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Going Once, Going Twice, Reported! Cartel Activity and the Effectiveness of Leniency Programs in Experimental Auctions

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Going Once, Going Twice, Reported! Cartel Activity and the Effectiveness of Leniency Programs in Experimental Auctions[1]

Jeroen Hinloopen[2] and Sander Onderstal[3]

OCTOBER, 2009

ABSTRACT:

We experimentally examine the effectiveness of a leniency program against bidding rings in two commonly used auctions: the English auction (EN) and the first-price sealed-bid auction (FPSB). Our results show that the leniency program does not affect the average winning bid, nor the average winning cartel bid. The program does deter cartel formation, but it makes cartels that do form more stable: subjects use the possibility to report the cartel as an additional stick to control cartel members. In fact, cartel defection is the sole reason for designated and non-designated winners to report the cartel. The results do not differ substantially across auction types although the deterrence effect of the leniency program is stronger in EN than in FPSB. At the same time we observe more defection from the cartel agreement in FPSB than in EN.

KEYWORDS: Leniency Programs; Auctions; Cartels; Laboratory Experiments

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1. INTRODUCTION

A substantial fraction of the price-fixing agreements that have been revealed involve (procurement) auctions. For instance, in the US in the 1980s, 75% of all cartel cases were related to auctions (Krishna, 2002). Instances of bid-rigging are exposed in road construction procurement (Feinstein *et al.*, 1985; Porter and Zona, 1993), school milk tenders (Porter and Zona, 1999; Pesendorfer, 2000), timber sales (Baldwin *et al.*, 1997), and stamp auctions (Asker, 2008). Competition authorities have several instruments to reduce cartel activity. Detecting cartels and punishing its members by levying substantial fines is their traditional set of actions. Recently this set is expanded with a novel instrument: leniency programs. In this paper, we experimentally study the effectiveness of leniency programs against cartel formation in auctions.

Leniency programs offer fine reductions to cartel members that report their cartel to the competition authorities. The aim of a leniency program is to reduce cartel activity. Because they reduce prospective fines, possibly waived altogether, it could be attractive to denounce the cartel. The EU and US leniency programs are considered to be a success after some modifications in 2002 and 1993 respectively. As Scott Hammond, the former Director of the Criminal Enforcement Antitrust Division of the U.S. Department of Justice, remarks: "Leniency is the single greatest investigative tool available to antitrust investigators. It destabilizes cartels by increasing the risk and fear of detection. It breaks up cartels by causing members to compete again, only this time the competition is a footrace to the government's door. […] The stakes are so high that the competitors can no longer afford to trust each other. Panic ensues, and it is a race for leniency." (Hammond, 2003, p.14).[1]

The theoretical support for leniency programs is mixed however. In some settings well-designed programs reduce cartel activity. But this depends crucially on the details of the program and on the environment in which it is applied. Leniency programs that offer generous fine reductions to multiple applicants may be "exploitable". Cartel members then take turn in reporting the cartel while colluding continuously (Motta and Polo, 2003, Spagnolo, 2004).[2]

[1] The success of leniency programs is also hailed by Neelie Kroes, the EU Commissioner for competition: "The leniency program is proving to be an efficient tool to detect and punish cartels" (New York Times, 2005). The leniency program in the Netherlands for instance pulled off overwhelming proof on nation-wide cartel activity in procurement auctions for construction projects. In 2001, an anonymous whistle blower provided evidence of about 3000 rigged bids in the period 1986-1998. When the Dutch competition authority subsequently initiated a leniency program 486 companies came forward with proof of bid rigging (Van Bergeijk, 2007).

[2] Chen and Rey (2009) derive an optimal leniency program that maximizes the likelihood of cartel reporting under the constraint that the program does not become exploitable. According to this optimal program some leniency

Leniency programs may also serve as an additional "stick" to discipline cartel behavior because cartel defection most likely triggers the cartel to be reported (Spagnolo, 2000; Apesteguia *et al.*, 2007). And leniency programs that reward individuals may create agency problems within firms. For instance, firms may be reluctant to fire unproductive employees who possess hard evidence of collusive agreements (Aubert *et al.*, 2006).

Empirical research sheds light on the actual working of cartels (Levenstein and Suslow, 2006, 2009; Brenner, 2009; Connor, 2009; Miller, 2009) but overlooks by definition cartels that have not been detected. It allows therefore only for a limited assessment of leniency programs. Experimental research does include the entire population and a number of recent studies have examined leniency programs in the lab. Apesteguia *et al.* (2007) are the first to consider endogenous cartel formation with varies leniency programs in place. The three subjects in each group first had to decide individually whether to join a cartel. If all subjects were in favor of cartel formation a communication window opened that allowed for a chat about anything but identity revelation. Any price agreement was non-binding. Next, each subject had to submit a market price whereby the lowest price captured the entire market. In case of ties, the market was split evenly. Finally, each subject had to decide whether or not to report the cartel if there was one to report. Leniency works quite well in this single-shot setting. The average price coincides with that obtained when the possibility to form a cartel is blocked. But the leniency program does not affect the fraction of cartels formed. A bonus treatment, whereby the fines collected per cartel were distributed evenly among the whistle blowers of that cartel, performed even worse. The average price went up and so did the fraction of cartels formed.

Hinloopen and Soetevent (2008) extend the setting of Apesteguia *et al.* (2007) in three significant directions: subjects interact repeatedly, there is an exogenous probability that any cartel is detected, and the fine reductions depend on the order of leniency application whereby the first applicant received full amnesty, the second a fine reduction of 50% and the third no fine reduction at all. The results of Hinloopen and Soetevent (2008) extent and partly confirm those of Apesteguia *et al.* (2007). A cartel detection probability deters cartel formation *per se*; the leniency program deters cartel formation further. It also destabilizes cartels; while a detection probability does not trigger defection, cartel members do defect more often if leniency is

should always be offered, it should not be restricted to first-time offenders, and it should be offered to the first applicant only (see also Harrington (2008) and Houba *et al.* 2009).

possible. In most cases the defecting cartel members then also apply for leniency. As a consequence, cartel duration is significantly reduced with a leniency program in place. Hinloopen and Soetevent (2008) also find that cartels establish higher prices, and that the average price under leniency coincides with the competitive benchmark.

The follow-up study of Bigoni *et al.* (2008) introduces two innovations: cartels can be denounced secretly before the pricing stage, and the authors run a treatment in which ringleaders cannot apply for leniency. In addition, they follow Apesteguia *et al.* (2007) in allowing cartels to be reported absent a leniency program and in considering a "bonus treatment". In line with the earlier two experiments, Bigoni *et al.* (2008) find that a cartel detection probability deters cartel formation, that a leniency program enforces this deterrence effect, that cartels are deterred less in the bonus treatment, and that cartels establish higher prices than non-cartels. They further observe that secret reports have a strong desistance effect: after a cartel has been reported secretly, the probability that a new cartel is established is reduced significantly. Moreover, excluding a ring leader from the leniency program reduces its deterrence effect and yields on average higher prices. Finally, and perhaps most surprisingly, they observe that detection and punishment has a perverse effect on price. A possible explanation is that also in this scenario subjects report the cartel in order to punish deviating cartel members, despite the fact that they do not qualify for a fine reduction if they do so.[3]

We study the effectiveness of leniency programs against cartel formation in auctions. This contrasts the existing experimental literature, which examines oligopolies under Bertrand competition. In our experiment, each subject participates in one of four treatments. Treatments vary in subjects' eligibility to form a ring, the possibility of cartel detection, and the possibility to apply for leniency. In each treatment, subjects repeatedly bid against the same bidders in either of two commonly used auction formats, i.e. the first-price sealed-bid auction (FPSB) or the English auction (EN). Because it is virtually impossible in an English auction that a leniency application is filed before all bids are known, we abstain from considering secret reports.

Explicit collusion in auctions has received surprisingly little attention in the experimental literature. In almost all auction experiments, subjects do not have the possibility to form a cartel

[3] Hamaguchi *et al.* (2009) experimentally test the effect of cartel size on the working of various leniency programs. They find that a cartel involving more firms is more likely to dissolve under a leniency program

before the auction.[4] Only a handful of studies consider explicit collusion in an experimental auction (Phillips *et al.*, 2003; Sherstyuk and Dulatre, 2008; Hu *et al.*, 2009). The main conclusion from this literature is that subjects manage to collude successfully if given the opportunity. To what extent this result maintains if cartels can be detected and members can apply for leniency is the focus of this paper.

Our experimental results sketch a less rosy picture with respect to the effectiveness of leniency programs than the received experimental literature. We do observe that detection and punishment are effective tools of competition policy in that they increase average winning bids. However, we do not observe a further increase when a leniency program is introduced. This is due to the double effect of leniency programs: they deter cartel formation, but cartels that do form are more stable because subjects are more likely to file for leniency if some cartel member deviates from the cartel agreement. That is, subjects use the leniency program as an additional "stick" to punish defectors. In fact, we find that deviation from the cartel agreement is the *only* reason for subjects to report the cartel.

In terms of these aggregate results we do not observe substantial differences between EN and FPSB, which adds to the robustness of our findings. This is perhaps surprising because the collusive properties for EN and FPSB are quite different. In theory, cartels are always incentive compatible in EN but not in FPSB in the case of one-shot interaction (Robinson, 1985; Marshall and Marx, 2007). The reason is that in FPSB the cartel bid of the designated winner creates a mark-up that triggers an incentive to submit a higher bid by the non-designated winners. With repeated interaction a cartel is therefore incentive compatible only if subjects are patient enough (see Aoyagi, 2007 and the references contained therein). In contrast, defection in EN is unprofitable because the designated winner can react immediately by outbidding a defecting cartel member. This has two important implications. First, cartels will be able to sustain a lower winning bid in EN than in FPSB, even in one-shot settings. Second, if cartel formation is costly, more cartels will be formed in EN than in FPSB. As a result, if bidders can form cartels, the revenue equivalence between the two auctions will break down: FPSB will raise more money

[4] If we define collusion in auctions as a situation where the winning bid is below the equilibrium bid however, most auction experiments are tests of collusion. It turns out that bidders hardly collude. In fact, if bidders deviate systematically from equilibrium, they bid *higher* than the equilibrium prediction, not lower. In other words, even if we take the broad definition of collusion, it is a rare phenomenon in experimental auctions (see Kagel, 1995 for an overview). The main exceptions are found in experiments on multi-unit auctions, where subjects sometimes do manage to collude tacitly, for instance by submitting identical bids (see e.g. Sherstyuk, 1999, 2002; Sade *et al.*, 2006).

than EN. Indeed, we observe in our experiment that if cartel formation is costly, more cartels are formed in EN than in FPSB and if bidders form a cartel, revenue in FPSB is higher than in EN. However, in contrast to theory, also in EN many cartels break down, especially in the final rounds of the experiment.

The set-up of the remainder of this paper is as follows. Section 2 presents our experimental design. In Section 3, we discuss the experimental results. Section 4 concludes.

2. EXPERIMENTAL DESIGN

The experiment was conducted at the Center for Experimental Economics and political Decision making (CREED) of the University of Amsterdam in September 2008. In total 171 students from the University's entire undergraduate population were recruited by public announcement. Each subject participated in one of eight sessions. Earnings were given in points with an exchange rate of 1 point = € 0.25. At the beginning of each session subjects were given 28 points, which corresponds to the show-up fee of € 7,-. On average subjects earned € 16.31 in about 60 to 90 minutes.

At the start of each session groups of three subjects were formed randomly. Groups did not change during the sessions and communication between groups was not possible. Hence, each group constitutes a statistically independent unit of observation. Members of a group competed in an auction for an abstract object against the other members of their group. The common value of the object is 10 points. In each round at most one subject in each group was the auction winner. There were 40 rounds.[5]

Table 1: Number of subjects (groups) per treatment

	FPSB	EN
BASELINE	18 (6)	21 (7)
AGREEMENT	24 (8)	21 (7)
DETECT & PUNISH	27 (9)	15 (5)
LENIENCY	21 (7)	24 (8)

[5] According to theory an infinite number of rounds is needed for cartels to be stable internally. A random stopping rule mimics this situation. However, as pointed out by Selten *et al.* (1997), an infinite horizon cannot be credibly implemented in the lab. Moreover, as observed by Selten and Stroecker (1983) for example, collusive play is often observed in finitely repeated games up to the last couple of rounds. We therefore prefer to use a commonly known finite number of periods, while correcting for possible end-game effects in the analyses of the data.

We examine the English auction (EN) and the first-price sealed-bid auction (FPSB) in four different treatments: BASELINE, AGREEMENT, DETECT & PUNISH, and LENIENCY. Each subject participated in one of these treatments in either EN or FPSB. Table 1 presents the resulting 4×2 between-subject design. LENIENCY is the most elaborate treatment. Every round in LENIENCY consists of the following three steps.

Step 1: Agreement. Each subject has to indicate whether or not she wants to join a possible cartel by pushing either a "yes" or a "no" button. A cartel forms if, and only if, all group members are in favor of cartel formation. Partial cartels are thus precluded. Subjects only learn whether a cartel has formed, not the individual votes. If a cartel is established, the computer assigns one subject as the designated winner. This subject pays 2.5 points to both other subjects in her group (5 points in total).[6] The cartel agreement is that the designated bidder is the only one submitting a bid. The other group members are to abstain from bidding. This agreement is nonbinding, though.

Step 2: Auction. This step differs between EN and FPSB. In FPSB, each subject chooses a bid from the set {0, 1, …, 10} or decides not to submit a bid. The highest bidder wins the object and pays her bid (ties are resolved randomly). If all group members decide not to submit a bid, nobody wins the object. EN on the other hand consists of several auction rounds. The first round is the same as FPSB, with the exception that the highest bidder only becomes the provisional winner. In subsequent rounds, bidders must bid strictly higher than the currently highest bid. The provisional winner in the previous round cannot submit a bid. A subject that is eligible to submit a bid and that chooses not to submit a bid, cannot submit a bid in later auction rounds. The provisional winner in a certain auction round wins the auction if both other group members do not submit a bid in the next round. The winner pays her highest bid, which she submitted in the previous auction round. If one of the subjects bids 10, the auction ends immediately.

Step 3. Reporting. If a cartel is formed in the current round, subjects have to decide whether or not to report the cartel by pressing the appropriate button. No information is given about the reporting decision of other cartel members before any member has submitted its reporting decision. Filing for leniency costs one point, irrespective of whether or not leniency is granted.

[6] We decided to enforce the designated winner to pay a side-payment to the other bidders in order to make the potential profits from the cartel agreement not too asymmetric among the cartel members. Moreover, in practice, it is quite common for the designated bidder to pay side-payments. Asker (2008) gives a particularly striking example of a bidding ring of stamp dealers who organized no less than 1700 pre-auction knockouts in which the level of side-payments were decided.

This cost covers administrative costs, legal fees, and possibly other consultant fees that firms typically incur when filing a leniency application. Moreover, levying a small reporting cost precludes a cartel member that observes defection from punishing defectors for free. If a cartel is reported, all group members are fined 10 points. Those who report may obtain a fine reduction:[7]

- If one subject reports, her fine is reduced with 100% to 0 points.
- If two subjects report, each subject's fine is reduced with 100% or 50%, with respective probability of 1/2.
- If all three subjects report, each subject's fine is reduced with 100%, 50% or 0%, with respective probability of 1/3.

If the cartel is not reported, a competition authority will detect the cartel with 15% probability.[8] In that case all group members pay the full fine of 10 points. The round closes with the display of information about the stage game: submitted bids (but not the bidders' identity), winning bid (but not the winners' identity), revenues gross of possible revenue deductions, revenue deduction, reporting costs, and net earnings. A history screen that displays this information for earlier periods is visible at all times.

Table 2: Treatments

Treatment	Cartel formation	Cartel detection	Cartel reporting
BASELINE	No	No	No
AGREEMENT	Yes	No	No
DETECT & PUNISH	Yes	Yes	No
LENIENCY	Yes	Yes	Yes

The treatments are summarized in Table 2. In BASELINE, subjects cannot form a cartel. They only take part in the auction (as in Step 2 above). AGREEMENT adds the possibility for subjects to form a cartel at no cost (as in Step 1 above). In DETECT & PUNISH, groups that form a cartel face in each period a probability of 15% of being detected. Reporting the cartel is not possible. Upon detection all group members have to pay the fine of 10 points. An example of the instructions is given in the appendix.

[7] The random draws mimic the situation that at the moment that a firm reports the cartel to the competition authorities it does not know whether other firms have already done so. It also precludes subjects "to race to the mouse-click", which could occur if the fine reduction depends on the order of reporting.

[8] This probability reflects the empirical finding by Bryant and Eckard (1991) that in a given year, 13%-17% of the existing price-fixing cartels are detected. Combe *et al.* (2008) find a similar detection rate.

3. EXPERIMENTAL RESULTS

We examine treatment effects on winnings bids, cartel formation, and cartel stability in sections 3.1, 3.2, and 3.3 respectively. We also analyze possible differences between the two auction formats.

3.1 *Winning bids*

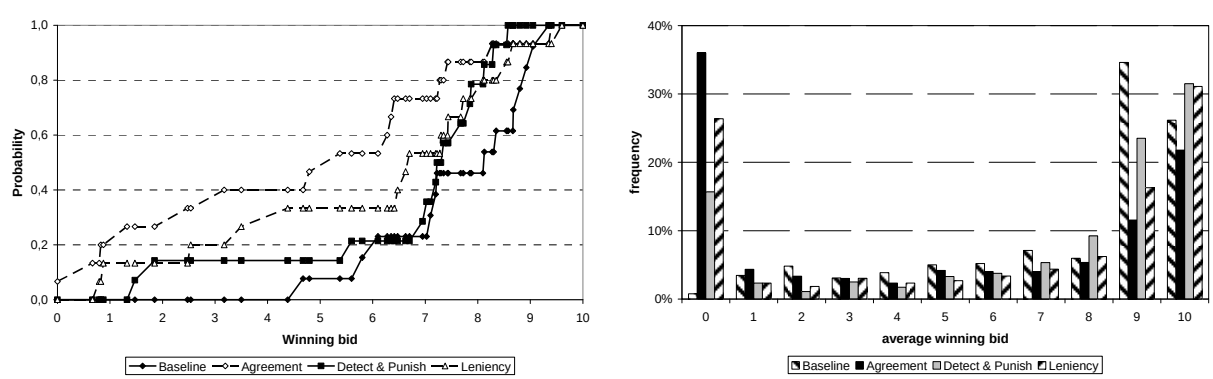
Table 3 contains the average winning bids across treatments for both auction formats, whereby the average cartel bids and non-cartel bids are reported separately as well.

Table 3: Average winning bids across treatments and auction types for cartels and non-cartels

	FPSB			EN		
	All bids	Cartel	Non-cartel	All bids	Cartel	Non-cartel
BASELINE	7.1	-	7.1	8.1	-	8.1
AGREEMENT	5.0	3.5	9.4	4.3	2.1	9.6
DETECT & PUNISH	7.1	5.0	8.6	5.9	3.5	9.7
LENIENCY	6.2	2.9	7.5	5.8	1.9	9.3

We first focus on the treatment effects. In doing so, we take observations of both auctions together, and apply Mann-Whitney U tests. Figure 1 displays the cumulative density function (cdf) and the frequency distribution of winning bids for the several treatments.

Figure 1: Cumulative distribution functions and frequency distributions winning bids across treatments



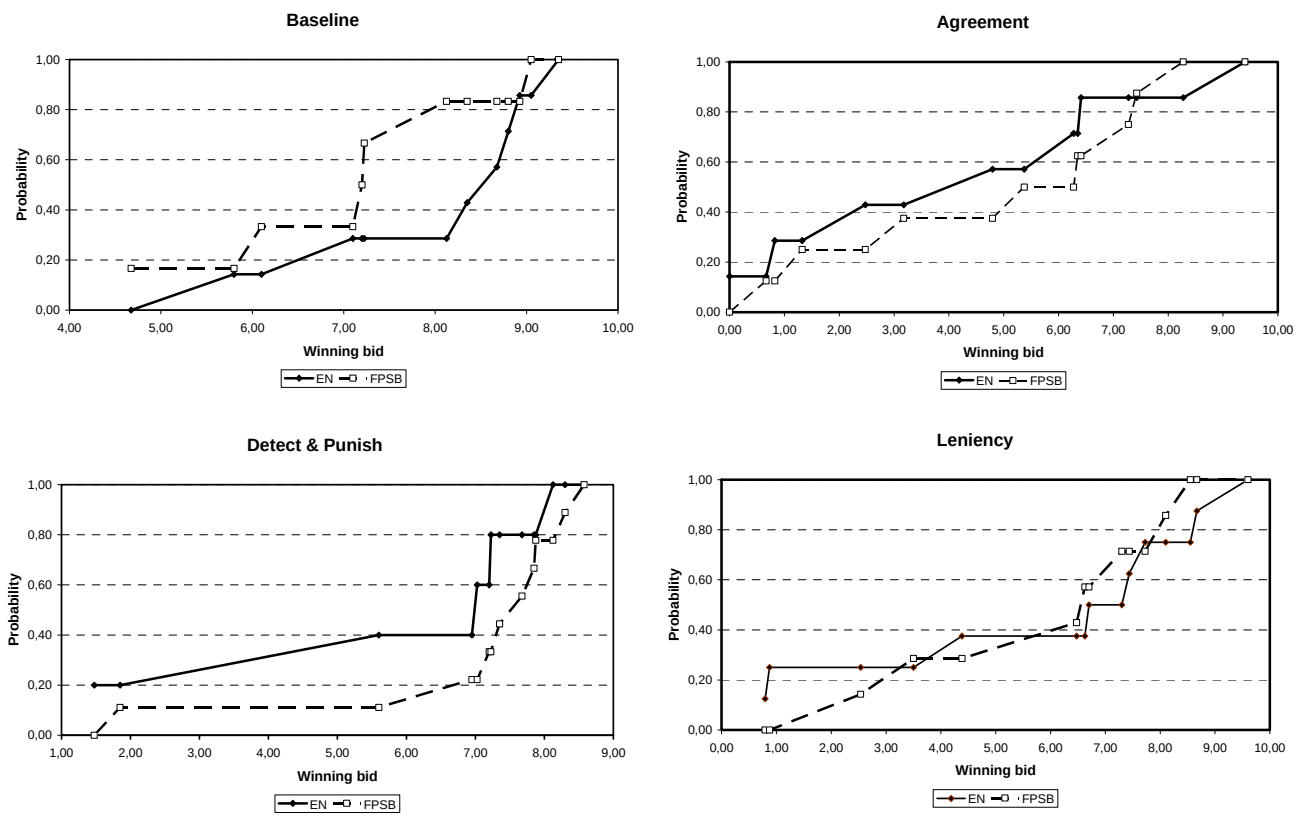
The possibility to form cartels for free clearly reduces the average winning bid significantly; the cdf of BASELINE first-order stochastically dominates the cdf of AGREEMENT (p = 0.012). The

average winning bid increases again if cartel formation is costly (p = 0.040). Introduction of a leniency program does not increase the average bid further. In fact, the average winning bid decreases relative to DETECT & PUNISH, although the difference is not statistically significant (p = 0.485). Moreover, there is no significant difference between the cdf of winning bids under LENIENCY and AGREEMENT (p = 0.13). In this sense, LENIENCY performs worse than DETECT & PUNISH. In sum:

<u>Result 1</u>

Absent an active competition authority, winning bids are lower if bidders can form a cartel than if they cannot. Possible cartel detection and subsequent punishment increases the average winning bid. The leniency program does not affect the average winning bid further. And the average winning with the leniency program in place does not differ significantly from the average winning bid if cartel formation is costless.

Figure 2: Cumulative distribution functions of average winning bids across treatments and auction formats.



What are the differences in bidding behavior between FPSB and EN? Figure 2 graphically compares the distribution of all winning bids between the two auctions for all treatments. Mann-Whitney U tests confirm the suggestion in this figure that there are no clear differences between EN and FPSB within treatments.[9] That is:

<u>Result 2</u>

Within treatments, winning bids are not different between FPSB and EN.

To further examine the effect of treatment characteristics, auction type, cartel formation, and period, we estimate the following random effects model whereby we explicitly control for possible within-group correlations:

$$\begin{aligned} B_{it}^{XY} &= \beta + \gamma_1 C_{it}^{XY} + \gamma_2 A_{it} C_{it}^{XY} + \gamma_3 A_{it}\left(1 - C_{it}^{XY}\right) + \sum_Y \gamma_Y T_{it}^Y + \sum_Y \delta_Y C_{it}^{XY} T_{it}^Y \\ &\quad + \varphi_1 E_{it}\left(t - 35\right) + \varphi_2 (1 - A_{it}) E_{it}\left(t - 35\right) + \varepsilon_{it}^{XY} + u_i^{XY}, \end{aligned} \tag{1}$$

i = 1,2,…,n^{XY}, t = 1,…,40, X = EN, FPSB, Y = BASELINE, AGREEMENT, DETECT & PUNISH, LENIENCY, where B denotes the winning bid, i the relevant group of 3 subjects, t the period, and n^{XY} the number of groups in treatment Y of auction X. Dummy variables A, C, T, and E are defined as follows:

$A_{it} = 1 \Leftrightarrow$ the observation concerns EN ;

$C_{it}^{XY} = 1 \Leftrightarrow$ in treatment Y of auction X, group i has formed a cartel in period t ;

$T_{it}^Y = 1 \Leftrightarrow$ the observation concerns treatment Y ;

$E_{it} = 1 \Leftrightarrow$ the observation concerns the final 5 periods.

The error terms ε and u are *iid* according to a normal distribution with zero mean, whereby u captures the panel structure of the data.

[9] For BASELINE, AGREEMENT, DETECT & PUNISH, and LENIENCY, the p-values are, respectively, 0.253, 0.563, 0.205, and 0.817.

Table 4 includes the regression results. Note that we take treatments BASELINE and AGREEMENT as the benchmarks for the dummies in the non-cartel and cartel data respectively. Several observations can be drawn from these estimates. Considering the role of cartel formation first, we observe:

Table 4: ML-estimates of (1).

	Coefficient
Constant	7.003*** (0.498)
C	–4.243*** (0.283)
A × C	–0.909** (0.455)
A × (1 – C)	0.985** (0.442)
$T^{\text{AGREEMENT}}$	0.797 (0.627)
$T^{\text{DETECT \& PUNISH}}$	1.237** (0.624)
T^{LENIENCY}	0.691 (0.606)
C × $T^{\text{DETECT \& PUNISH}}$	0.870*** (0.349)
C × T^{LENIENCY}	–0.548 (0.371)
E × (t – 35)	0.212*** (0.065)
(1 – A) × E × (t – 35)	0.182** (0.090)
LR-test for random effects	$p < 0.001$

Notes: Standard errors are within parentheses; ***, **, and * denote statistical significance at the 1%, 5%, and 10% level respectively; the LR-test for random effects tests $u = 0$.

<u>Result 3</u>

Across all treatments cartels establish lower winning bids than non-cartels. Introducing possible cartel detection and punishment increases the average winning cartel bid. The leniency program does not affect the average winning cartel bid further.

The concern about cartel formation in auctions is justified by our experimental results. In an environment where cartel formation is possible they are actually formed. Moreover, cartels that do form obtain the object for a substantially lower winning bid than non-cartels, the average difference being 4.2 points. These findings are in line with experimental results reported earlier (Apesteguia *et al.*, 2007; Hinloopen and Soetevent, 2008; Bigoni *et al.*, 2008). In addition, detection and punishment are effective in the sense that the average bids of cartels increase compared to AGREEMENT. At the same time, the leniency program does not affect the average winning cartel bid further.

Contrary to result 2, there are marked differences between EN and FPSB if cartel bids and non-cartel bids are considered separately. According to the regression results in Table 4, the average winning bid of [non-]cartels is about 1.0 [0.9] points higher [lower] in EN than in FPSB.

Result 4

Cartels establish lower winning bids in EN than in FPSB; non-cartels establish higher winning bids in EN than in FPSB.

Figure 3: Frequency distribution winning cartel bids

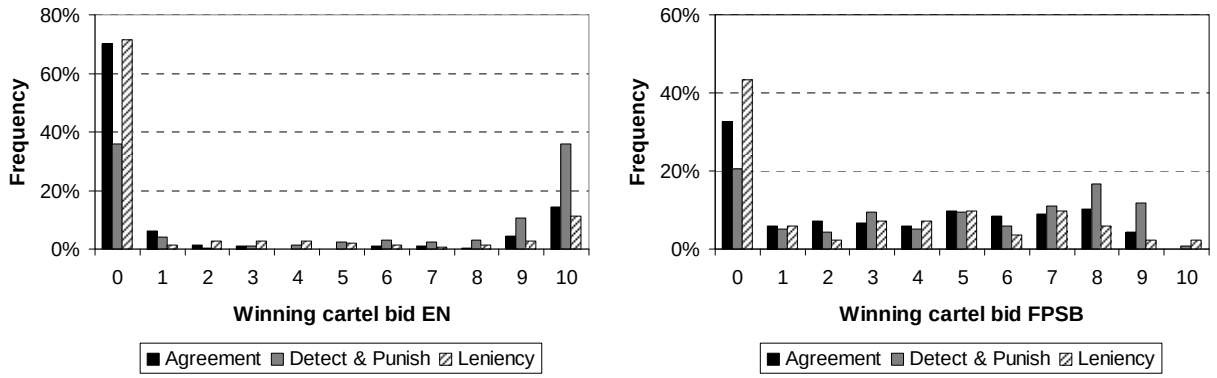
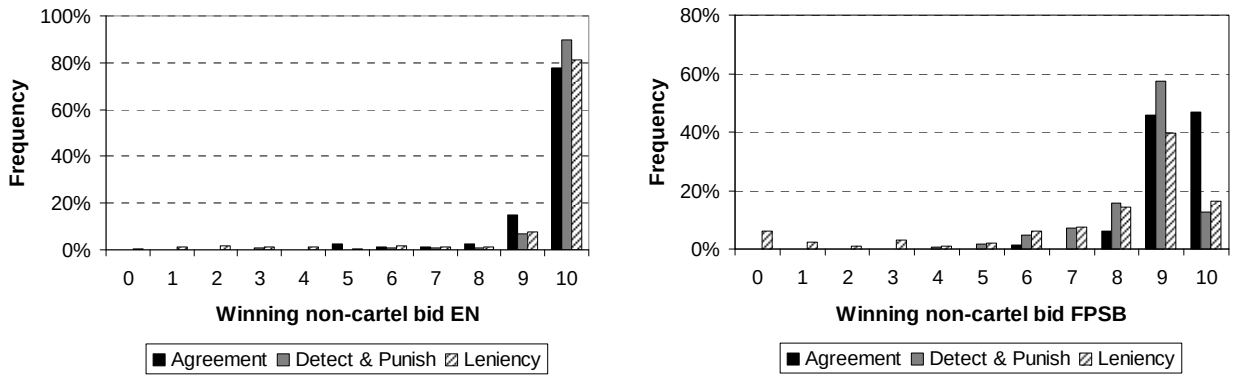


Figure 3 contains the frequency distribution of winning cartel bids for both auction types. For EN, the distribution shows two distinct peaks: one at 0 and one at 10. Only the peak at 0 is also present in FPSB. There may be at least three explanations for the peak at 10 in EN. First, bidding up to 10 constitutes a symmetric equilibrium strategy in EN. The same holds true for FPSB, but in though. The difference between EN and FPSB is that in the latter, bidding 10 is a weakly dominant strategy, while in EN, a bidder is just indifferent between bidding 10 and stepping out of the auction when the price has reached 9 in a certain auction round. Second, a winning bid of 10 could be the result of the provisional winner's punishment strategy. If someone outbids the provisional winner, the latter may respond by starting a "race to the top". In fact, the feasibility of a race to the top in EN implies that winning bids of zero can be sustained as an equilibrium outcome, although the race will not emerge on the equilibrium path. Third, an "endowment effect" could explain the race to the top (Knez *et al.*, 1985). A subject that is the provisional winner in some auction round may be likely to bid again if another subject outbids her because

she feels that the object was hers in the previous auction round. In FPSB, such a reaction to rivals' bidding behavior is not possible.[10]

Bidding behavior of non-cartels is markedly different from that of cartels. Figure 4 displays the frequency distributions of the winning non-cartel bids. EN triggers more aggressive bidding behavior than FPSB when no cartel forms. For FPSB, there is a clear spike at 9, which is the unique Nash equilibrium outcome in non-weakly dominated strategies. In EN, almost all winning non-cartel bids are equal to 10. This is somewhat remarkable because a non-winning bid of 9 yields the same pay-off for a bidder as a winning bid of 10. On the other hand, all of the above three explanations for high bids in the case of cartels may also be valid for non-cartels. Note that EN has an equilibrium in which subjects collude tacitly at a price of zero: all bid zero in the first round of the auction and then step out of the auction; they start a race to the top as soon as anyone deviates. By playing this strategy, bidders do not have to form a cartel, which reduces the cost of collusion in DETECT & PUNISH and LENIENCY. Clearly, subjects do not manage to coordinate on this equilibrium. Perhaps some try to do so, but they end up in a race to the top because at least one bidder in their group "deviates" by bidding more than zero.

Figure 4: Frequency distribution winning non-cartel bids



Finally, the results in Table 4 point to a clear end-game effect. In FPSB, the average winning bid increases by 0.2 points per round in the final 5 rounds, and by 0.4 points per round in EN:

[10] The data allow for a distinction between the first and the latter two motives. The fraction of times that the designated winner in a cartel wins the object for 10 is 75%, 47% and 65% in treatments AGREEMENT, DETECT & PUNISH, and LENIENCY, respectively. If bidding up to 10 follows from a symmetric equilibrium strategy, all bidders should be equally likely to obtain the item for 10 (implying that in two-third of all cases a non-designated winner should win). Clearly this assumption is violated, which suggests that a bidding race up to 10 is either the result of a punishment phase or induced by an endowment effect.

Result 5

In the final 5 rounds, winning bids increase significantly. This end-game effect is stronger in FPSB than in EN.

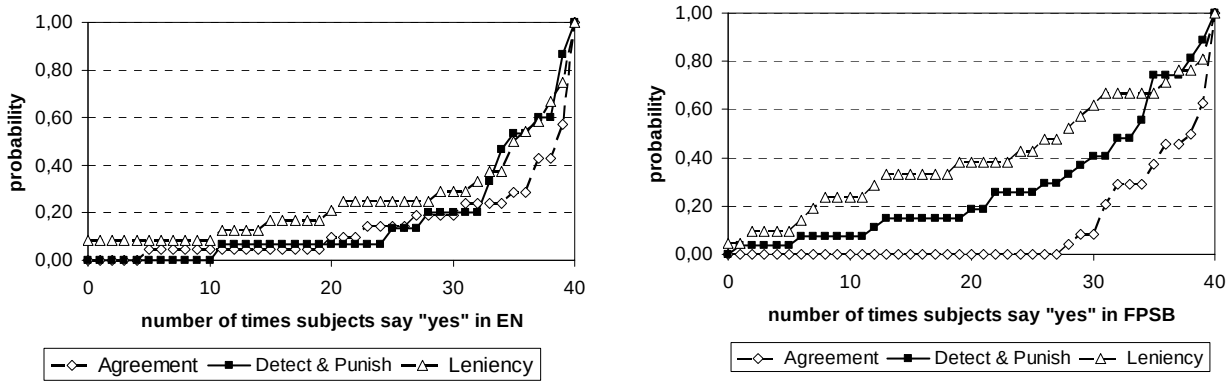
3.2 *Cartel formation*

An important goal of competition policy is to prevent cartel formation. Table 5 contains the fraction of subjects in favor of cartel formation and the fraction of cartels actually formed. Figure 5 maps the cdfs of the number of times subjects are in favor of cartel formation.

Table 5: Cartel formation

	Fraction of subjects in favor of cartel formation		Fraction of cartels formed	
	FPSB	EN	FPSB	EN
AGREEMENT	91%	87%	74%	71%
DETECT & PUNISH	73%	84%	42%	62%
LENIENCY	60%	76%	30%	48%

Figure 5: Cumulative distribution functions of the number of periods individual subjects want to form a cartel



The propensity to join a cartel differs across treatments. The cdf of AGREEMENT clearly first-order stochastically dominates the cdf of LENIENCY (p = 0.000). That is, the leniency program has a strong deterrence effect compared to a situation where no competition authority is at work. The deterrence effect of traditional competition policies is more ambiguous. In FPSB cartels are deterred by the cartel detection probability (p = 0.000) in contrast to EN (p = 0.535). In sum:

Result 6

Subjects are less likely to be in favor of cartel formation in LENIENCY than in AGREEMENT. In FPSB, detection and punishment makes it less likely that subjects vote in favor of cartel formation, and a leniency program increases this effect; in EN, detection and punishment makes it less likely that subjects are in favor of cartel formation only if there is also a leniency program in place.

The difference in cartel deterrence between the two auctions could be due to cartels always being incentive compatible in EN, even in one-shot settings, in contrast to FPSB. Apparently, increasing the cost of cartel formation through detection and punishment is not enough to deter cartel formation in EN while it does deter cartel formation in FPSB. Competition policy has a deterrence effect in EN only if subjects are given the possibility to denounce the cartel as well. Introduction of a leniency program thus triggers proportionally more cartels to be deterred in EN than in FPSB.

To examine what factors drive subjects' willingness to vote in favor of cartel formation, we estimate the following random effects discrete choice binomial logit model:

$$\begin{aligned} y_{jit}^{*XY} &= \beta + \sum_{Y}\left(\delta_{1Y}T_{it}^{Y}A_{it} + \delta_{0Y}T_{it}^{Y}\left(1-A_{it}\right)\right) + \varphi_1 E_{it}\left(t-35\right) + \varphi_2(1-A_{it})E_{it}\left(t-35\right) + \varepsilon_{jit}^{XY} + u_i^{XY} \\ y_{jit}^{XY} &= 1 \Leftrightarrow y_{jit}^{*XY} \geq 0, \end{aligned} \tag{2}$$

j = 1,2,3, $j \in i$ = 1,2,…,n^{XY}, t = 1,…,40, X = EN, FPSB, Y = AGREEMENT, DETECT & PUNISH, LENIENCY, whereby the dummy variables A, D, T, and E are those used in (1), and

$$y_{jit}^{XY} = 1 \Leftrightarrow \text{subject } j \text{ in group } i \text{ is in favor of forming a cartel.}$$

Table 6 presents the regression results. These results confirm the non-parametric tests. Prospective fine payments reduce expected cartel profits. In FPSB this suffices to deter cartel formation. The leniency program deters cartel formation further. The possibility of reporting the cartel makes it possible to secure defection profits and to escape the fine payments. As a result, cartel formation is less likely to be incentive compatible; defection is just too attractive. A

leniency program deters cartel formation in EN for the same reason. However, detection and punishment alone do not deter cartel formation in EN. Forming a cartel remains attractive despite the rise in expected costs because of fine payments.

Table 6: ML-estimates of (2).

	Coefficient
Constant	2.822^{***} (0.456)
$A \times T^{\text{AGREEMENT}}$	–0.074 (0.671)
$A \times T^{\text{DETECT \& PUNISH}}$	–0.937 (0.717)
$A \times T^{\text{LENIENCY}}$	-1.139^{*} (0.635)
$(1 - A) \times T^{\text{DETECT \& PUNISH}}$	-1.519^{**} (0.612)
$(1 - A) \times T^{\text{LENIENCY}}$	-2.145^{***} (0.649)
$E \times (t - 35)$	-0.136^{***} (0.049)
$(1 - A) \times E \times (t - 35)$	-0.137^{**} (0.063)
LR-test for random effects	$p < 0.001$

Notes: Standard errors are within parentheses; ***, **, and * denote statistical significance at the 1%, 5%, and 10% level respectively; the LR-test for random effects tests $u = 0$.

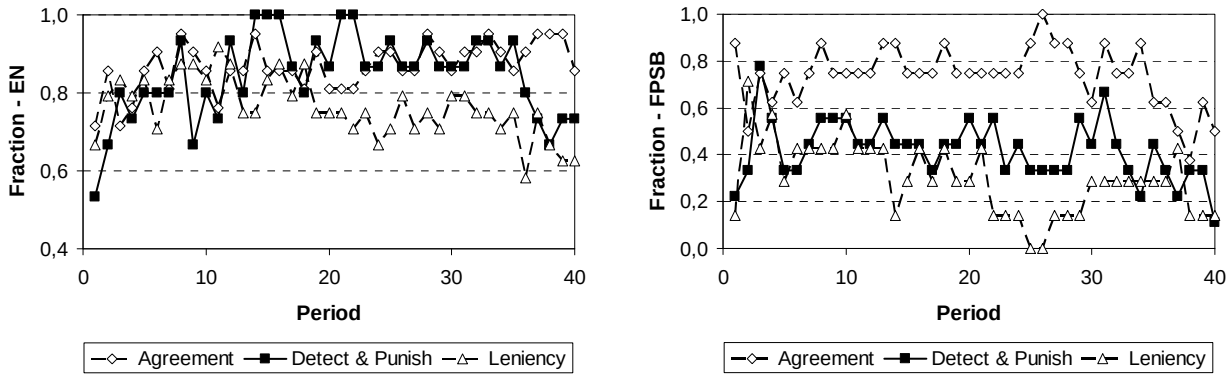
There is an obvious end-game effect: the likelihood of cartel formation decreases substantially after round 35. This effect is stronger in FPSB than in EN.

Result 7

In the final 5 rounds, subjects are less likely to vote in favor of cartel formation. This end-game effect is stronger in FPSB than in EN.

Subjects' willingness to join a cartel translates into the number of cartels formed. Recall that a cartel forms if, and only if, all group members are in favor of cartel formation. As preferences for cartel formation are distributed randomly across groups, the fraction of cartels formed is below the fraction of subjects willing to join a cartel. Figure 6 displays the fraction of cartels formed in each period. Treatment effects are more pronounced in FPSB than in EN. In case of the latter, only LENIENCY stands out clearly. Especially in FPSB there is a marked end-game effect: in the final rounds fewer cartels form.

Figure 6: Fraction of cartels formed over time



To capture the dynamics in the first 35 rounds, we estimate for each treatment a first-order Markov chain. Table 7 includes the ML-estimates of the per-period transition probabilities, together with the implied limiting fractions and the observed fractions.[11] Comparing these shows that the estimated transition matrices capture accurately the dynamics of the underlying process.

In the long run, absent an active competition authority, 72% of all groups forms a cartel in EN, which is significantly below the 77% in FPSB.[12] In EN, this fraction drops to 69% in DETECT & PUNISH in EN, which is significant. The effect of possible cartel detection and fine payments is much stronger in FPSB: only 44% of all groups establish a cartel in the long run. The leniency program has a strong effect in both auctions. When it is in place about half of all groups establish a cartel in EN; in FPSB this is about one third. To sum up:

<u>Result 8</u>

Introduction of possible cartel detection and concomitant fine payments reduces the number of cartels formed significantly. Introduction of a leniency program significantly reduces cartel formation further. The influence on cartel formation of the various competition policies is stronger in FPSB than in EN.

[11] The transition matrices are estimates using the data from the first 35 periods only to avoid end-period effects; the observed fractions are also based on these first 35 periods. Note that the entries in Table 5 are based on all observations.

[12] To examine the statistical equivalence of transition matrices we use a non-parametric Chi^2-test; see e.g. Proudman and Redding (1998).

Table 7: Transition probabilities of cartel formation.

EN											
AGREEMENT				DETECT & PUNISH				LENIENCY			
714		To		*510*		To		*816*		To	
		No	Yes			No	Yes			No	Yes
From	No	0.70	0.30	From	No	0.57	0.43	From	No	0.81	0.19
	Yes	0.12	0.88		Yes	0.20	0.80		Yes	0.18	0.82
Ergodic distribution				Ergodic distribution				Ergodic distribution			
		No	Yes			No	Yes			No	Yes
Observed		0.31	0.69	Observed		0.34	0.66	Observed		0.50	0.50
Implied		0.28	0.72	Implied		0.31	0.69	Implied		0.49	0.51
FPSB											
AGREEMENT				DETECT & PUNISH				LENIENCY			
816		To		*918*		To		*714*		To	
		No	Yes			No	Yes			No	Yes
From	No	0.48	0.52	From	No	0.76	0.24	From	No	0.88	0.12
	Yes	0.16	0.84		Yes	0.29	0.71		Yes	0.26	0.74
Ergodic distribution				Ergodic distribution				Ergodic distribution			
		No	Yes			No	Yes			No	Yes
Observed		0.23	0.77	Observed		0.56	0.44	Observed		0.69	0.31
Implied		0.23	0.77	Implied		0.55	0.45	Implied		0.68	0.32

Notes: Estimates are based on the first 35 rounds of the experiment; the numbers in italics are the number of transitions for that particular treatment and auction.

The limiting fractions refer to the shape of the distribution in the long run. To capture the persistence of cartel formation over time the transition matrices are translated into a persistence index. Let M be a transition matrix and let k be the number of classes. We then compute for each matrix (see Shorrocks, 1978):

$$P = \left(k - tr(M)\right) / (k-1) \tag{3}$$

The value of P lies between 0 and 1; a more persistent process yields a lower value of P. The values of the persistence index are in Table 8. The process of cartel formation is most persistent in LENIENCY; it yields the highest probability to remain in the same state (cartel or non-cartel) from one period to the next. The auctions differ in persistence for the other treatments. In EN persistence is the weakest in DETECT & PUNISH; especially the probability to remain a non-cartel is with 57% low. This probability increases to 70% in AGREEMENT, while the probability to

remain a cartel increases from 80% to 88%. In FPSB on the other hand, competition policies make the process of cartel formation always more persistent. That is:

Result 9

Cartels and non-cartels are most persistent in LENIENCY. In FPSB, cartels and non-cartels are more persistent in DETECT & PUNISH than in AGREEMENT; in EN, cartels and non-cartels are more persistent AGREEMENT than in DETECT & PUNISH.

Table 8: Persistence of cartel formation

	FPSB	EN
AGREEMENT	0.69	0.42
DETECT & PUNISH	0.53	0.63
LENIENCY	0.38	0.37

Notes: Indices are computed using the entries in Table 7.

3.3 *Cartel stability*

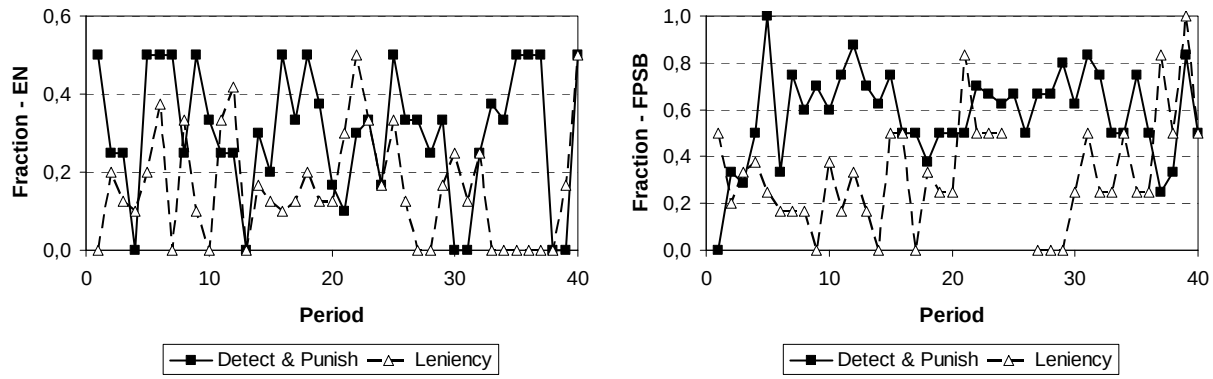
Once cartels are formed, would prospective fine payments and/or leniency programs de-stabilize them? Empirical studies suggest they do (Levenstein and Suslow, 2006, 2009; Brenner, 2009; Miller, 2009). Cartel stability can be defined in several ways. A strong definition states that a cartel is stable if, and only if, all bidders stick to the cartel agreement. For our experiment, this means that a cartel is stable if, and only if, the non-designated winners abstain from bidding. Defined in this way, Table 9 suggests that cartels are less stable in DETECT & PUNISH than in both AGREEMENT and LENIENCY. This finding seems stronger in FPSB than in EN.

Table 9: Cartel stability

	Non-designated winners stick to agreement		Designated winner wins		Cartel revealed	
	FPSB	EN	FPSB	EN	FPSB	EN
AGREEMENT	59%	80%	60%	93%	0%	0%
DETECT & PUNISH	40%	70%	44%	81%	11%	11%
LENIENCY	68%	83%	60%	85%	71%	53%

Figure 7 displays the defection behavior over time. In both auctions there is no clear time pattern. We do observe that the difference between DETECT & PUNISH and LENIENCY is more pronounced in FPSB than in EN.[13]

Figure 7: Fraction of cartel members deviating over time



Another, weaker, indicator of cartel stability is whether the designated winner actually wins the object. Table 9 indicates that the conclusions will not change much in comparison with the ones we draw on the basis of the stronger definition. Note that for EN, the designated winner wins in many instances in which another bidder in the cartels deviated. That is, the designated winner reacts to a deviation by topping a non-designated winner's bid.

To further explore a non-designated winner's decision to deviate by submitting a bid, we estimate a binomial logit model with random effects similar to (2), whereby

$$y_{jit}^{XY} = 1 \Leftrightarrow \text{non-designated winner } j \text{ in group } i \text{ submits a bid.}$$

Table 10 contains the regression results (the benchmarks are DETECT & PUNISH and FPSB). Considering cartel stability across auctions first, the estimates in Table 10 show that:

<u>Result 10</u>

Subjects are more likely to defect in FPSB than in EN. The likelihood of cartel defection increases substantially after round 35. This end-game effect is stronger in FPSB than in EN.

[13] The missing values under LENIENCY in periods 25 and 26 in FPSB are due to no cartels being formed in those periods.

Table 10: Cartel defection

	Coefficient
Constant	–0.565 (0.355)
A	–1.012*** (0.389)
$T^{\text{AGREEMENT}}$	–0.603 (0.449)
T^{LENIENCY}	–0.818* (0.492)
E × (t – 35)	0.159** (0.075)
(1 – A) × E × (t – 35)	0.204** (0.103)
LR-test random effects	$p < 0.001$

Notes: Standard errors are within parentheses; ***, **, and * denote statistical significance at the 1%, 5%, and 10% level respectively; the LR-test for random effects tests $u = 0$.

Results 4, 5, 7, and 10 are in line with Robinson's (1985) and Marshall's and Marx' (2007) theory that cartels in EN are more stable than in FPSB. Subjects are more likely to defect in FPSB than in EN and establish lower average winning bids in EN than in FPSB. Moreover, end-game effects are stronger in FPSB than in EN: In the final 5 rounds of the experiment, (1) winning bids increase more, (2) the decrease in subjects voting in favor of cartel formation is higher, and (3) likelihood of defection increases more in FPSB than in EN. However, our data do not confirm the conclusion that cartels are stable even in a one-shot setting: In EN, subjects form fewer cartels in the final rounds of the experiment.

Perhaps more important is the perverse effect of the leniency program revealed in Table 10: non-designated winners are less likely to submit a bid in LENIENCY than in DETECT & PUNISH. Put differently, non-designated winners defect less in LENIENCY than in DETECT & PUNISH. Hence:

<u>Result 11</u>

Introducing a leniency program makes cartels more stable.

To examine *why* leniency programs induce less defection, we consider subjects' decision to report the cartel. Figure 8 displays the fraction over time of cartel members in LENIENCY that report the cartel. Although this fraction varies considerably over time, there is no obvious time pattern, nor are there marked differences between EN and FPSB.

Figure 8: Fraction of cartel members reporting over time

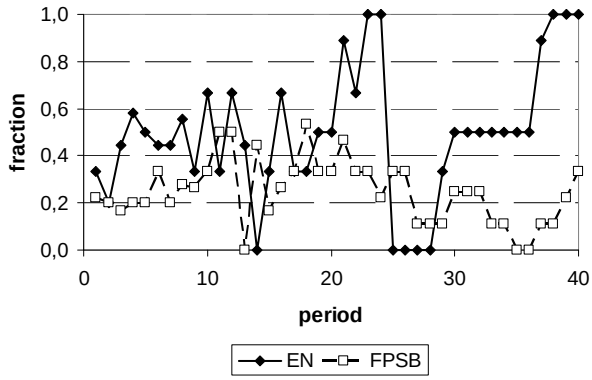
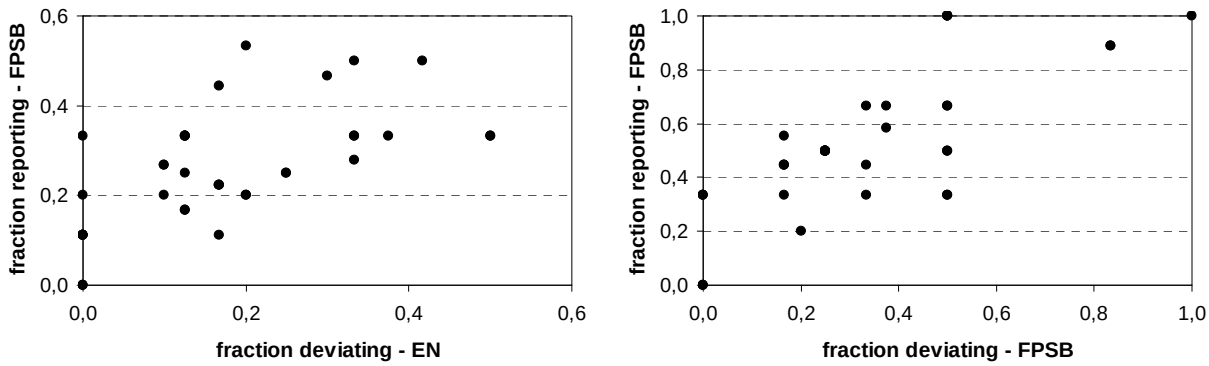


Figure 9: Fraction of cartel members reporting versus fraction of cartel members deviating



Theory suggests that if leniency is available, a defecting cartel member should always file for leniency (Spagnolo, 2000). Figure 9 supports this notion as it shows a clear positive correlation between the fraction of cartel members defecting from the cartel agreement and the fraction of cartel members denouncing the cartel. It thus seems that the possibility to report the cartel strengthens cartel stability as any deviating cartel member realizes that defection triggers cartel revelation. To examine this suggestion we estimate the following random effects binomial logit model in which we explain the decision to report for subjects who formed a cartel in treatment LENIENCY.

$$
\begin{aligned}
r_{jit}^{*X} &= \beta + \gamma_1 A_{it}^X + \gamma_2 D_{it}^X + \gamma_3 D_{it}^X A_{it}^X + \gamma_4 D_{it}^X W_{it}^X + \gamma_5 NW_{it}^X + \gamma_6 NW_{it}^X A_{it}^X + \\
&\quad + \gamma_7 B_{it}^X + \gamma_8 B_{it}^X D_{it}^X + \gamma_9 B_{it}^X NW_{it}^X + \varphi_1 E_{it}\left(t-35\right) + \varphi_2 A_{it} E_{it}\left(t-35\right) + \varepsilon_{jit}^X + u_i^X \qquad (4) \\
r_{jit}^X &= 1 \Leftrightarrow r_{jit}^{*X} \geq 0,
\end{aligned}
$$

$j = 1,2,3$, $j \in i = 1,2,\ldots,n^{XY}$, $t = 1,\ldots,40$, and X = EN, FPSB, whereby B denotes the winning bid and dummy variables r, D, NW, and W are defined as follows:

$r_{jit}^{X} = 1 \Leftrightarrow$ subject j in group i reports the cartel.

$D_{it}^{X} = 1 \Leftrightarrow$ group i deviated from the cartel agreement in auction X in period t

$NW_{it}^{X} = 1 \Leftrightarrow$ in group i the designated winner did not win in auction X in period t

$W_{jit}^{X} = 1 \Leftrightarrow$ subject j in group i is the designated winner in auction X in period t

Table 11: Reporting decision in LENIENCY

	Coefficient
Constant	–1.487 ** (0.746)
A	–1.144 (1.023)
D	1.529 *** (0.536)
D × A	–0.458 (0.745)
D × W	–0.459 (0.376)
NW	0.883 (0.789)
NW × A	0.824 (0.770)
B	0.134 (0.131)
B × D	0.063 (0.142)
B × NW	–0.184 (0.128)
E × (t – 35)	0.050 (0.157)
A × E × (t – 35)	–0.819 (0.580)
LR-test random effects	$p < 0.001$

Note: Standard errors are within parentheses; ***, **, and * denote statistical significance at the 1%, 5%, and 10% respectively; the LR-test for random effects tests $u = 0$.

The regression results are summarized in Table 11. Clearly, cartel defection is a strong motivation for any cartel member to report the cartel. Perhaps more importantly, it is the *only* factor that induces cartels to be reported. In sum:

<u>Result 12</u>

Both the designated winner and the other cartel members are more likely to report the cartel if defection has occurred. The reporting decision is not influenced by the auction type, the height of the winning bid, whether a subject is the auction winner, whether the designated winner wins the auction, or the round number.

This result supports the idea that bidders use a leniency program as an additional stick to punish defectors. In case of defection all bidders are more likely to report the cartel; the designated winner may report the cartel in order to punish a defecting bidder, who in turn may also report because she anticipates reports by the other bidders.

4. CONCLUSIONS

We have studied the effectiveness of leniency programs in experimental auctions. Our main conclusions are as follows. First, the traditional competition policy of cartel detection and punishment is by and large an effective instrument. The number of cartels decreases, the average winning bid increases, and the average winning cartel bid increases.

Second, the leniency program we examine is only partially successful. On the one hand it deters cartel formation and it leads more cartels to be revealed. On the other hand, cartels that do form are less likely to experience cartel defection because members use the possibility to report the cartel as an additional stick to discipline cartel behavior. In fact, cartel defection is the only reason for designated and non-designated winners to report the cartel. As a result, the leniency program does not increase the average winning bid, nor the average winning cartel bid. These findings qualify the acclaimed success of leniency programs.

Third, while on aggregate EN and FPSB produce roughly the same results, we observe substantial differences in outcomes between EN and FPSB at a more detailed level. Bidders who do not form a cartel establish lower winning bids in FPSB than in EN, while cartels in EN are better able to reduce the winning bid than cartels in FPSB. Moreover, we observe less defection from the cartel agreement in EN than in FPSB. Finally, end game effects are stronger in FPSB than in EN. Therefore, if an auctioneer has a strong indication that bidders have formed a cartel prior to the auction, our findings suggest that he should use FPSB instead of EN.

APPENDIX: INSTRUCTIONS

The instructions are computerized. Subjects could read through the html-pages at their own pace. Below is a translation of the Dutch instructions for treatment LENIENCY with the English auction.

Welcome!

You are about to participate in an auction experiment. The experiment consists of 40 rounds, and each round consists of 3 steps.

At the beginning of the experiment, all participants will be randomly divided in groups of 3 members. During the entire experiment, you will stay in the same group.

Group members remain anonymous; you will not know with whom you are matched. Moreover, there will not be contact between separate groups.

In every round of the experiment, you can earn points. At the end of the experiment, points will be exchanged for Euros. The exchange rate will be

1 point = € 0.25

At the beginning of the experiment, you will receive a starting capital of 28 points. At the end of every round, the points you will earn in this round will be added to your capital. If you earn a negative number of points in a round, these points will be subtracted from your capital.

In the remainder of these instructions, we will present an overview of the experiment followed by a further explanation of the 3 steps of each round. We will conclude with examples and test questions.

Overview of the experiment

You aim at buying a product in an auction, just like the other two members of your group. Only 1 item of the product is available in each round. In every round, you can bid in an auction.

In step 1 of the experiment, before the auction, you will get the opportunity to make an agreement with your group members about who will win the auction. An agreement will only be made if all group members desire to do so. An agreement is not binding, though.

In step 2, you and the other two group members will bid in the auction. You will earn points if you win the auction. If you win, the number of points that you earn in the auction will be equal to

10 – your winning bid

Overview of the experiment (continued)

If your group makes an agreement, you and your group members run the risk that points will be subtracted from your score. This happens in either of the following two cases:

1. You or one of your group members report the agreement.

2. Chance determines that you and your group members lose points. The probability that this happens equals 15%.

In both cases, 10 points will be subtracted from your score.

The possibility to report is step 3 of every round. Reporting an agreement costs one point. If you report, the number of points that you lose can be reduced or even eliminated.

Now, further specification of the separate steps follows.

Step 1: Agreement

In step 1 of every round, you will be asked the following question: "Would you like to make an agreement? If yes, press the YES button. If not, press the NO button." You must answer YES or NO. The other two group members will have to make the same decision at the same time.

If all group members choose YES, an agreement will be made. The agreement will be that only one of the three group members will submit a bid. The others will not bid.

Chance determines who of the three group members will submit a bid according to the agreement. This agreement is not binding, though.

If one or more group members press the NO button, there will not be an agreement.

Step 1: Agreement (continued)

The group member the computer picks out to submit a bid, will pay the two other group members 2.5 points, so 5 points in total.

If an agreement is made, you will run the risk to lose points in this round because one or more of your group members report the agreement.

If nobody reports the agreement, you and your group members can still lose points if chance determines so. In that case, the probability of losing points is 15%.

In both cases, you will lose 10 points.

Step 2: The auction

The auction consists of several rounds. The winner of the auction obtains 10 points. You don't have to stick to an agreement (if any). This also holds true for the other two group members.

In every auction round, you can submit a bid by entering one of the following numbers:

0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

You can also indicate not to enter any number. If you decide to do so, you will step out of the auction and you cannot submit a bid in later rounds of the auction.

In every round of the auction, bidders can only choose a higher number than the currently highest bid. The bidder with the current highest bid is the provisional winner of the object. In the

case of identical highest bids, chance determines who of the highest bidders will become the provisional winner.

Step 2: The auction (continued)

In each round of the auction, the provisional winner cannot submit a bid. Only the other group members can do so.

The provisional winner will win the auction if the other group members decide not to enter a number. In that case, the winner will pay his highest bid (entered in the previous round). The earnings in the auction for the winner is then equal to

10 – winning bid

A bid of 10 guarantees that someone wins the auction, provided that none of the other bidders has also submitted a bid of 10. If several group members bid 10, chance determines who will win the auction.

If all group members decide not to submit a bid in the first round, nobody will win the object.

Step 3: Reporting

Step 3 will only take place if an agreement is made in the current round.

You can report the agreement by pressing the YES button. If you decide not to report, press the NO button. The other group members have to make the same decision. Reporting costs one point.

If your group has made an agreement and none of the group members reports, each group member loses 10 points with 15% probability.

Step 3: Reporting (continued)

Reporting decreases the number of points that you lose as follows.

- If you are the only one who presses the YES button, the number of points that you lose reduces by 10 (you lose 0 points).
- If you and only one other group members press the YES button, the number of points that you lose reduces by 10 with 50% probability (you lose 0 points) and by 5 with 50% probability (you lose 5 points).
- If you and the other two group members press the YES button, the number of points that you lose reduces by 10 with 33.3% probability (you lose 0 points), by 5 with 33.3% probability (you lose 5 points), and by 0 with 33.3% probability (you lose 10 points).

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