Capra (2000). Subjects repeatedly interact with the same person. In each round participants have to play either a red (R) or a black (B) card. Only if both players play a red card they overtly collude. There are four different treatments. In the first, labeled BENCHMARK, there is no penalty for playing (R, R). This is different in ANTITRUST where a cartel detection probability of 40% is introduced. The concomitant fine equals what subjects earn when playing (R, R). The first leniency program is EXPLOITABLE. Upon self-reporting subjects receive full amnesty if they are the only one to report the cartel. A 90% fine reduction is given when both subjects self-report. In NON-EXPLOITABLE, the latter is reduced to 50% while full amnesty is given to a single self-reporting subject.

The experiment partly confirms the danger of having too generous leniency programs. A significant fraction of all subjects is able to exploit the program if it is exploitable. Perhaps more interestingly, in case the non-exploitable leniency program is in place, a substantial number of pairs succeeds in switching to a more intricate form of collusion whereby subjects take turn in capturing the entire market. As this behavior does not qualify as overt collusion in the experiment, it successfully avoids the probability of having to pay a fine. We think that this shift from overt collusion to tacit collusion questions the acclaimed success of leniency programs.

In what follows we first present a theoretical framework that corresponds to our experimental setting. From this several hypotheses are derived. Section 3 presents the experimental design and Section 4 discusses the results. Section 5 concludes.

2 Theoretical Framework

Consider the two-person simultaneous move one-shot game depicted in Figure 1, and denote the action of player i in period t by s_{it} and by $s_i = (s_{i1}, s_{i2}, ..., s_{iT})$ the strategy of player $i, i = \{Row, Column\}$, $t = \{1,2,...,T\}$. The row and column player simultaneously decide whether to play R or B. The game has the form of a prisoner's dilemma when $\pi^D > \pi^C > \pi^N > 0$, whereby superscripts D, C, and N respectively stand for "Defection", "Collusion", and "Nash". When played only once, playing B is for both players the dominant strategy and $(s_{Row,1}, s_{Column,1}) = (B, B)$ is thus the unique Nash equilibrium of this game. At the same time each player would receive a higher payoff when (*R*, *R*) is played.

		Column player	
		R	B
Row player	R	(π^C, π^C)	$(0, \pi^D)$
	B	$(\pi^D, 0)$	(π^N, π^N)

Figure 1: The one-shot prisoner's dilemma game

Playing the game repeatedly allows for equilibrium outcomes that are not equilibria in the one-shot game. The most straightforward example of an alternative equilibrium is that (R, R) is played each period. This equilibrium maximizes joint payoffs if, and only if, $2\pi^D \geq \pi^C$. An example of a pair of strategies that could sustain (R, R) as an equilibrium is the following trigger strategy:

(1)
$$s_{Row,1} = R;\, s_{Row,t} = \begin{cases} R & if\ (s_{Row,t-1}, s_{Column,t-1}) = (R,R) \\ B & otherwise \end{cases}$$
$$s_{Column,1} = B;\, s_{Column,t} = \begin{cases} R & if\ (s_{Row,t-1}, s_{Column,t-1}) = (R,R) \\ B & otherwise \end{cases} \qquad t = 2,...$$

With a continuation probability (or common discount factor) $\delta \in [0,1)$, the individual net present value (NPV) of adherence to this strategy is:

(2) $$V^{OC} = \pi^C + \delta V^{OC} \quad \Leftrightarrow \quad V^{OC} = \frac{\pi^C}{1-\delta},$$

where *OC* stands for "Overt Collusion". We call the pair of strategies in (1) a collusive scheme because subjects receive higher payoffs compared to the one-shot Nash equilibrium play.[3] Strictly speaking some form of binding communication is required to label this strategy overt collusion. But in the experiment it was explicitly communicated that playing (R, R) comes with a detection probability.

The given pair of strategies is an equilibrium of the game if no player can benefit by unilaterally deviating to another strategy. Assuming both players to adhere to the trigger strategy the NPV of playing B rather then R is:

[3] This game can be interpreted as a repeated Bertrand pricing game with homogeneous goods and constant marginal costs. Suppose there is a market with two firms who each have constant marginal cost of 5 and where in each period market demand equals $D(p) = 14 - p$. Demand is rationed in that the firm charging the lowest price captures the entire market while the market is split evenly in case both firms charge the same price. There are no capacity constraints and firms can only charge integer prices. Both firms setting a price of 6 is a Nash equilibrium of the one-shot game with each firm receiving a payoff of 4 (both firms setting a price equal to 5 is another Nash equilibrium, but in that case payoffs are 0). This corresponds to the situation where both players play B. Joint profits are maximized when the market price is 10 (or 9), in which case total demand is 4 and the individual firm's profit equals 10. This situation corresponds to both players playing R. Undercutting is mimicked if one player chooses B while the other plays R. Playing B then corresponds to a price of 9 while R reflects a price of 10, yielding as payoffs 20 and 0, respectively.

(3) $$V^D = \pi^D + \delta \frac{\pi^N}{1-\delta} = \pi^D + \delta V^N,$$

with $V^N = \pi^N/(1-\delta)$ being the NPV of repeatedly playing the one-shot Nash equilibrium (B, B). The pair of strategies in (1) is then incentive compatible if and only if $V^{OC} > V^D$. This is the case in the BENCHMARK treatment of our experiment. Subjects repeatedly play the one-shot game of Table 1 with the same player. At the end of each period the probability that the game continues for another period equals $\delta = 0.8$. Furthermore, $\pi^C = 10$, $\pi^D = 20$, and $\pi^N = 4$ such that $V^N = 20$ and $V^{OC} = 50 > 36 = V^D$.

Note that the pair of strategies in (1) is not the only possible strategy profile to avoid playing (B, B) in every period. Another, somewhat more complicated scheme is the following:

(4) $$s_{Row,1} = R;\ s_{Row,t} = B \ always;\quad s_{Row,t+1} = \begin{cases} R & if\ (s_{Row,t}, s_{Column,t}) = (B,R) \\ B & otherwise \end{cases}$$
$$s_{Column,1} = B;\ s_{Column,t} = \begin{cases} R & if\ (s_{Row,t-1}, s_{Column,t-1}) = (R,B) \\ B & otherwise \end{cases};\quad s_{Column,t+1} = B \ always,$$

t = 2, 4,… According to this strategy profile players alternate between playing R and B. Subjects receive full undercutting profits π^D in periods in which they play B and zero in all other periods. This strategy profile is based on players returning favors. Of course, the NPV of this scheme in a given period is the lowest for the player whose turn it is to play R, and equals[4]

(5) $$V^{TC} = 0 + \delta\pi^D + \delta^2 V^{TC} \quad \Leftrightarrow \quad V^{TC} = \frac{\delta\pi^D}{1-\delta^2},$$

where TC stands for "Tacit Collusion" as there is no penalty for playing (R, B). Note that this type of tacit collusion yields the highest possible pay-off and is the least difficult to implement amongst all possible forms of tacit collusion that are aimed at avoiding playing (B, B) in every period.

Given the strategy of the opponent, the optimal deviation is the same as before: play B this period and also in all future periods, which carries a NPV of $V^D = 36$. With the parameter values given above this results $V^{TC} = 0.8 \times 20/(1-0.8^2) = 44.44$, such that $V^{TC} > V^D$. That is, colluding tacitly is also

[4] The player whose turn it is to play B earns 20 and has no incentive to deviate by playing R. Her NPV equals 20 + 0.8 × 44.44 = 55.55.

incentive compatible in BENCHMARK. Overt collusion is more likely to be observed however because $V^{OC} > V^{TC}$ and because strategy profile (1) implies a type of coordination that is less difficult than the one in (4). Therefore:

Hypothesis 1:

In BENCHMARK,

a) subjects will collude to avoid playing (B, B) in each period;
b) overt collusion is more likely to be observed than tacit collusion.

In the second treatment of the experiment, labeled ANTITRUST, an antitrust authority is introduced. Denote with $p \in [0,1]$ the probability that the antitrust authorities discover overt collusion and with F the concomitant fine. Accordingly, the NPV of the strategy profile (1) reduces to:

$$(6) \qquad V^{OC*} = (1-p)\pi^C + p(\pi^C - F) + \delta V^{OC*} \quad \Leftrightarrow \quad V^{OC*} = \frac{\pi^C - pF}{1-\delta}.$$

Here we expect that being detected by the antitrust authority does not affect the resolve of subjects to play R in future periods. In the experiment the detection probability is set at 40% and $F = \pi^C = 10$. Overt collusion is then no longer incentive compatible since $V^D = 36 > 30 = V^{OC*}$. At the same time, the NPV of colluding tacitly is not affected and, therefore, remains incentive compatible. This leads to our second hypothesis:

Hypothesis 2:

a) In ANTITRUST, subjects will not collude overtly;
b) rather, they will collude tacitly in order to avoid playing (B, B) in each period.

Next we consider two different leniency programs. These programs are implemented to make it less likely that overt collusion is incentive compatible. With a leniency program in place, defection can occur in two ways. First at the pricing stage, whereby a lower price is charged than the one agreed upon by the members of the cartel, and second at the reporting stage, whereby one cartel member reports the cartel to the antitrust authorities.

Consider the case where a cartel member does charge the collusive price but defects in the reporting stage. The NPV of this type of defection is:

(7) $$V^{DR} = \pi^C - K - G + \frac{\delta}{1-\delta}\pi^N,$$

where DR stands for “Defection by Reporting”. In (7) G ($< F$) is the reduced fine and $K > 0$ are the cost of applying for leniency. These include administrative costs, legal fees, and other consultant fees firms typically incur when filing a leniency application. However, because $\pi^D = 2\pi^C = 5\pi^N$, it is immediate that $V^D > V^{DR}$. This means that defection at the reporting stage only is always less attractive than defection at the pricing stage. Defection at the reporting stage will therefore not be observed *if* that triggers ever lasting noncooperative Nash play.

Alternatively, reporting the cartel can be part of the collusive agreement. In this case, reporting is followed by collusive play instead of noncooperative Nash play in future pricing stages. Both players then collude and apply for leniency in every period.

In the experiment, the leniency program is introduced by adding a reporting stage to the pricing stage in each period. Subjects had to play again R or B in case the first pair was (R, R). Playing B in the reporting stage corresponds to applying for leniency; playing R in this stage means that no leniency application is filed. Within this context exploiting the leniency program most obviously boils down to the following strategy profile:

(8)
$$\begin{aligned}
&s^{PRC}_{Row,1} = R;\ s^{REP}_{Row,1} = B;\\
&s^{PRC}_{Row,t} = \begin{cases} R & if\ \{(s^{PRC}_{Row,t-1}, s^{PRC}_{Column,t-1}) = (R,R) \wedge (s^{REP}_{Row,t-1}, s^{REP}_{Column,t-1}) = (B,B)\} \\ B & otherwise \end{cases};\ s^{REP}_{Row,t} = B,\\
&s^{PRC}_{Column,1} = B;\ s^{REP}_{Column,1} = B;\\
&s^{PRC}_{Column,t} = \begin{cases} R & if\ \{(s^{PRC}_{Row,t-1}, s^{PRC}_{Column,t-1}) = (R,R) \wedge (s^{REP}_{Row,t-1}, s^{REP}_{Column,t-1}) = (B,B)\} \\ B & otherwise \end{cases};\ s^{REP}_{Column,t} = B,
\end{aligned}$$

with t = 2, 3, …, where $s^{PRC}_{i,t}$ and $s^{REP}_{i,t}$ denotes subject *i*’s decision in the pricing and reporting stage of period *t*, respectively. According to the strategy profile in (8), in each round subjects first play (R, R) and then (B, B). The NPV of this strategy profile equals:

(9) $$V^{OCL} = \pi^C - K - G + \delta V^{OCL} \quad \Leftrightarrow \quad V^{OCL} = \frac{\pi^C - K - G}{1-\delta},$$

where OCL stands for “Overt Collusion and applying for Leniency”. This type of overt collusion is incentive compatible if and only if $V^{OCL} > V^D$.

For a leniency program to be *exploitable* two conditions must hold simultaneously: (i) overt collusion and applying for leniency is a subgame perfect Nash equilibrium, and (ii) overt collusion and not applying for leniency is not a subgame perfect Nash equilibrium. That is:

(10) $$V^{OCL} > V^{D} > V^{OC*}.$$

If (10) holds then overt collusion is triggered by the introduction of the leniency program. A non-exploitable leniency program does not carry this feature. That is:

(11) $$V^{D} > V^{OCL}.$$

For the leniency program in EXPLOITABLE we set $K = 1$. If one subject self-reports it obtains full amnesty ($G = 0$) while a 90% fine reduction is given in case both subjects file for leniency ($G = (1-0.9)\times 10 = 1$). Accordingly, we have that $V^{OCL} = 40 > V^{D} = 36 > V^{OC*} = 30$. At the same time tacit collusion remains the most attractive strategy: $V^{TC} = 44.44 > V^{OCL}$. But in relative terms, tacit collusion is less attractive than in ANTITRUST since overt collusion and applying for leniency now comes with a higher NPV than defection. This leads us to conjecture that:

<u>Hypothesis 3</u>:

a) In EXPLOITABLE subjects will collude overtly and apply for leniency in every period;
b) the number of pairs playing (R, R) in the pricing stage will be larger than in ANTITRUST; and,
c) the number of pairs colluding tacitly will be smaller than in ANTITRUST.

In the final treatment, coined NON-EXPLOITABLE, the only change is the fine reduction in case both subjects self-report: 50%, yielding as reduce fine $G = (1-0.5)\times 10 = 5$. Accordingly, the NPV of exploiting the leniency program is $V^{OCL} = (10-1-5)/(1-0.8) = 20 < V^{D}$, making it in fact non-exploitable. We then arrive at our final hypothesis:

<u>Hypothesis 4</u>:

a) In NON-EXPLOITABLE subjects will not collude overtly and apply for leniency in every period;
b) the number of pairs playing (R, R) in the pricing stage will be smaller than in ANTITRUST; and
c) the number of pairs colluding tacitly will be larger than in both ANTITRUST and EXPLOITABLE.

The treatments in the experiment are summarized in Table 1.

	BENCHMARK	ANTITRUST	EXPLOITABLE	NON-EXPLOITABLE
P	0	0.4	0.4	0.4
δ	0.8	0.8	0.8	0.8
F	-	10	10	10
K	-	-	1	1
G (if both file)	-	-	1	5
π^C	10	10	10	10
π^N	4	4	4	4
π^D	20	20	20	20
V^{OC}	50	30	30	30
V^{TC}	44.4	44.4	44.4	44.4
V^D	36	36	36	36
V^{OCL}	-	-	40	20

Table 1: Experimental Design

3 Experimental Design and Procedures

The experiment was conducted at the Tinbergen Institute in Amsterdam on April 9, 2008. It lasted in total for 60 minutes and 16 subjects took part. These were first-year economics PhD-students. In addition to a show-up fee of €5, the points subjects earned during the experiment were converted to euros whereby 1 point was worth €0.05. Average earnings were €17.90, with a minimum of €15.50 and a maximum of €21.80. Four people administered the experiment. One called out the pairs and the cards being played, another recorded play in an Excel spreadsheet, a third rolled the die after each round to determine whether or not there would be a re-matching of pairs, and, when appropriate, to decide whether or not a fine was to be paid, and the fourth person overlooked the room to spot any irregularity.

1	2	3	4
5	6	7	8
9	10	11	12
13	14	15	16

Figure 2: Seating pattern subjects

Upon arrival in the (large) seminar room subjects had to sit at designated places according to the seating pattern in Figure 2 with ample space in between participants. This allows for pairings that made non-verbal communication impossible. Obviously, matching 1 with 9, 2 with 10, and so on, qualifies as such a pairing. But other pairings are possible as well. In total 6 different pairing schemes were used, which are given in Appendix A. We need for more pairing schemes because we follow Bigoni *et al.* (2008a, 2008b) in that δ specifies the probability of a re-matching of pairs within the same treatment. In this way enough observations are obtained for each treatment while it preserves the notion that δ is the common discount factor. For the four respective treatments 2 (#1, #2), 3 (#6, #5, #4), 1 (#3), and 3 (#3, #2, #1) pairings were used, where the numbers in brackets refer to the matching scheme numbers in Appendix A.

		Column player	
		R	B
Row player	R	(10, 10)	(20, 0)
	B	(0, 20)	(4, 4)

Figure 3: The one-shot prisoner's dilemma game in BENCHMARK

The experiment is a card game that builds on Holt and Capra (2000). It began with distributing the instructions for the BENCHMARK treatment. These are in Appendix B. After reading out loud the instructions subjects could indicate if they had a question by raising their hand. These were then answered in private. Each subject was given two playing cards, a red and a black one, and a identification number corresponding to the seating pattern in Figure 2. Playing a card meant holding it to one's chest with the back side up. In this way it was clear that a card was played but not which color. Next the identification numbers were called according to the pairing scheme in use. Subjects had to show the color of their card whenever their identity number was called. The experimenter then called out the colors of the two cards and these were recorded in the Excel sheet. At the same time subjects that had been asked to reveal their card put down their card, recorded their private earnings in their income table, and waited for the round to end. What a subject earned depends on his own card choice, and that of the other player, as in Figure 3. This continued until all 8 pairs had been called, after which a ten-sided die was thrown in order to see whether a re-matching of pairs would occur.

In ANTITRUST the ten-sided die was also thrown in case of (R, R). If either of four numbers (0, 3, 6, and 9) came up both players earned 0 rather than 10. In both leniency treatments (R, R) meant that both players had to put down their card face down, and then play again a card again. If a second (R, R) appeared the die was thrown and the same rule applied as with (R, R) in ANTITRUST. This situation corresponds to overt collusion and not applying for leniency. Alternatively B was played in the second stage, which mimicked an individual leniency application. The number of points then earned depends on the leniency program in place, see Figure 4.

	EXPLOITABLE			NON-EXPLOITABLE		
	Column player			Column player		
		R	B		R	B
Row player	R	(10, 10)*	(0, 9)	R	(10, 10)*	(0, 9)
	B	(9, 0)	(8, 8)	B	(9, 0)	(4, 4)

Figure 4: Payoffs in the reporting phase (following (R, R) in the pricing phase).

* in case of (R, R) a ten-sided die was thrown to determine if a fine had to be paid.

4 Experimental Results

In discussing the experimental results we first focus on the extent of overt collusion across the four different treatments. We then examine to what extent the exploitable leniency program is exploited. And we conclude with analyzing subject's intention towards tacit collusion.

4.1 Overt Collusion

Figure 5 gives for each treatment the distribution by pairs of cards played at the pricing stage. The figure shows that in BENCHMARK overt collusion is paramount: over 70 percent of all decisions is (R, R). The introduction of a detection probability has a tremendous effect on this behavior. Compared to BENCHMARK, the fraction of pairs playing (R, R) is reduced with 90%. Thus the data support hypotheses 1a, 1b and 2a. As conjectured, introduction of an exploitable leniency program increases the number of pairs playing the collusive strategy (R,R), thereby confirming hypothesis 3b. Yet, this increase is quite below what is predicted by theory. That is, the data only mildly support the notion that an exploitable leniency program induces overt collusion. However, and in line with hypothesis 4a, the fraction of pairs that overtly collude in NON-EXPLOITABLE is substantially below that in EXPLOITABLE. This again supports the idea that too generous leniency programs trigger overt collusion. Finally, the fraction of 16% of all pairs that overtly collude in NON-EXPLOITABLE is above the comparable fraction in ANTITRUST, which is inconsistent with hypothesis 4b.

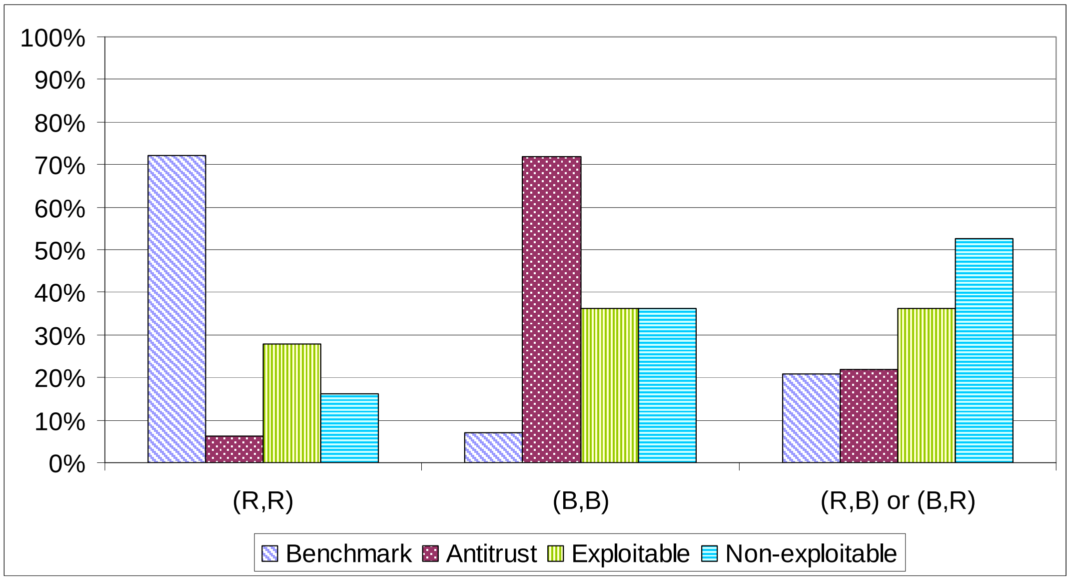


Figure 5: Distribution of card color in the pricing stage at the group level

4.2 Exploitable versus Non-exploitable Leniency Programs

Figure 5 does not tell whether pairs who play (R, R) in the pricing stage really exploit the leniency program by filing for leniency, that is, to play B in the reporting stage. Figure 6 shows the distribution of the cards played in the reporting stage. The figure clearly illustrates that the exploitable leniency program is indeed exploited: more than 70 percent of subjects in pairs that play (R, R) at the pricing stage decide to apply for leniency. Under the less generous leniency program in NON-EXPLOITABLE this percentage drops to about 10 percent.

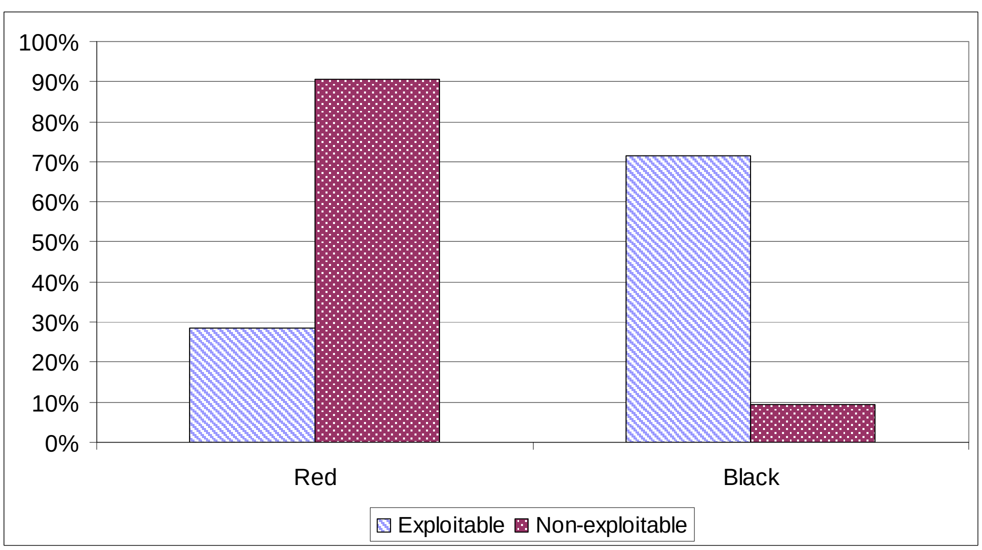


Figure 6: Distribution of the card color in the reporting stage at subject level

4.3 Overt Collusion versus Tacit Collusion

On basis of the evidence above, it is tempting to conclude that non-exploitable leniency programs are a great way to reduce collusion. Care is needed however, because we have so far considered overt collusion only: both subjects playing R in the pricing stage. But not observing (R, R) does not necessarily imply that all subjects play black cards, the socially preferred outcome.

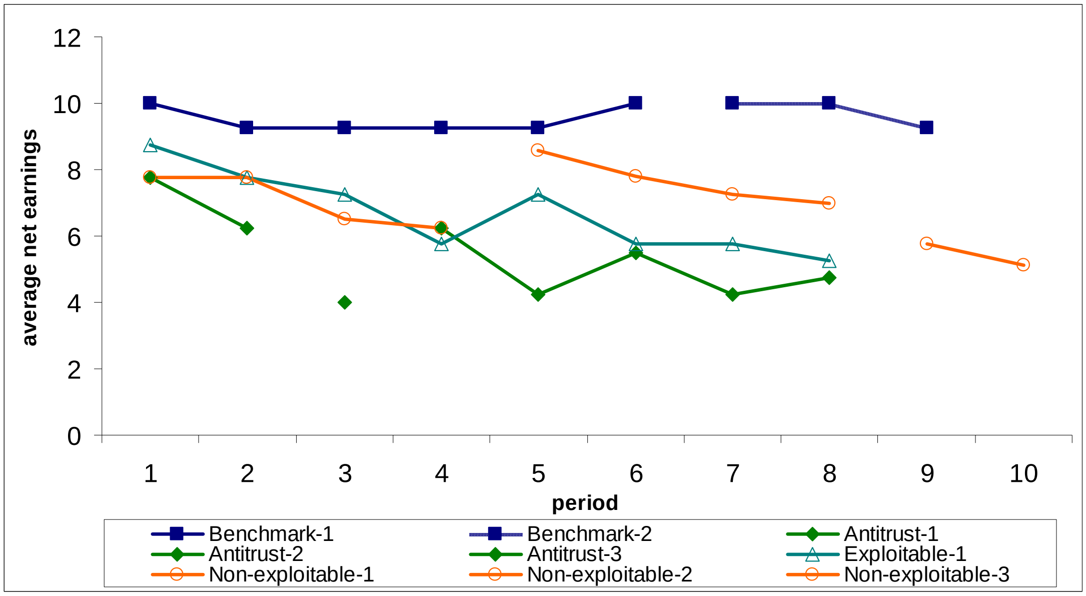


Figure 7: Average net earnings of subjects per treatment

Figure 7 plots the average earning of subjects for each treatment (the lines are disconnected at points where a re-matching of subjects occurs). As expected, average net earnings in BENCHMARK are close to 10 ($p = 0.490$) because almost none of the pairs plays (B, B) and the other combinations (R, R), (B, R) and (R,B) all imply average net earnings of 10 per subject.[5] Likewise, earnings in ANTITRUST are significantly lower ($p < 0.001$) because of the detection probability. Hypothesis 3a predicts that in EXPLOITABLE, subjects *en masse* exploit the leniency program and earn 8 units on average. Figure 7 however shows that realized earnings are significantly lower ($p = 0.008$) and are comparable to earnings in ANTITRUST in later periods ($p = 0.109$). Most striking however is that in NON-EXPLOITABLE subjects' average net earnings are not below those in EXPLOITABLE ($p = 0.535$) while they exceed those in

[5] The *p*-values in this section are calculated on basis of Wilcoxon signed rank tests. The test compares two treatments using the paired difference of subjects' average net earnings in the two treatments as observations (16 in total for each test). An objection to using this test is that subjects play in pairs such that there is dependence between subjects' average earnings. For this reason, one should interpret the reported *p*-values with some care, but we believe that the pattern is sufficiently clear to warrant our conclusions.

ANTITRUST ($p = 0.052$). Further, as Figure 5 illustrates, increased overt collusion cannot be the reason for the difference in earnings between EXPLOITABLE and NON-EXPLOITABLE. Increased popularity of colluding tacitly, as suggested by hypothesis 4c might offer an alternative explanation.

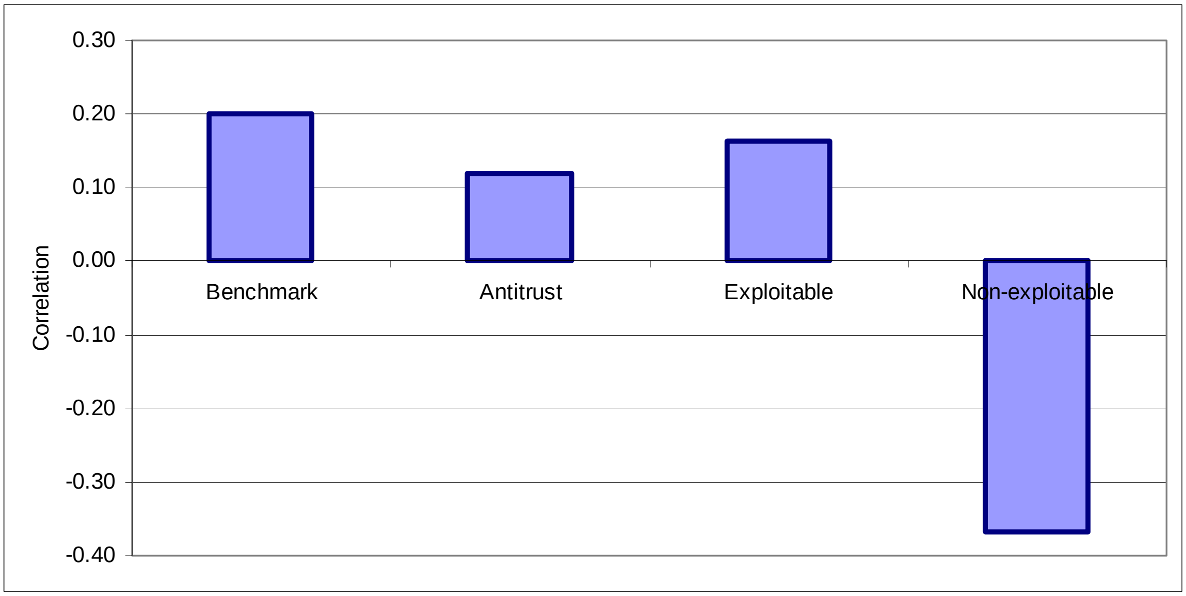


Figure 8: Correlation between $s_{i,t}^{PRC}$ and $s_{i,t+1}^{PRC}$ at the subject level

To investigate this, we first have to specify how we identify tacit collusion as described in (4). For that we calculate for each subject *i* the correlation between her bids in the pricing stage of the game in periods t and $t+1$, that is corr($s_{i,t}^{PRC}$, $s_{i,t+1}^{PRC}$) conditional on subjects not being re-matched between periods t and $t+1$. For a subject alternating between R and B, the correlation score is -1. In principle, we end up with 16 individual correlation scores for each treatment, but for subjects who play the same color in each period of a treatment, the correlation score cannot be calculated.[6] The average scores per treatment for the remaining subjects are given in Figure 8. The figure shows a sharp drop in average correlation scores in NON-EXPLOITABLE, which reflects the increased popularity of tacit collusion as specified in (4). This supports hypotheses 4a and 4c.

Figure 9 displays per period the average earnings of subjects playing a black card in BENCHMARK and ANTITRUST. The few subjects that play B in BENCHMARK in most cases cheat and earn defection profits of 20. In ANTITRUST, playing B most often is part of the one-shot Nash equilibrium (B,B) and subjects that play black for this reason earn only slightly more than 4 units on average. There is no evidence that in ANTITRUST playing B is part of a scheme to collude tacitly as in (4). This contradicts hypothesis 2b.

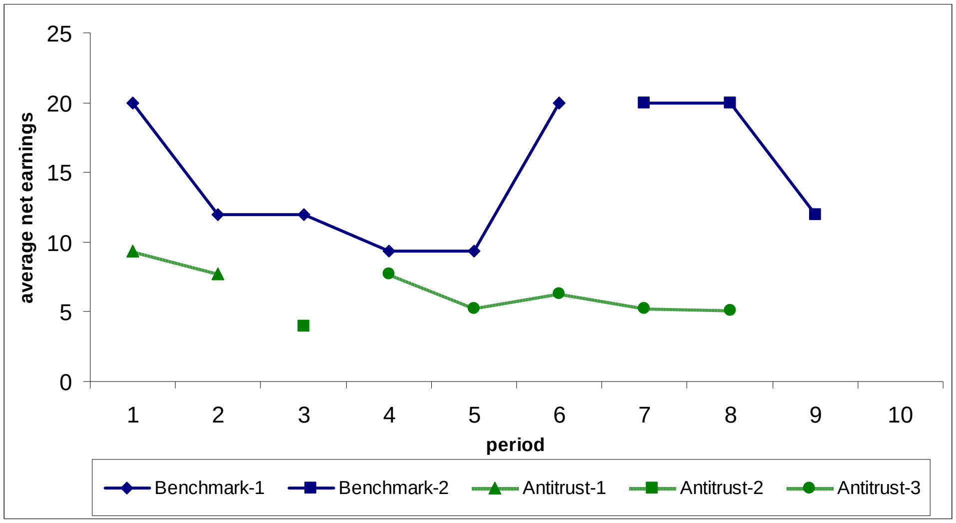
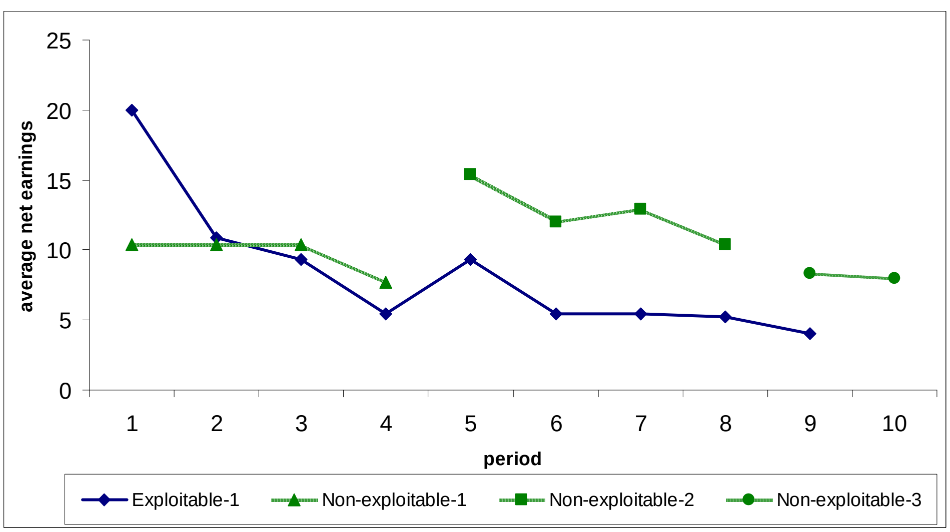


Figure 9: Average net earnings for subjects i who play $s_{i,t}^{PRC}$ = B: BENCHMARK vs. ANTITRUST

Recall that the idea behind the tacitly collusive scheme in (4) is that subjects alternate between playing R and B in the pricing stage whereby the subject who plays B receives the full collusive profits of 20 in that period and is expected to return the favor in the next period by playing R. Thus, cheating on the collusive agreement is not the sole explanation for why subjects that play B may earn 20 in a period. The difference between the two explanations is that we expect the payoff of cheating to die out in time.

Figure 10 indicates that subjects playing black in NON-EXPLOITABLE indeed achieve average earnings in the range of 10 to 15 units. Over time, these earnings somewhat decrease but stay well above the levels observed in ANTITRUST and EXPLOITABLE, suggesting that increased play of the tacitly collusive scheme in (4) is triggered by the implementation of the non-exploitable leniency program.



[6] In BENCHMARK, ANTITRUST, EXPLOITABLE and NON-EXPLOITABLE, the fraction of subjects who never change card color in the pricing stage is 44, 56, 50 and 13 percent, respectively.

Figure 10: Average net earnings for subjects *i* who play $s_{i,t}^{PRC}$ = B: EXPLOITABLE vs. NON-EXPLOITABLE

5 Conclusions

Leniency programs are considered to be a success in fighting overt collusion. Yet, programs that provide too generous fine reductions in exchange for self-reporting could trigger such overt collusion. Firms in that case overtly collude and self-report in each period. The experimental results in this paper show that this type of exploitable program is exploited indeed, albeit to a lower extent than what is predicted by theory. Perhaps more importantly, the experiment reveals that implementation of non-exploitable leniency programs trigger a form of tacit collusion. As this type of coordination does not qualify as being illegal it avoids the probability of having to pay a fine. We think that this experimental observation qualifies the recently acclaimed success of leniency programs.

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Appendix A: Matching Schemes

Matching scheme 1		**Matching scheme 2**		**Matching scheme 3**	
1	9	1	10	1	11
2	10	2	11	2	12
3	11	3	12	3	9
4	12	4	9	4	10
5	13	5	14	5	15
6	14	6	15	6	16
7	15	7	16	7	13
8	16	8	13	8	14
Matching scheme 4		**Matching scheme 5**		**Matching scheme 6**	
1	12	1	15	1	7
2	9	2	16	2	15
3	10	3	13	3	14
4	11	4	14	4	6
5	16	5	11	5	12
6	13	6	12	8	9
7	14	7	9	10	16
8	15	8	10	11	13

Appendix B: Instructions

Setup

We are going to play a card game in which every person in the room will be matched with another person in the room. The game consists of several rounds and in each round you will face the same opponent.

I will give each of you two playing cards, a red card (Hearts or Diamonds) and a black card (Clubs or Spades). The number or faces on the cards will not matter, just the color. You will be asked to play one of these cards by holding them to your chest (so we can see that you have made your decision, but not what that decision is). Your earnings are determined by the card that you play and by the card played by the person matched with you.

Points

If you each play your black card, you will each earn 4 points. If you each play your red card you will each earn 10 points. If you play your red card and the other person plays her black card, then you earn no points and the other person earns 20 points (and vice versa).

Game play

After you choose which cards to play, hold them to your chest. I then call out the identification numbers in pairs, and you can each reveal the cards that you played. Record your earnings in the table on the other side of this form. After I have called out all identification numbers a ten-sided die will be thrown. In case the numbers 0 or 5 occur the next round starts with a new matching of pairs. In all other cases the existing matching applies for the next round.

Earnings

The points that you earn during the experiment will be converted to euros at a rate of 1 point being € 0,05. Payment will be done in the next recitation class.

Any questions? If not then I ask you to play your first card.