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Going Once, Going Twice, Reported!

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

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ABSTRACT:

We experimentally examine the effectiveness of antitrust policies against bidding rings in the English auction (EN) and the first-price sealed-bid auction (FP). We consider both traditional antitrust policy (without a leniency program) and modern antitrust policy (with a leniency program). In EN, neither antitrust policy has a significant effect on cartel deterrence, cartel stability, cartel recidivism, and winning bids. In FP, traditional antitrust policy deters cartel formation, destabilizes cartels, reduces the probability that a cartel re-establishes, and reduces the average winning bid. In contrast, while a leniency program has no additional effect on cartel formation or cartel recidivism, it makes cartels more stable and reduces the winning cartel bid.

KEYWORDS: Antitrust policy; Leniency Programs; English Auction; First-Price Sealed-Bid Auction; Laboratory Experiments

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1. INTRODUCTION

Antitrust policies are actively enforced in all modern economies and price-fixing agreements are continuously revealed.[1] A large fraction of these agreements involve auctions. Cartel cases where an oral or English auction (EN) was used include the sale of tobacco (Phillips *et al.*, 2003) and stamps (Asker, 2010), while a first-price sealed-bid auction (FP) was used for school milk tenders (Porter and Zona, 1999) and infrastructure procurement (Bajari and Ye, 2003).[2] More generally, in the US in the 1980s, 75% of all cartel cases were related to auctions (Krishna, 2009).

In this paper, we experimentally examine how effective antitrust policies are against cartel activity in both EN and FP. We consider both traditional antitrust policy (without a leniency program) and modern antitrust policy (with a leniency program). Our research question is not only of academic interest. First of all, a substantial fraction of goods are traded in auctions. For example, public procurement alone comprises about 15% of worldwide GDP (OECD, 2008). Second, both sealed-bid and open auction formats are commonly used in practice. Procurement auctions tend to be of the sealed-bid type (see, e.g., Carpineti *et al*., 2006) while art and radio spectrum for mobile telecommunication applications are typically sold in ascending auctions (see, e.g., Ashenfelter and Graddy, 2003, and Klemperer, 2002, respectively.). Third, our experiment could inform antitrust authorities on which auction type they should concentrate their scare detection resources.

Ever since the advent of antitrust laws, antitrust authorities have tried to detect and punish cartels (Mueller, 1996). Bryant and Eckard (1991) estimate that in a given year, between 13% and 17% of the existing price-fixing agreements are detected (Combe *et al*., 2008, find a similar detection rate in a more recent study). To increase the effectiveness of antitrust policy, in the past few decades most developed countries have introduced leniency programs. According to these programs cartel members can qualify for fine reductions in return for reporting their cartel.[3] Leniency programs may work well if cartel members find it attractive to denounce the cartel in

[1] Harrington (2006) reviews the operations of some 20 cartels that were fined by the European Commission in the period 2000 – 2004. Connor (2003) surveys 167 international cartels that were discovered after January 1990.

[2] In FP, each bidder independently submits a concealed bid and the winner is selected among the highest bidders and pays her bid. In EN, the price is raised successively until one bidder remains who wins the object at the final bid.

[3] The United States adopted the first leniency program in 1978; the European Commission implemented its first program in 1996 (Hinloopen, 2003). Meanwhile, leniency programs are part of antitrust law in all modern economies, although the details of the programs typically differ between jurisdictions; see OECD (2002). These differences may help cartel members to coordinate on reduced self-reporting (Choi and Gerlach, 2012).

return for reduced fines. The theoretical support for leniency programs is mixed however. The effectiveness of a leniency program depends crucially on its details 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).[4] 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).

A number of recent studies have examined the effectiveness of antitrust policies in the laboratory.[5;6] Lab experiments have the advantage over field studies that the latter only allow for indirect measures regarding undiscovered cartels (see Miller, 2009, and Brenner, 2009).[7] In a pioneering study, Apesteguia *et al*. (2007) examine the effect of leniency programs in a one-shot homogeneous-goods Bertrand game where each market consists of three players. Subjects could form a cartel before submitting a price. After the pricing decision, each subject had to decide whether or not to report the cartel if there was one to report. A leniency program that offered a fine reduction turned out to work quite well: The average price was lower than in the absence of a leniency program and coincided with that obtained when the possibility to form a cartel was

[4] 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 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).

[5] Explicit collusion has received surprisingly little attention in the experimental literature on auctions (for an overview, see Kagel, 1995). In almost all auction experiments, subjects do not have the possibility to form a cartel before the auction. Only a handful of studies consider explicit collusion in an experimental auction (Phillips *et al*., 2003; Sherstyuk and Dulatre, 2008; Hu *et al*., 2011; Hinloopen and Onderstal, 2013). 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 the current paper.

[6] 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. In their design, however, subjects are forced to collude, which makes it less suitable for a study into the effectiveness of antitrust policy. Hamaguchi *et al.* (2007) examine the effect of antitrust policies in sealed-bid procurement auctions. Their leniency program turns out to be equally effective as traditional antitrust policy in terms of cartel deterrence and winning bids. Their design differs in several dimensions with the ones in the literature and ours. First of all, the number of competitors equals five instead of two or three. Second, partial cartels could form. Third, cartels communicated in a 'chat room' that was 'monitored' by another experimental subject. Further, the antitrust authority could detect individual cartel members rather than the entire cartel. Moreover, the cartel fine was calculated as a percentage of an individual's gross earnings in the last three periods.

[7] Levenstein and Suslow (2006, 2011) study the properties of revealed cartels in the field.

blocked. At the same time, the leniency program did not affect the fraction of cartels formed. A 'bonus treatment' (inspired by Spagnolo, 2000), whereby the fines collected per cartel were distributed evenly among the whistle blowers of that cartel, performed 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 directions: subjects interact repeatedly, a cartel can be detected and punished even if it is not reported, and the fine reductions depend on the order of leniency application. Hinloopen and Soetevent (2008) find that traditional antitrust policy (i.e., without a leniency program) has no effect on the average price, cartel stability, or cartel recidivism compared to a situation without antitrust authority. Traditional antitrust policy only has a desirable effect in that it deters cartel formation, although not completely. Hinloopen and Soetevent (2008) also observe that antitrust policy is more successful with a leniency program: It reduces the average price, it destabilizes cartels, and it reduces the probability that a cartel is re-established; it also has a stronger cartel deterrence effect than traditional antitrust policy.

Bigoni *et al*. (2012) introduce another innovation: to allow subjects to report cartels 'secretly', i.e., before the pricing stage. This enables the authors to distinguish between two reasons for applying for leniency: to escape a possible fine payment, and to punish defecting cartel members. Bigoni *et al*. (2012) find that traditional antitrust policy deters cartel formation, that a leniency program strengthens this deterrence effect, and that cartels are deterred less in a bonus treatment à la Apesteguia *et al*. (2007). They further observe that the leniency program has a strong effect on cartel recidivism: after a cartel has been reported, the probability that a new cartel is established is reduced significantly compared to traditional antitrust policy. Finally, and perhaps most surprisingly, they observe that traditional antitrust policy has a perverse effect on price, mainly because cartels that do form are more stable. A possible explanation is that subjects report the cartel to punish deviating cartel members, even though they do not qualify for a fine reduction if they do so.

In contrast to the above studies, we examine auctions instead of Bertrand oligopolies. In our design, subjects repeatedly bid against the same bidders in either EN or FP in groups of three. We have three treatments. In AGREEMENT, subjects can engage in non-binding cartel agreements, but cartels cannot be detected or reported. In DETECT & PUNISH, cartels are detected and fined with 15% probability. The same holds true for LENIENCY, where bidders can also report the

cartel in return for a fine reduction.[8] The main difference between EN and FP is that only in the former collusion is always incentive compatible because designated winners can react to deviation by increasing their own bid (Robinson, 1985; Marshall and Marx, 2007). Hence, antitrust policies should have no effect on cartel activity in EN. For FP, we hypothesize that subjects are less likely to (re)establish a cartel, are more likely to deviate from a cartel agreement, and establish higher winning bids in DETECT & PUNISH than in AGREEMENT. The leniency program makes defection less attractive as it triggers the cartel to be reported. In LENIENCY we thus expect more cartels, less deviation, more cartel recidivism, and lower winning bids than in both DETECT & PUNISH and AGREEMENT.

Most, but not all, of our results are in line with our predictions. Antitrust policies tend to be ineffective in EN: We do not observe significant treatment differences in terms of cartel deterrence, cartel stability, cartel recidivism, or winning bids. In FP antitrust policies do have an effect. In DETECT & PUNISH, we observe significantly fewer cartels, a higher fraction of unstable cartels, less cartel recidivism and higher winning bids than in AGREEMENT. That is, traditional antitrust policy tends to have the desired effects in FP. The leniency program, on the contrary, has the perverse effect that cartels are more stable and realize lower winning bids in LENIENCY than in DETECT & PUNISH. In contrast to our predictions, we do not observe significant treatment effects between LENIENCY and DETECT & PUNISH on cartel deterrence, cartel stability, cartel recidivism, or winning bids.

The set-up of the remainder of this paper is as follows. Section 2 presents our experimental design, followed by our hypotheses in Section 3. In Section 4, we discuss the experimental results. Section 5 concludes.

2. PROCEDURES AND EXPERIMENTAL DESIGN

The computerized experiment was conducted at the Center for Research in Experimental Economics and political Decision making (CREED) of the University of Amsterdam. Students were recruited by public announcement from the university's entire undergraduate population. In total 132 students participated in one of six sessions. At the beginning of each session, the show-up fee of € 7 was transferred to 28 points for all subjects that entered the experiment. The

[8] We do not consider secret reports because an auctioneer will call off the auction if he has proof that bids are rigged. In this respect, auctions differ fundamentally from oligopolies with continuous sales.

exchange-rate of 1 point = € 0.25 was use throughout the experiment. Sessions lasted 60 to 90 minutes during which subjects earned € 16.74 on average.

Table 1: Number of subjects (groups) per treatment

	FP	EN
AGREEMENT	24 (8)	21 (7)
DETECT & PUNISH	27 (9)	15 (5)
LENIENCY	21 (7)	24 (8)

Groups of three subjects were formed randomly at the beginning of each session, all of which consisted of 40 periods. Groups did not change during a session and communication between groups was not possible. Each group, therefore, constitutes a statistically independent unit of observation (see Table 1). In each period, group members competed for an abstract object with a common value of 10.[9] Either EN or FP was used in one of three different treatments: AGREEMENT, DETECT & PUNISH, and LENIENCY.[10] LENIENCY is the most elaborate treatment. Every period 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.[11] Subjects only learn whether a cartel has formed, not the individual votes. If a cartel is established, a designated winner is randomly assigned. This subject pays 2.5 points to both other subjects in her group (5 points in total).[12] The cartel agreement is that the designated winner is the only one submitting a bid. The other group members (the "designated losers") are to abstain from bidding. This agreement is nonbinding, though.[13]

[9] Because this is the first experimental study that compares the effects of antitrust policies in different auctions, we decided to keep the experimental design as simple as possible leaving more complex settings with incomplete information and/or private values for further research. Moreover, we are interested in the collusive properties of both EN and FP in relation to antitrust policy, and not so much on their role to elicit private information.

[10] Unlike Apesteguia *et al.*'s (2007) and Bigoni *et al.*'s (2012), we do not include a 'bonus treatment' to stay as close as possible to leniency programs in practice (where whistle blowers typically do not obtain a reward other than a fine reduction).

[11] See Clemens and Rau (2012) for an experimental study of partial cartels.

[12] These side-payments are introduced to make the potential gains from joining the cartel not too asymmetric between designated winners and losers in order to diminish behavior driven by inequality-aversion. Note that these side-payments do not affect the collusive properties of both EN and FP as they constitute a sunk cost (Robinson, 1985). Also, in practice, it is quite common for the designated winner to pay side-payments (Asker, 2010).

[13] Hinloopen and Soetevent (2008) introduce a structured price-discussion upon cartel formation (which is adopted by Bigoni *et al*., 2012) whereby cartel members have to submit consecutive admissible ranges for the (non-binding)

Step 2: Auction. This step differs between EN and FP. In FP, 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, and there was no auction winner if all subjects chose not to submit a bid). Her earnings are equal to the difference between the common value of the object and her bid. EN on the other hand consists of several auction rounds. The first auction round is the same as FP, with the exception that the highest bidder only becomes the provisional winner. In subsequent auction rounds, bidders must bid strictly higher than the currently highest bid. The provisional winner in the previous auction round cannot submit a bid in the current auction round. 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 from a certain auction round wins the auction if both other group members do not submit a bid in the next auction 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 period, 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 (as in Hinloopen and Soetevent, 2008). This cost reflects administrative costs, legal fees, and possibly other consultant fees that firms typically incur when filing a leniency application. It also 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:[14]

- 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.

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cartel price. In almost all cases this process converged quickly to the joint profit-maximizing (monopoly) price. Because of this quick and widespread convergence we have not included this type of price discussion.

[14] The random draws mimic the situation that at the moment that a firm reports the cartel to the antitrust authorities it does not know if other firms have already done so.

If, and only if, the cartel is not reported, a competition authority will detect the cartel with 15% probability.[15] Hence, if a cartel is revealed subjects know whether that is due to reporting or not. In case of detection all group members pay the full fine of 10 points.

The period 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. Appendix A includes the instructions for EN with treatment LENIENCY.

Table 2: Treatments

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

AGREEMENT only consists of steps 1 and 2 and models a setting without antitrust authority in the sense that cartels cannot be detected. DETECT & PUNISH also includes only steps 1 and 2. It models traditional antitrust policy as cartels can be detected (with 15% probability) and punished (upon detection, all group members have to pay a fine of 10 points). Table 2 summarizes the treatments.

3. HYPOTHESES

In this section, we develop a number of hypotheses with respect to cartel deterrence, cartel stability, cartel recidivism and winning bids. Cartel deterrence is the opposite of cartel formation: a particular antitrust policy is successful in deterring cartels if fewer cartels form than absent the policy. We follow Robinson (1985) in our definition of cartel stability: a cartel is stable if, and only if, all designated losers abstain from bidding. Cartel recidivism refers to the probability a cartel is re-established in the next period. In our analysis, we assume that bidders do not collude tacitly: Bidders need to form a cartel to establish a winning bid lower than the winning bid in a

[15] This probability is in line with the annual cartel detection rates documented by Bryant and Eckard (1991) and Combe *et al.* (2008). Hinloopen and Soetevent (2008) also used an exogenous cartel detection rate of 15%.

one-shot Nash equilibrium.[16] To obtain a measure of the incentives for bidders to form a cartel and to stick to the cartel agreement that the designated winner is the only one submitting a bid, we have derived the minimum number of periods bidders require for stable cartels to be sustained in a subgame-perfect equilibrium (see Table 3).

Despite the fact that bidders only interact in a finite number of periods, they can establish stable cartels (i.e., only the designated winner enters the auction and bids zero) in equilibrium. They can do so for the following reasons. First of all, in EN, the designated winner can punish a deviating designated loser by driving up the price in the current auction. More in particular, the following cartel strategy constitutes a Nash equilibrium (see, e.g., Robinson, 1985): the designated losers abstain from bidding, the designated winner bids zero and, as long as any other bidder is active in the auction, continues raising the price up to the point where it equals the object's value.[17] It is readily verified that this bidding strategy establishes stable cartels in equilibrium up to the final period in AGREEMENT and DETECT & PUNISH. Note that in LENIENCY, reporting the cartel is a dominant strategy in the one-shot case. As a consequence, the costs of forming a cartel (1 for reporting the cartel plus 5 for the expected fine) do not outweigh the expected benefits (even if the cartel manages to drive the price down from 9 to 0, the expected benefits are only 3 per cartel member). It takes at least three periods for a stable cartel to be feasible in equilibrium. In that case, bidders can punish a cartel member that reports the cartel by driving up the price to 10 in the final two periods.

Table 3: The most profitable price path sustainable in a subgame-perfect equilibrium[a]

# remaining periods		16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
EN	AGREEMENT	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
	DETECT & PUNISH	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
	LENIENCY	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	9	9
FP	AGREEMENT	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	***0***	***1***	***4***	***6***	***7***	***8***	9
	DETECT & PUNISH	**0**	***0***	***0***	***2***	***3***	***4***	***4***	9	9	9	9	9	9	9	9	9
	LENIENCY	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	***0***	***0***	***1***	9	9

[a] Numbers in bold [bold italics; regular font] mark stable cartels [unstable cartels; no cartel].

[16] In a review of Cournot experiments, Huck *et al*. (2004) conclude that tacit collusion "is very rare in markets with more than two firms." Dufwenberg and Gneezy (2000) and Fonseca and Normann (2012) find the same result in a homogeneous Bertrand oligopoly. In auction experiments, subjects hardly ever manage to collude tacitly (see Kagel, 1995).

[17] In contrast to EN, stable cartels are not an equilibrium outcome in FP in the one-shot case (Robinson 1985).The experimental results of Hinloopen and Onderstal (2013) support this theoretical result: in a one-shot setting all cartels that form in FP break down.

This brings us to the second reason why bidders can establish stable cartels in equilibrium: Deviation can be punished by reverting to an unattractive one-shot Nash equilibrium in later periods. Note that FP has two one-shot Nash equilibria: one in which all bid 9 and another in which all bid 10. If the game is repeated, bidders can sustain lower prices in equilibrium by playing a grim-trigger strategy where deviation from a collusive price path is punished by bidding 10 in all subsequent periods. Table 3 presents the most attractive collusive price path for AGREEMENT and DETECT & PUNISH where bidders employ this strategy. Consider, for example, interaction in AGREEMENT when there are eight periods left. A designated loser can earn 9 in the current period by entering the auction and outbidding the designated winner. However, the designated winner will punish her in all remaining seven periods by bidding 10 so that the deviating bidder forgoes 1/3 of the expected profits obtained on the equilibrium path: (10 + 9 + 6 + 4 + 3 + 2 + 1)/3 = 35/3. In the case of six or less remaining periods, stable cartels are not feasible on the equilibrium path. Bidders can still sustain prices below 9 by all entering the auction and submitting the bid displayed in table 3.

Table 3 indicates that DETECT & PUNISH requires more periods of interaction than AGREEMENT to sustain a stable cartel on the equilibrium path. The intuition is that forming a cartel is less profitable in DETECT & PUNISH than in AGREEMENT because only in the former, cartels can be detected and punished. Note that cartels are only profitable if they manage to establish a price of at most 4 because otherwise the expected benefits of forming the cartel (in order to obtain a price below the most attractive one-shot Nash price of 9) do not outweigh the expected costs (whereby all pay an expected fine of 1½ because the cartel is discovered with 15% probability).

In LENIENCY, bidders have a third possibility to enforce low winning bids in equilibrium: They can punish deviation by reporting the cartel. Bidders can exploit this feature to establish low winning cartel bids in FP. Like in EN, bidders require at least three periods for cartels to be profitable. As Table 3 shows, in the case of three (remaining) periods, bidders are able to establish a price as low as 1 in equilibrium. The reason is that a bidder deviating to a price of 2 will induce all to report the cartel. The designated loser's expected deviation profits are 2 (8 for winning the object minus reporting costs of 1 minus the expected fine of 5) while sticking to the cartel agreement yields 13/6 (expected cartel profits of 3 minus the expected fine equal to 3/2 plus expected profits of 2/3 in the remaining two periods). As Table 3 indicates, four periods are

sufficient to obtain a winning bid equal to zero in FP while bidders can establish a stable cartel in the case of five periods.

The results in Table 3 suggest that in EN, apart from the final two periods, we will not observe differences across treatments with respect to cartel deterrence, cartel stability, cartel recidivism, and winning bids; in all treatments bidders can establish stable cartels and winning bids equal to zero up to period 38. Table 3 does suggest treatment effects for FP. Indeed, if bidders follow the collusive path described in Table 3, fewer [more] stable cartels will form and average winning bids will be higher [lower] in DETECT & PUNISH [LENIENCY] than in AGREEMENT. In addition, cartels are more [less] stable in LENIENCY [DETECT & PUNISH] than in AGREEMENT. The reason is that cartels can only establish equilibrium prices above zero if in the final periods, at least one of the designated losers enters the auction (otherwise the designated winner is better off by bidding zero). Indeed, the most attractive equilibrium path has both designated losers entering the auction and submitting the same bid as the designated winner. This minimizes the incentives for designated losers to deviate from the cartel price. However, in the final periods, the cartels are no longer stable if we follow Robinson's (1985) definition of stability. Finally, in terms of cartel recidivism, forward looking bidders do not condition their behavior on a cartel being formed or not. This implies that expected treatment effects in terms of cartel recidivism are the same as those expected regarding cartel formation.

Our reasoning is based on strong assumptions with respect to bidder rationality. Still, in the case of boundedly rational bidders (cf. Dufwenburg and Gneezy, 2000), we might expect similar treatment effects. To be more specific, in DETECT & PUNISH, it takes bidders 15 periods to effectively punish deviation from the cartel agreement, while in AGREEMENT seven periods suffice and in LENIENCY five. As a consequence, a designated loser requires a weaker [stronger] belief that the other designated loser will not stick to the cartel agreement to make it attractive to deviate herself in AGREEMENT than in DETECT & PUNISH [LENIENCY].

We thus arrive at the following hypotheses. First, in EN, cartel formation, cartel stability, cartel recidivism and the average winning bid will not differ across treatments.[18] Second, in FP, antitrust policy will be more [less] successful on those four dimensions in DETECT & PUNISH [LENIENCY] than in AGREEMENT.

[18] All statistical analyses are based on the results of periods 6 through 35 to avoid possible learning and end-game effects. Including all periods yields qualitatively identical results.

4. EXPERIMENTAL RESULTS

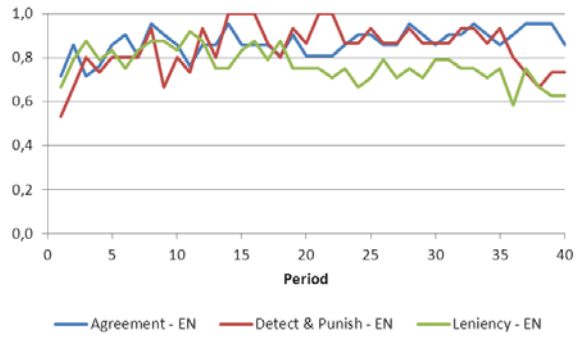
In this section, we present our experimental results. We start in section 4.1 by discussing the effects of the two antitrust policies in both auctions on the aggregate level. To explain our main results, we take a closer look at individual bidding behavior and cartel member's decisions to report a cartel in sections 4.2 and 4.3 respectively.

4.1 Aggregate results

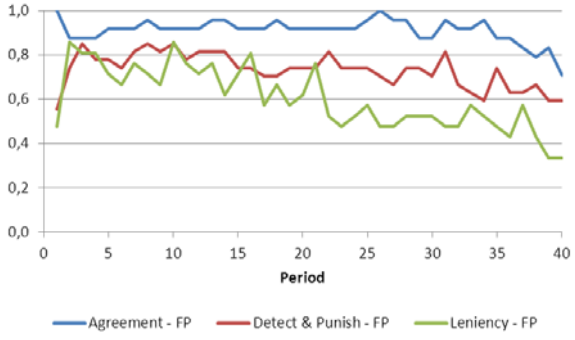
Table 4 contains the fractions of subjects in favor of cartel formation across treatments and auctions. The underlying data are listed in Appendix B, which are also mapped in Figure 1. The data show that antitrust policies do not affect cartel formation in EN, as hypothesized: subjects' propensity to collude does not differ significantly between AGREEMENT, DETECT & PUNISH, and LENIENCY. In FP, we observe fewer votes in favor of cartel formation in DETECT & PUNISH than in AGREEMENT, which is also in line with our hypotheses. However, in contrast to what we have expected, subjects are not more inclined to vote for cartel formation in LENIENCY than in DETECT & PUNISH.

Figure 1: Fraction of subjects in favor of cartel formation over time in EN (panel a) and FP (panel b)

Panel a



Panel b



Result 1 (Cartel deterrence)

In EN, cartel formation is not significantly deterred in DETECT & PUNISH or LENIENCY. In FP, cartel formation is deterred in both DETECT & PUNISH and LENIENCY; DETECT & PUNISH and LENIENCY do not differ significantly in terms of deterrence effect.

Table 4: Fraction of subjects in favor of cartel formation[a]

	AGREEMENT		DETECT & PUNISH		LENIENCY		AGREEMENT
EN	0.87	<	0.88	>	0.78	<	0.87
	^		v		v		^
FP	0.91	>**	0.75	>	0.61	<**	0.91

[a] Significance levels are calculated with exact Wilcoxon rank-sum tests, counting each group as one, independent observation; ***, ** and * indicate statistical significance at the 1%, 5% and 10% level, respectively.

Table 5 reports the fraction of designated losers defecting. Figure 2 maps these fractions over time, which are also listed in Appendix B. For EN, the data reveal a pattern in line with the results on cartel deterrence: designated losers are equally likely to defect across all treatments; that is, antitrust policies do not affect cartel stability. Antitrust policies do have an effect in FP: designated losers are more likely to defect in DETECT & PUNISH than in AGREEMENT and LENIENCY. There is no statistical significant difference in designated losers' propensity to defect between AGREEMENT and LENIENCY though.

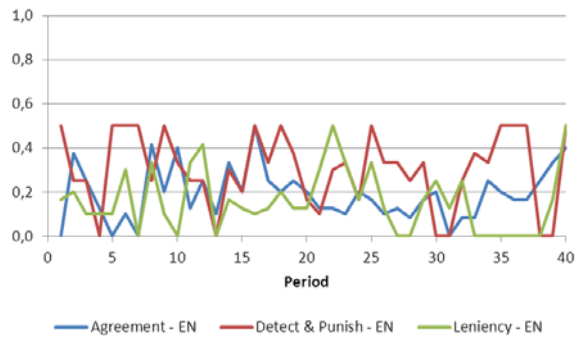
Table 5: Fraction of designated losers submitting a bid[a]

	AGREEMENT		DETECT & PUNISH		LENIENCY		AGREEMENT
EN	0.26	<	0.30	>	0.25	<	0.26
	^		^**		^		^
FP	0.43	<**	0.72	>**	0.37	<	0.43

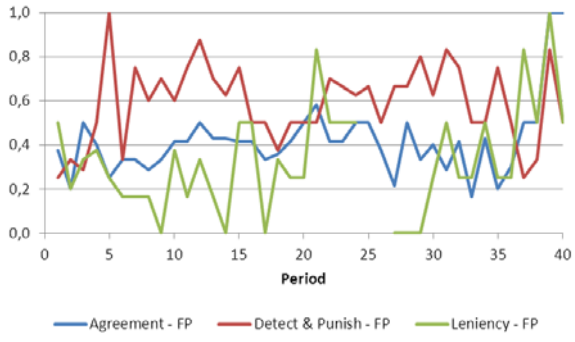
[a] Significance levels are calculated with exact Wilcoxon rank-sum tests, counting each group as one, independent observation; ***, ** and * indicate statistical significance at the 1%, 5% and 10% level, respectively.

Figure 2: Fraction of cartel members deviating over time in EN (panel a) and FP (panel b)

Panel a



Panel b



Result 2 (Cartel stability)

In EN, designated losers are equally likely to defect in AGREEMENT, DETECT & PUNISH and LENIENCY. In FP, designated losers are more likely to defect in DETECT & PUNISH than in AGREEMENT, less likely to defect in LENIENCY than in DETECT & PUNISH, and equally likely to defect in AGREEMENT and LENIENCY.

To examine cartel recidivism we consider the probability that a cartel is re-established in the next period. The results are summarized in Table 6. In EN, neither antitrust policy has an effect on cartel recidivism: the probability that a cartel is re-established in the next period is not affected significantly by introducing a detection probability nor by the previous cartel having been reported or not. In FP on the other hand, antitrust policies have a strong effect on cartel recidivism: introducing a detection probability lowers the probability that a cartel is re-estbalished in the next period, and even more so in LENIENCY. These findings support the idea that in FP the leniency program can be used to discipline cartel behavior: cartel defection triggers the cartel to be reported, which in turn makes it more difficult for the cartel to be re-established again.

Result 3 (Cartel recidivism)

In EN, cartels are equally likely to be re-established in AGREEMENT, DETECT & PUNISH and LENIENCY In FP, cartels are less likely to be re-established in DETECT & PUNISH and LENIENCY than in AGREEMENT, and equally likely to be re-established in LENIENCY and DETECT & PUNISH.

Table 6: Probability that a cartel is re-established in the next period[a]

	AGREEMENT		DETECT & PUNISH		LENIENCY		AGREEMENT
EN	0.75	>	0.70	>	0.67	<	0.75
	^		v		v		^
FP	0.79	>**	0.50	>	0.34	**<	0.79

[a] Votes are considered only after a first cartel has been established. Significance levels are calculated with exact Wilcoxon rank-sum tests, counting each group as one, independent observation; ***, ** and * indicate statistical significance at the 1%, 5% and 10% level, respectively.

Probably the most relevant indicator of the success of antitrust policies is their effect on winning bids. Table 7 lists the average winning bids across treatments for both auctions; the underlying frequency distributions are in Figure 3. In line with the previous results, in EN we do not find

treatment effects in terms of winning bids, winning cartel bids, or winning non-cartel bids. In FP, winning bids are significantly higher in DETECT & PUNISH than in AGREEMENT. This finding is consistent with the observation that cartels are less likely to form and are less stable in DETECT & PUNISH than in AGREEMENT. Likewise, cartels establish significantly lower winning bids in LENIENCY than in DETECT & PUNISH. Finally, observe that apart from DETECT & PUNISH in FP, the average winning bid for non-cartels is never statistically significantly below 9.[19] And in case of DETECT & PUNISH in FP the difference is marginal. These results support our assumption that bidders do not manage to collude tacitly.

Table 7: Winning bids

	AGREEMENT		DETECT & PUNISH		LENIENCY		AGREEMENT
			All bids				
EN	4.2	<	5.5	<	5.7	>	4.2
	^		^*		^		^
FP	4.8	<**	7.3	>	6.0	>	4.8
			Cartel bids				
EN	3.3	<	3.9	>	3.1	<	3.3
	^		^*		^		^
FP	4.0	<	5.9	>**	3.3	<	4.0
			Non-cartel bids				
EN	9.7	<	9.8	>	9.4	<	9.7
	v		v***		v*		v
FP	9.3	>*	8.8	>	7.9	<*	9.3

[a] Significance levels are calculated with exact Wilcoxon rank-sum tests, counting each group as one, independent observation; ***, ** and * indicate statistical significance at the 1%, 5% and 10% level, respectively.

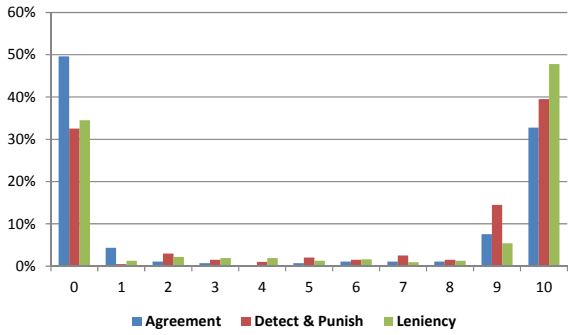
Result 4 (Winning bids)

In EN, the winning bid, the winning cartel bid, and the winning non-cartel bid do not differ significantly between AGREEMENT, DETECT & PUNISH and LENIENCY. In FP, the winning bid and the winning non-cartel bid are higher in DETECT & PUNISH than in AGREEMENT, and the winning cartel bid is lower in LENIENCY than in DETECT & PUNISH.

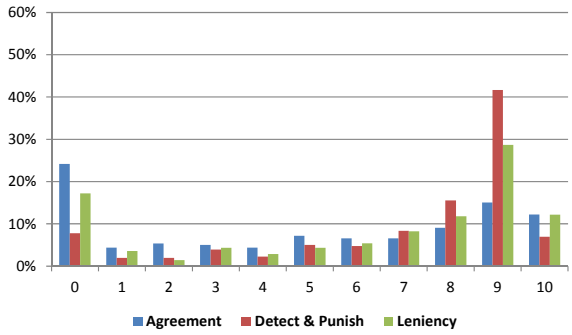
[19] In FP, p = 0.081 and p = 1.000 for DETECT & PUNISH and LENIENCY respectively.

Figure 3: Relative frequency distributions of winning bids across treatments and auctions

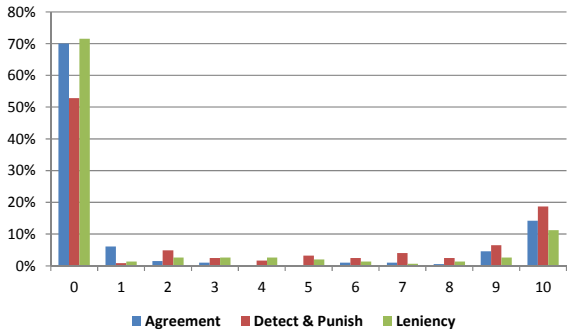
Panel a: Winning bids EN



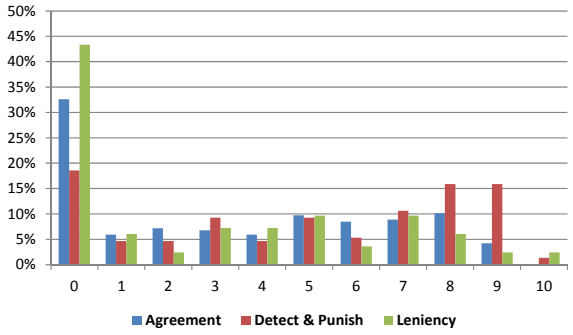
Panel b: Winning bids FP



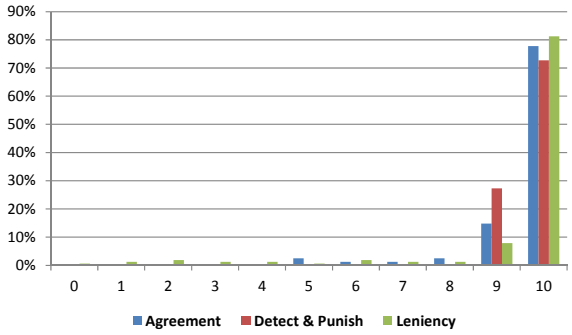
Panel a: Winning cartel bids EN



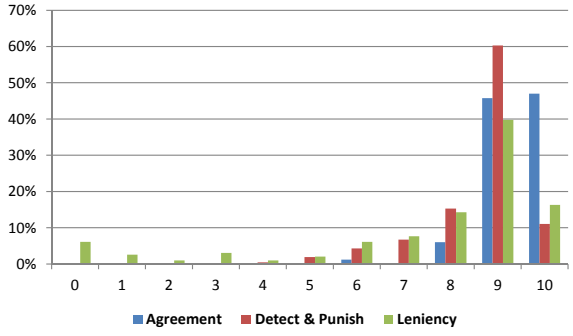
Panel b: Winning cartel bids FP



Panel a: Winning non-cartel bids EN



Panel b: Winning non-cartel bids FP



4.2 Bidding behavior

We have seen that in EN, antitrust policies have no significant effect on cartel deterrence, cartel stability, cartel recidivism and winning bids. These observations are consistent with our theoretical predictions in section 2.2, where we hypothesized that cartels would employ the

following bidding strategy: designated losers stay out of the auction while the designated winner submits a bid of zero and continues bidding up to 10 in case one of the designated losers enters the auction. Our data, which are summarized in Table 8 and Figure 4, provide some support for this conjecture. Theoretically, stable cartels establish a winning bid of zero, which appears to be confirmed by our data for all treatments. Moreover, in case of defection, the designated winner tends to increase the price so that designated losers only acquire the object at a price close to 9 in all treatments. As a result, we do not find treatment effects in terms of cartels' bidding behavior in EN, which explains why antitrust policies have no effect in EN.[20]

Table 8: Cartel bids in EN[a]

	Designated winner					Designated loser
	Initial bid	Final, winning bid				Final, winning bid
		Unstable cartel		Stable cartel		Unstable cartel
AGREEMENT	1.8	5.9	$>^{**}$	0.0	$<^{***}$	8.5
	∨	∧		∧		∨
DETECT & PUNISH	0.4	8.2	$>^{**}$	0.7	$<^{**}$	7.8
	∧	∨		∨		∨
LENIENCY	0.9	6.7	$>^{***}$	0.1	$<^{**}$	7.0
	∧	∨		∨		∧
AGREEMENT	1.8	5.9	$>^{**}$	0.0	$<^{***}$	8.5

[a] Significance levels are calculated with exact Wilcoxon rank-sum tests, counting each group as one, independent observation; ***, ** and * indicate statistical significance at the 1%, 5% and 10% level, respectively.

In contrast to EN, we have found that antitrust policies do have an effect in FP, including less cartel formation in DETECT & PUNISH and LENIENCY than in AGREEMENT, and higher winning bids in DETECT & PUNISH than in AGREEMENT. Table 9 separates cartel bids into bids submitted by designated winners and designated losers. The bids of both designated winners and designated losers are higher in DETECT & PUNISH than in AGREEMENT, but the differences are not statistically significant. In other words, the difference in average winning bids mainly emerges because fewer cartels form in DETECT & PUNISH than in AGREEMENT.[21] Finally, observe that the

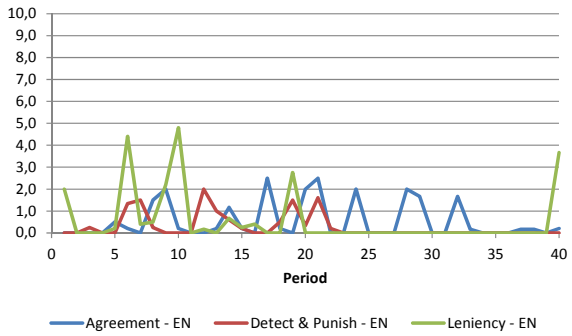
[20] Related, in all treatments, designated winners have a much higher probability of securing the item than designated losers: the probability that the designated winner secures the item in AGREEMENT, DETECT & PUNISH and LENIENCY is, 87%, 81% and 76% respectively, which exceeds the complementary probabilities that designated losers win the auction ($p = 0.002$, $p = 0.009$ and $p = 0.004$ respectively).

[21] Note that with FP the difference in cartel bids between AGREEMENT and DETECT & PUNISH is on the verge of being statistically significant ($p = 0.115$).

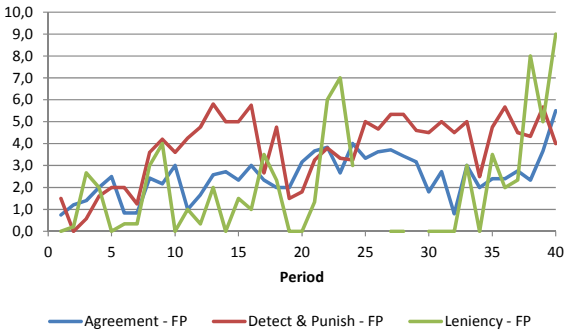
leniency program does have a statistically significant effect on cartel bids: both designated winners and designated losers submit lower bids in LENIENCY than in DETECT & PUNISH.

Figure 4: (initial) bids and winning probabilities of designated winners, over time across treatments for EN (panel a and panel c) and FP (panel b and panel d).

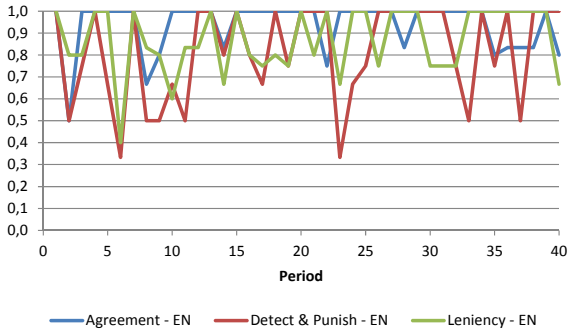
Panel a



Panel b



Panel c



Panel d

Table 9: Cartel bids in FP[a]

	Designated winner		Designated loser
AGREEMENT	2.9 ^	<	3.7 ^
DETECT & PUNISH	4.4 v**	<	5.5 v*
LENIENCY	1.6 ^	<	3.4 ^
AGREEMENT	2.9	<	3.7

[a] Significance levels are calculated with exact Wilcoxon rank-sum tests, counting each group as one, independent observation; ***, ** and * indicate statistical significance at the 1%, 5% and 10% level, respectively.

4.3 Reporting behavior

When developing our hypotheses, we assumed that bidders would use the possibility to report the cartel as a cartel disciplining device in LENIENCY. Table 10 summarizes the reporting behavior across auction formats. We observe that bidders are less likely to report stable cartels than unstable cartels, i.e., cartels where at least one designated loser deviates from the cartel agreement. In EN, this difference is only statistically significant if a designated loser wins the auction. In FP, on the other hand, unstable cartels are more likely to be reported than stable cartels, independent of the designated winner winning the auction or not, by both defectors and non-defectors. Cartel defection will almost surely lead to cartel reporting. The inability to react to rivals' bidding behavior in this auction type is partly restored by the possibility to report the cartel in case of defection. In line with what we have assumed in our theoretical analysis, bidders seem to use the possibility to report the cartel as a stick to discipline cartel behavior.

Next to punishing defection, cartel members may have another reason to apply for leniency: to avoid fine payments (the 'protection-from-fines motive' (Spagnolo, 2004) or 'deviator-amnesty motive' (Harrington, 2008)). In both auctions the protection-from-fines motive features prominently: a substantial fraction of stable cartels is reported. As such, this could be considered a success of the leniency program, as it leads to the revelation of cartels that otherwise would have remained undetected. Indeed, the fear of being reported seems to explain why subjects in LENIENCY are (weakly) less likely in favor of forming a cartel in LENIENCY than in DETECT & PUNISH and AGREEMENT despite cartels being (weakly) more stable in the former.

Table 10: subject's propensity to report a cartel in LENIENCY [a]

	Stable cartels		Unstable cartels	Unstable cartels				
				Designated winner wins		Designated loser wins	Defector	Non-defector
EN	0.23	<	0.51	0.50	$<^{*}$	0.84	0.54	0.42
	^		$\wedge^{*}$	$\wedge^{*}$		^	$\wedge^{**}$	$\wedge^{**}$
FP	0.38	$<^{**}$	0.89	0.92	>	0.88	0.94	0.93

[a] Significance levels are calculated with exact Wilcoxon rank-sum tests, counting each group as one, independent observation; ***, ** and * indicate statistical significance at the 1%, 5% and 10% level, respectively.

5. DISCUSSION AND CONCLUSIONS

In our experiment, antitrust policies affect cartel activity in different ways in EN and FP. In EN, we do not observe statistically significant treatment effects in terms of cartel deterrence, cartel stability, cartel recidivism, and the average winning bid. In FP, traditional antitrust policy deters cartel formation, makes cartels less stable and cartel recidivism less likely, and increases the average winning bid. Compared to traditional antitrust policy we find the leniency program to have two perverse effects in FP: cartels become more stable and the average winning cartel bid decreases. Subjects appear to use the possibility to report the cartel in the leniency program as an additional stick to discipline cartel behavior in a similar way as they use secret reports in Bigoni *et al*. (2012). Our findings suggest that antitrust authorities should focus their scare detection resources on bidding markets using a sealed-bid auction format (such as procurement auctions) rather than those employing an open format.

Some of our results are markedly different than those reported in the literature on the effect of antitrust policies in oligopoly games.[22] In particular, our finding that antitrust policies have no significant effect in EN is quite in contrast to what is observed in oligopoly experiments. The explanation seems to lie in the fact that the open auction format allows bidders to punish deviation in the auction itself so that cartels become stable, even in the presence of antitrust measures. We also observe several differences between our FP results and those reported in the literature, although FP is isomorphic to a homogeneous-goods Bertrand game, that is, the setting analyzed in Hinloopen and Soetevent (2008).[23] Hinloopen and Soetevent (2008) find traditional antitrust policy to have no effect on cartel stability and average price, whereas we observe that in FP traditional antitrust policy destabilizes cartels and increases the average winning bid. One explanation could be that in our design the fine for joining a cartel does not depend on actual earnings; defection by a rival does not reduce it to zero, as in Hinloopen and Soetevent (2008). Not defecting is, therefore, less risky in their set-up. Perhaps more importantly, Hinloopen and Soetevent (2008) find cartels to become *less* stable in the presence of a leniency program, in contrast to Bigoni *et al.*'s (2012) and our findings. In addition, our finding that the average

[22] Recall that this is the first experimental paper that compares the effect of antitrust policies on cartels in different auctions. This restricts the scope of comparison to oligopoly games (see also footnote 6).

[23] Bigoni *et al*. (2012) consider a differentiated-goods Bertrand oligopoly with markets consisting of two players only. That makes it quite different from our design, also with FP. For instance, tacit collusion is frequently observed if subjects interact repeatedly in a Bertrand duopoly, but not if the market consists of more players (Dufwenberg and Gneezy, 2000, Fonseca and Normann, 2012). Our results for FP are therefore less directly comparable with those of Bigoni *et al*. (2012).

winning cartel bid is lower under a leniency program compared to traditional antitrust policy contrasts the results in both Hinloopen and Soetevent (2008) and Bigoni *et al*. (2012). This suggests that details of the leniency program are important. The leniency program tested by Hinloopen and Soetevent (2008) is unique in that it explicitly takes into account the order of leniency applications. This could trigger 'a race for leniency' making the program particularly effective. And the possibility to secretly report a cartel is a unique feature of the design in Bigoni *et al*. (2012). It hinders the use of public reports to punish defectors, which makes the leniency program less suitable to be used to discipline cartel members. If anything, these observations suggest that more research is needed to elicit which details of antitrust policies are particularly crucial for their success.

Table 11: Fraction of cartels revealed[a]

	DETECT & PUNISH		LENIENCY			
	Detected		Total	Detected	Reported	
					Stable cartel	Unstable cartel
EN	0.12	$<^{**}$	0.63	0.06	0.19	0.38
	∨		∧	∨	∧	∧
FP	0.08	$<^{***}$	0.83	0.01	0.23	0.60

[a] In LENIENCY, detected cartels are cartels that are not reported while reported cartels could have been detected. Significance levels are calculated with exact Wilcoxon rank-sum tests, counting each group as one, independent observation; ***, ** and * indicate statistical significance at the 1%, 5% and 10% level, respectively.

We conclude with a cautionary remark on the number of revealed cartels as a measure of the effectiveness of antitrust policy. Policymakers sometimes claim that leniency programs are successful because many cartels are reported.[24] Although leniency programs unmistakably yield more cartels to be revealed (Miller, 2009, Brenner, 2009), that observation alone cannot be a measure of success, because leniency applications could also serve to punish deviating cartel members, as our experimental results suggest. Table 11 includes the fraction of cartels revealed in DETECT & PUNISH and LENIENCY. Clearly, for both auction formats, the number of cartels that

[24] 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). The success of leniency programs is also hailed by Neelie Kroes at the time she was EU Commissioner for competition: "The leniency program is proving to be an efficient tool to detect and punish cartels" (New York Times, 2005).

is revealed in LENIENCY is significantly higher than in DETECT & PUNISH. The leniency program is also quite successful in the sense that bidders do not only report cartels that break down but also quite a few stable cartels due to the protection-from-fines incentive. Still, our data indicate that it is misleading to use the number of revealed cartels as a measure of the effectiveness of antitrust policy because on dimensions like cartel deterrence, cartel stability, cartel recidivism, and the average winning bid, we do not observe statistically significant treatment differences in either auction. In sum, in the context of auctions, the leniency program might not be as successful as the results from previous experiments suggest.

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APPENDIX A: 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).

APPENDIX B: GROUP AVERAGES OVER TIME

AGREEMENT				DETECT & PUNISH				LENIENCY			
Propensity to collude		Propensity to defect		Propensity to collude		Propensity to defect		Propensity to collude		Propensity to defect[25]	
EN	FP	EN	FP	EN	FP	EN	FP	EN	FP	EN	FP
0.71	1.00	0.00	0.38	0.53	0.56	0.50	0.25	0.67	0.48	0.17	0.50
0.86	0.88	0.38	0.20	0.67	0.74	0.25	0.33	0.79	0.86	0.20	0.20
0.71	0.88	0.25	0.50	0.80	0.85	0.25	0.29	0.88	0.81	0.10	0.33
0.76	0.88	0.13	0.40	0.73	0.78	0.00	0.50	0.79	0.81	0.10	0.38
0.86	0.92	0.00	0.25	0.80	0.78	0.50	1.00	0.83	0.71	0.10	0.25
0.90	0.92	0.10	0.33	0.80	0.74	0.50	0.33	0.75	0.67	0.30	0.17
0.81	0.92	0.00	0.33	0.80	0.81	0.50	0.75	0.83	0.76	0.00	0.17
0.95	0.96	0.42	0.29	0.93	0.85	0.25	0.60	0.88	0.71	0.33	0.17
0.90	0.92	0.20	0.33	0.67	0.81	0.50	0.70	0.88	0.67	0.10	0.00
0.86	0.92	0.40	0.42	0.80	0.85	0.33	0.60	0.83	0.86	0.00	0.38
0.76	0.92	0.13	0.42	0.73	0.78	0.25	0.75	0.92	0.76	0.33	0.17
0.86	0.92	0.25	0.50	0.93	0.81	0.25	0.88	0.88	0.71	0.42	0.33
0.86	0.96	0.10	0.43	0.80	0.81	0.00	0.70	0.75	0.76	0.00	0.17
0.95	0.96	0.33	0.43	1.00	0.81	0.30	0.63	0.75	0.62	0.17	0.00
0.86	0.92	0.20	0.42	1.00	0.74	0.20	0.75	0.83	0.71	0.13	0.50
0.86	0.92	0.50	0.42	1.00	0.74	0.50	0.50	0.88	0.81	0.10	0.50
0.86	0.92	0.25	0.33	0.87	0.70	0.33	0.50	0.79	0.57	0.13	0.00
0.81	0.96	0.20	0.36	0.80	0.70	0.50	0.38	0.88	0.67	0.20	0.33
0.90	0.92	0.25	0.42	0.93	0.74	0.38	0.50	0.75	0.57	0.13	0.25
0.81	0.92	0.20	0.50	0.87	0.74	0.17	0.50	0.75	0.62	0.13	0.25
0.81	0.92	0.13	0.58	1.00	0.74	0.10	0.50	0.75	0.76	0.30	0.83
0.81	0.92	0.13	0.42	1.00	0.81	0.30	0.70	0.71	0.52	0.50	0.50
0.86	0.92	0.10	0.42	0.87	0.74	0.33	0.67	0.75	0.48	0.33	0.50
0.90	0.92	0.20	0.50	0.87	0.74	0.17	0.63	0.67	0.52	0.17	0.50
0.90	0.96	0.17	0.50	0.93	0.74	0.50	0.67	0.71	0.57	0.33	
0.86	1.00	0.10	0.38	0.87	0.70	0.33	0.50	0.79	0.48	0.13	
0.86	0.96	0.13	0.21	0.87	0.67	0.33	0.67	0.71	0.48	0.00	0.00
0.95	0.96	0.08	0.50	0.93	0.74	0.25	0.67	0.75	0.52	0.00	0.00
0.90	0.88	0.17	0.33	0.87	0.74	0.33	0.80	0.71	0.52	0.17	0.00
0.86	0.88	0.20	0.40	0.87	0.70	0.00	0.63	0.79	0.52	0.25	0.25
0.90	0.96	0.00	0.29	0.87	0.81	0.00	0.83	0.79	0.48	0.13	0.50
0.90	0.92	0.08	0.42	0.93	0.67	0.25	0.75	0.75	0.48	0.25	0.25
0.95	0.92	0.08	0.17	0.93	0.63	0.38	0.50	0.75	0.57	0.00	0.25
0.90	0.96	0.25	0.43	0.87	0.59	0.33	0.50	0.71	0.52	0.00	0.50
0.86	0.88	0.20	0.20	0.93	0.74	0.50	0.75	0.75	0.48	0.00	0.25
0.90	0.88	0.17	0.30	0.80	0.63	0.50	0.50	0.58	0.43	0.00	0.25
0.95	0.83	0.17	0.50	0.73	0.63	0.50	0.25	0.75	0.57	0.00	0.83
0.95	0.79	0.25	0.50	0.67	0.67	0.00	0.33	0.67	0.43	0.00	0.50
0.95	0.83	0.33	1.00	0.73	0.59	0.00	0.83	0.63	0.33	0.17	1.00
0.86	0.71	0.40	1.00	0.73	0.59	0.50	0.50	0.63	0.33	0.50	0.50

[25] The missing values for LENIENCY in periods 25 and 26 in FP occur because in these periods none of the 7 groups formed a cartel.

APPENDIX B (CONTINUED): GROUP AVERAGES OVER TIME

AGREEMENT						DETECT & PUNISH						LENIENCY					
Winning bid		Winning cartel bid		Winning non-cartel bid		Winning bid		Winning cartel bid		Winning non-cartel bid		Winning bid		Winning cartel bid		Winning non-cartel bid	
EN	FP	EN	FP	EN	FP	EN	FP	EN	FP	EN	FP	EN	FP	EN	FP	EN	FP
6.57	1.88	0.00	1.88	9.20		8.20	5.44	3.00	1.50	9.50	6.57	5.63	7.14	3.00	6.00	7.20	7.33
6.29	4.00	2.00	1.60	9.33	8.00	7.40	4.89	3.50	1.33	10.00	6.67	3.50	3.57	1.00	1.80	7.67	8.00
5.43	5.13	2.25	3.20	9.67	8.33	3.60	2.78	2.00	1.43	10.00	7.50	4.00	5.14	0.60	2.67	9.67	7.00
5.43	4.88	2.25	2.40	9.67	9.00	3.80	4.33	0.00	2.40	9.50	6.75	4.75	4.86	1.60	2.00	10.00	8.67
4.43	4.25	0.50	2.67	9.67	9.00	7.80	6.56	6.33	4.00	10.00	7.83	4.88	6.00	1.80	0.50	10.00	8.20
3.00	4.50	0.20	3.00	10.00	9.00	7.60	6.00	6.33	2.67	9.50	7.67	7.33	5.71	5.00	1.67	9.67	8.75
4.14	3.50	0.00	1.50	9.67	9.50	8.00	6.67	5.00	4.75	10.00	8.20	4.00	5.29	0.40	0.67	10.00	8.75
5.29	3.50	4.50	2.57	10.00	10.00	5.00	6.00	3.75	4.00	10.00	8.50	5.00	6.43	3.33	3.00	10.00	9.00
4.43	4.63	2.20	3.00	10.00	9.50	7.80	6.44	4.50	5.60	10.00	7.50	2.63	6.57	0.00	4.00	7.00	8.50
5.71	5.13	4.00	3.50	10.00	10.00	4.80	6.33	1.67	4.60	9.50	8.50	4.67	5.00	0.67	2.75	8.67	8.00
4.29	5.00	0.25	3.33	9.67	10.00	7.00	7.00	2.50	4.50	10.00	9.00	4.25	5.29	2.33	1.33	10.00	8.25
5.57	4.00	2.75	2.17	9.33	9.50	5.40	7.44	4.25	5.50	10.00	9.00	6.63	5.86	5.50	2.33	10.00	8.50
4.43	4.38	2.20	3.71	10.00	9.00	6.40	8.00	1.00	7.20	10.00	9.00	7.50	5.57	0.00	2.00	10.00	8.25
4.29	4.13	3.33	3.29	10.00	10.00	2.40	7.67	2.40	6.50		8.60	7.25	7.43	3.67	0.00	9.40	8.67
5.57	4.75	3.80	3.00	10.00	10.00	1.60	8.00	1.60	7.25		8.60	5.38	6.86	0.75	1.50	10.00	9.00
5.71	4.63	4.00	3.00	10.00	9.50	7.80	7.11	7.80	5.75		8.20	4.25	6.86	1.00	3.67	9.67	9.25
6.86	4.38	5.00	2.83	9.33	9.00	7.20	7.44	5.33	5.00	10.00	8.67	5.00	6.43	2.25	3.50	7.75	7.60
3.57	3.88	1.60	3.14	8.50	9.00	6.80	7.44	2.00	5.75	10.00	8.80	4.50	5.00	3.20	2.33	6.67	7.00
2.29	4.88	1.67	3.33	6.00	9.50	5.40	7.22	4.25	4.50	10.00	9.40	4.13	5.86	0.00	2.50	8.25	7.20
5.57	5.00	4.00	3.50	9.50	9.50	5.80	6.22	3.33	4.00	9.50	9.00	4.13	5.86	0.00	2.00	8.25	7.40
5.71	5.75	2.50	4.50	10.00	9.50	2.40	6.67	2.40	4.00		8.80	5.88	5.71	5.20	3.33	7.00	7.50
5.57	5.63	2.25	4.33	10.00	9.50	5.40	6.44	5.40	5.00		8.25	8.63	6.57	6.33	7.00	10.00	6.50
2.86	5.38	0.00	4.17	10.00	9.00	7.00	7.11	5.00	4.33	10.00	8.50	6.88	6.86	3.33	7.00	9.00	6.83
4.57	5.38	2.40	4.00	10.00	9.50	5.60	7.44	2.67	6.25	10.00	8.40	7.25	7.14	3.33	6.00	9.60	7.33
1.57	5.75	0.17	5.14	10.00	10.00	5.80	7.78	4.75	6.00	10.00	8.67	7.38	7.00	3.33		9.80	7.00
4.29	4.50	2.00	4.50	10.00		6.20	7.78	3.67	5.67	10.00	8.83	5.00	6.43	1.00		9.00	6.43
4.29	4.75	0.00	4.14	10.00	9.00	4.60	8.00	1.33	5.67	9.50	9.17	6.25	5.29	0.00	0.00	10.00	6.17
3.33	4.75	2.00	4.29	10.00	8.00	4.40	7.89	3.25	5.67	9.00	9.00	6.25	5.43	0.00	0.00	10.00	6.33
4.14	5.75	3.17	4.33	10.00	10.00	5.40	7.33	2.67	6.00	9.50	9.00	6.25	6.33	0.00		10.00	6.33
4.29	5.63	2.00	3.20	10.00	9.67	3.60	7.89	0.00	6.25	9.00	9.20	5.13	5.14	2.50	3.50	7.75	5.80
2.14	4.50	0.00	3.86	7.50	9.00	3.80	7.11	0.00	6.00	9.50	9.33	5.50	5.14	2.50	3.50	8.50	5.80
2.86	5.86	1.67	4.40	10.00	9.50	3.60	7.67	2.00	5.75	10.00	9.20	5.63	5.29	2.50	2.50	8.75	6.40
0.86	4.50	0.17	3.00	5.00	9.00	5.60	7.89	4.75	5.33	9.00	9.17	5.88	6.14	0.00	3.00	9.40	7.40
2.86	4.88	1.67	4.29	10.00	9.00	5.80	8.11	3.33	4.50	9.50	9.14	6.13	5.86	0.00	2.50	9.80	7.20
4.29	5.00	2.00	2.40	10.00	9.33	5.80	7.78	5.00	6.00	9.00	9.20	6.25	6.00	0.00	3.50	10.00	7.00
3.33	5.25	2.00	2.80	10.00	9.33	7.80	7.67	5.00	5.67	9.67	8.67	7.50	6.43	0.00	4.00	10.00	7.40
3.00	6.38	1.83	3.25	10.00	9.50	7.80	8.00	5.00	4.50	9.67	9.00	6.25	6.14	0.00	4.67	10.00	7.25
3.14	7.00	2.00	3.33	10.00	9.20	7.80	8.00	0.00	5.67	9.75	9.17	6.25	8.71	0.00	9.00	10.00	8.67
4.14	7.25	3.17	5.80	10.00	9.67	7.60	8.11	0.00	6.00	9.50	9.17	6.75	9.14	1.33	10.00	10.00	9.00
5.71	8.63	4.00	7.50	10.00	9.75	9.80	9.11	10.00	8.00	9.75	9.25	8.57	9.29	5.00	10.00	10.00	9.17