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Jeroen Hinloopen
Sander Onderstal

FEB/ASE, University of Amsterdam, and Tinbergen Institute.

Tinbergen Institute

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Tinbergen Institute Amsterdam
Roetersstraat 31
1018 WB Amsterdam
The Netherlands
Tel.: +31(0)20 551 3500
Fax: +31(0)20 551 3555

Tinbergen Institute Rotterdam
Burg. Oudlaan 50
3062 PA Rotterdam
The Netherlands
Tel.: +31(0)10 408 8900
Fax: +31(0)10 408 9031

Collusion and the choice of auction: An experimental study[1]

Jeroen Hinloopen[2] and Sander Onderstal[3]

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ABSTRACT:

We experimentally examine the collusive properties of two commonly used auctions: the English auction (EN) and the first-price sealed-bid auction (FPSB). In theory, both tacit and overt collusion are always incentive compatible in EN while both can be incentive compatible in FPSB if the auction is repeated and bidders are patient enough. We find that the auctions do not differ in subjects' propensity to collude overtly and in the likelihood that subjects defect from a collusive agreement. Moreover, the average winning bid does not differ between the auctions unless subjects can collude overtly. Under overt collusion, stable cartels buy at a lower price in EN than in FPSB resulting in a lower average winning bid in EN.

KEYWORDS: Collusion; English auction; First-price sealed-bid auction; Laboratory experiments

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[2] Corresponding author. University of Amsterdam, FEB/ASE, Roetersstraat 11, 1018 WB Amsterdam, The Netherlands; J.Hinloopen@uva.nl.

[3] University of Amsterdam, FEB/ASE, Roetersstraat 11, 1018 WB Amsterdam, The Netherlands; Onderstal@uva.nl.

1. Introduction

The two most commonly used auctions are the English auction (EN) and the first-price sealed-bid auction (FPSB). Robinson (1985) argues that a crucial difference between the two is that only in the former, collusion is always incentive compatible (see also Marshall and Marx, 2007). In EN, submitting a higher bid than that of the designated winner does not secure winning the auction as the designated winner can always react to this 'defection'. Repeating the stage-game does not alter this conclusion. In FPSB in contrast, collusion is not incentive compatible if the auction is played once because the designated winner cannot retaliate in case of defection. Collusion can become incentive compatible if the auction is repeated and if bidders are sufficiently patient (see, e.g., Aoyagi, 2003, 2007; Blume and Heidhues, 2008).[4] Collusion is thus expected to be more stable in EN than in FPSB. In this paper, we report on an experiment that brings this prediction to the lab.

We are not the first to study collusion in experimental auctions. One important insight from the literature to date is that tacit collusion is rare: If subjects deviate systematically from the one-shot Nash prediction, they bid more aggressively instead of less (see Kagel, 1995, for an overview). Collusion in terms of bid reduction does emerge if the experimenter gives subjects the possibility to communicate prior to the auction (Isaac and Walker, 1985; Phillips *et al.*, 2003; Sherstyuk and Dulatre, 2008). As far as we know, Hu *et al.* (2010) is the only paper that compares EN and FPSB in terms of collusive properties in a setting where bidders can collude overtly. In contrast to Robinson's result, they find that EN is more successful in fighting collusion than FPSB. However, Hu *et al.*'s environment differs crucially from Robinson's in the sense that they study 'strong cartels' (McAfee and McMillan, 1992), i.e., cartels whose members cannot defect. In contrast, and in line with Robinson's framework, subjects in our experiments can collude overtly, but the agreement is not binding.

The sharp difference in outcomes between overt and tacit collusion are somewhat surprising in the light of the industrial organization (IO) literature. In this literature, it is usually argued that the difference between the two is not essential. The reason is that cartel members cannot write binding cartel agreements because those are illegal according to antitrust law. Still, bidders may prefer to engage in overt collusion because the cartel agreement allows them to coordinate on the

[4] Cartels in first-price auctions were discovered in infrastructure procurement (Porter and Zona, 1993, Bajari and Ye 2003, and Boone *et al*., 2009) and school milk tenders (Porter and Zona, 1999, and Pesendorfer, 2000).

collusive outcome more easily. Moreover, side-payments guarantee also those who are not designated to win a share of the short-run spoils. Indeed, in IO experiments subjects are tempted to communicate when given the opportunity to do so and “often they manage to come to some form of price fixing agreement” (Potters, 2009, p. 85).

Our experiment provides some support to Robinson’s result that EN is more conducive to stable collusion than FPSB: If bidders can collude overtly, the average winning bid in EN is lower than in FPSB. This is not because subjects are more likely to join a cartel in EN than in FPSB, or because the likelihood of cartel defection is lower in EN. Rather, in EN, the designated winner submits a lower (final) bid than in FPSB so that stable cartels in EN buy at a lower price. Additionally, we observe strong end-game effects in FPSB but not in EN in the sense that in the final rounds of the experiment (1) fewer cartels are formed, (2) cartels that do form experience more defection, and (3) stable cartels buy at a higher price. These end-game effects support the theory that in one-shot settings, cartels are stable in EN but not in FPSB. In contrast, the auctions reveal no difference if bidders can only collude tacitly.

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

2. EXPERIMENTAL DESIGN AND HYPOTHESES

2.1 *Procedures and Parameters*

The experiment took place in September 2008 at the Center for Research in Experimental Economics and political Decision making (CREED) of the University of Amsterdam. Students were recruited by public announcement. In total 84 students from the University’s entire undergraduate population participated in one of four sessions. The points that subjects earned were converted according to an exchange rate of 1 point = € 0.25. A show-up fee of € 7 was converted to 28 points for those subjects that entered the experiment. To make sure that all subjects understood the experiment, they had to correctly answer several test questions before the experiment started. Average earnings were € 20.17 while sessions took 60 to 90 minutes to complete.

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. All sessions consisted of 40 rounds.[5] In each round, members of a group competed for a single object in either EN or FPSB. To focus on the main effects, we implemented a very simple common value setting in which the value for all bidders was commonly known to be 10 points. We leave richer environments with private values or affiliated signals for future research.

Table 1: Number of subjects (groups) per treatment

	FPSB	EN
TACIT	18 (6)	21 (7)
CARTEL	24 (8)	21 (7)

We examine the auctions in two different treatments: TACIT and CARTEL. Table 1 presents the resulting 2×2 between-subject design. In TACIT, subjects participated in the auction only; there was no possibility to form a cartel. In CARTEL, subjects could form a cartel with the other members of their group. At the beginning of each round, each subject was asked if she wanted to 'make an agreement'. When, and only when, all group members pushed the 'yes' button (rather than the 'no' button), a cartel formed. We thus do not consider partial cartels. Individual votes were not disclosed; subjects only learned whether or not 'an agreement had been reached'. When a cartel had formed, the computer assigned randomly a designated winner. Cartel members then learned whether or not they had been chosen as the designated winner. According to the cartel agreement, only the designated winner would submit a bid. This agreement was not binding however. Designated winners automatically paid 2.5 points to both other cartel members (5 points in total) prior to the auction. In this way, the potential profits of the cartel agreement were not too asymmetric among cartel members.[6]

In FPSB, each subject could submit a bid from the set {0, 1, …, 10} or decides not to submit a bid at all. The highest bidder won the auction. Ties were resolved randomly (nobody won the

[5] Selten's (1978) chain-store paradox has taught us that, in theory, collusion in FPSB is never incentive compatible if the stage game is repeated a finite number of times (see also Kreps and Wilson, 1982). For a cartel to be stable in FPSB, an infinite number of rounds is required. In the lab this could be mimicked with a random stopping rule, although in itself this is not credible: each subject understands that the experiment comes to an end some time in the near future (Selten *et al.*, 1997). Moreover, collusive play in a finitely repeated-game setting is often observed until the last couple of rounds (Selten and Stroecker, 1983). We therefore prefer to use a commonly known finite number of rounds in order to obtain data sets of comparable size across sessions. In the statistical analyses, possible end-game effects are taken into account.

[6] In practice, side-payments are quite common. Asker (2010) 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.

object when all group members decided not to submit a bid). The winner earned the difference between her bid and the common value of the object. In EN, the first round was almost the same as in FPSB, the difference being that the highest bidder only became the provisional winner. In the next rounds, subjects had to bid strictly higher than the currently highest bid (whereby the provisional winner was excluded from bidding) or leave the auction. A bidder left the auction when she was not the provisional winner in the previous round and when she did not submit a bid in the current round. Once a bidder had left the auction, she could not submit a bid in later auction rounds. The provisional winner became the auction winner when both other group members had chosen not to submit a bid in a certain round. The auction winner paid her highest bid, which she had submitted in the pen-ultimate auction round. When a subject bid 10, the auction ended immediately.

2.2 *Hypotheses*

Friedman's (1971) theory of grim-trigger strategies can be used to obtain a measure for the likelihood that bidders collude, i.e., establish a winning bid below the one-shot Nash equilibrium. These strategies yield a critical discount factor that supports collusion in a subgame perfect equilibrium of the infinitely repeated stage game. The lower is the critical discount factor, the more likely it is that subjects collude. The various critical discount factors are listed in Table 2, where Π^C, Π^N, and Π^D denote the expected stage game payoffs under collusion, in the one-shot Nash equilibrium, and of the optimal defection respectively. Further, δ^t [δ^c] is the critical discount factor for tacit [overt] collusion, i.e., bidders collude without [while] forming a cartel.

Table 2: Critical discount factors

		Tacit collusion				Overt collusion			
Auction	Treatment	Π^N	Π^C	Π^D	δ^t	Π^N	Π^C	Π^D	δ^c
FPSB	TACIT	1/3	3 1/3	9	17/26 ≈ 0.65	-	-	-	-
	CARTEL	1/3	3 1/3	9	17/26 ≈ 0.65	1/3	3 1/3	9	3/4 = 0.75
EN	TACIT	1/3	3 1/3	0	0	-	-	-	-
	CARTEL	1/3	3 1/3	0	0	1/3	3 1/3	0	0

Notes: Profits under overt collusion are net of the side payments.

In EN, both tacit and overt collusion are always incentive compatible (Robinson, 1985, Marshall and Marx, 2007). First note that for all bidders, staying in the auction up to a price of 9 is a weakly dominant strategy. We take these strategies as the one-shot Nash equilibrium. Because a bidder only wins in one out of three auctions on average, the resulting expected Nash payment is 1/3. Bidders can collude in the following way. In the case of overt collusion, each subject learns whether she is the designated winner or not at the start of the auction. Non-designated bidders stay out of the auction while the designated winner bids 0 in the first round of the auction and overbids others up to a price of 10. Observe that those strategies constitute a subgame perfect Nash equilibrium. The equilibrium outcome is that the designated winner obtains the object for a price of zero. Bidders can collude tacitly if all submit a bid of zero in the first round of the auction. With equal probability, one bidder is selected to be the provisional winner; the other two bidders step out of the auction in the next auction round. If not, the provisional winner in the first round stays in the auction up to a price of 10. In EN, therefore, defection never secures winning the auction. This is reflected in Table 2 by the critical discount factor of zero for both TACIT and CARTEL. Because collusion is always incentive compatible in EN, it should not matter if the auction is repeated or not; collusion, both overt and tacit, is incentive compatible even in a one-shot setting.

For FSPB, the incentive to collude differs between TACIT and CARTEL. In TACIT, the value of sticking to the collusive strategy is $\Pi^C/(1-\delta)$, where Π^C denotes the stage game payoffs under collusion and δ the discount factor. Bidders collude optimally if all submit a bid of zero. A bidder can defect by submitting a bid of 1. Defection thus yields $\Pi^D + \delta\Pi^N/(1-\delta)$, where Π^N and Π^D respectively denote the stage game payoffs in the one-shot Nash equilibrium and of the optimal defection (given that both other bidders stick to the collusion strategy). Observe that there is a unique Nash equilibrium in weakly dominant strategies in which all bidders bid 9. The critical discount factor follows:

$$\delta^t = \frac{\Pi^D - \Pi^C}{\Pi^D - \Pi^N}. \tag{1}$$

Collusive profits in CARTEL are maximal if only the designated winner submits a bid, and this bid equals zero. Optimal defection by a non-designated bidder entails submitting a bid of 1, again yielding $\Pi^D + \delta\Pi^N/(1-\delta)$. However, a non-designated bidder earns nothing in the first period if she sticks to the collusive agreement. Her value of collusion is therefore $\delta\Pi^C/(1 - \delta)$, which yields as critical discount factor:

$$\delta^c = \frac{\Pi^D}{\Pi^D + \Pi^C - \Pi^N}. \tag{2}$$

Comparing (1) and (2) suggests that in FPSB tacit collusion is more stable than overt collusion. At the same time, and for the same reasons as discussed earlier, subjects have incentives to collude overtly if given the opportunity. Whether in FPSB overt collusion occurs more frequently than tacit collusion is thus an open question. Moreover, in the final round, FPSB resembles a one-shot pricing game in which collusion is not subgame perfect. Hence, and in contrast to EN, we expect to observe an end-game effect in FPSB. Finally, comparing the critical discount factors between the two auction formats yields a clear prediction: Subjects collude more in EN than in FPSB, both tacitly and overtly.

3. EXPERIMENTAL RESULTS

We discuss our results along three aspects of collusion: cartel formation, cartel stability, and winning (cartel) bids.

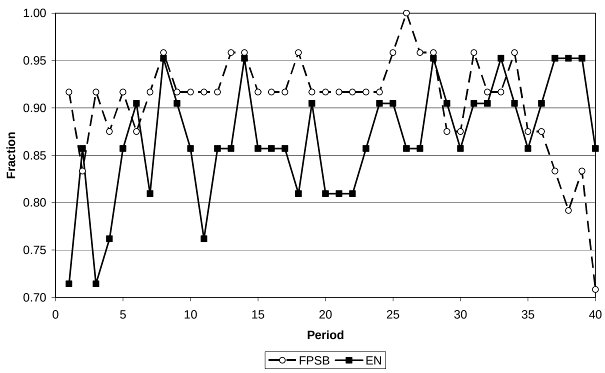
3.1 *Cartel formation*

Treatment CARTEL allows us to observe directly the incentives to collude in the sense of forming a cartel.[7] For this treatment, Figure 1 maps the fraction of subjects in favor of cartel formation over time. The figure shows that this fraction is (very) high: on average 87% for EN and 91% for FPSB. The data clearly support the hypothesis that subjects will collude overtly if given the opportunity. In contrast to what theory predicts, this incentive is not stronger in FPSB than in EN ($p = 0.600$).[8]

[7] The concomitant analysis for TACIT necessarily involves the winning bids, which is postponed to Section 3.3 below.

[8] Unless specified otherwise, all statistical tests are based on the first 35 rounds. The reported p-value emerges from a Wilcoxon rank-sum test based on group averages. If we also take the final 5 rounds into account, the difference is still not statistically significant ($p = 0.908$).

Figure 1: Fraction in favor of cartel formation over time in CARTEL.



Result 1

The fraction of subjects in favor of cartel formation does not differ significantly between EN and FPSB.

If anything, Figure 1 suggests that cartel formation becomes ever more likely in EN in the early rounds. But as of round 5 the fraction of subjects in favor of cartel formation hovers around 87% right until the final round. In FPSB, the fraction of subjects willing to form a cartel is stable at about 92% up to the final 5 rounds and goes down quickly after that. To test for end-game effects with respect to cartel formation, we estimate the following random effects binomial logit model whereby we explicitly control for possible within-group correlations:

$$y_{jit}^{*} = \beta_0 + \beta_1 E_{it} + \varepsilon_{jit} + u_i\,, \quad y_{jit} = 1 \Leftrightarrow y_{jit}^{*} \geq 0, \tag{3}$$

$j \in i = 1,2,\ldots,n^X$, $t = 1,\ldots,40$, where n^X is the number of subjects participating in CARTEL in auction $X \in \{\text{FPSB, EN}\}$, E is a dummy that equals 1 if, and only if, the observation concerns the final 5 rounds, and y^* is a dummy with $y_{jit}^{*} = 1 \Leftrightarrow$ subject j in group i is in favor of forming a cartel in round t.

Table 3: ML-estimates of (3).

	FPSB	EN
Constant	2.83^{**} (0.43)	2.79^{**} (0.73)
E	-0.33^{**} (0.08)	0.20 (0.13)

LR-test for random effects	$p < 0.001$	$p < 0.001$

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

Table 3 contains the estimation results. These results clearly support what theory predicts: There is no end-game effect in EN while there is a highly significant end-game effect in FPSB. In sum:

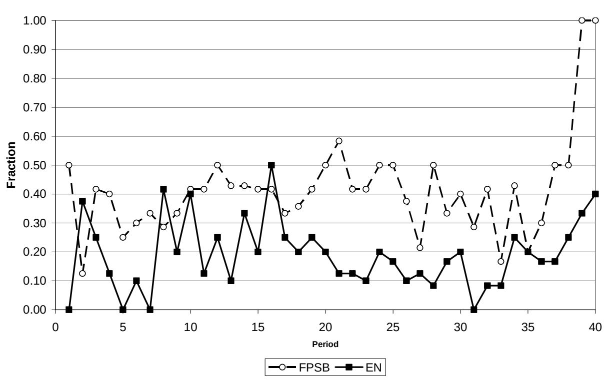
<u>Result 2</u>

In EN, there is no end-game effect in cartel formation: The fraction of subjects in favor of cartel formation in the final rounds does not differ significantly from those in earlier rounds. In FPSB there is a strong end-game effect in cartel formation: The fraction of subjects in favor of cartel formation in the final rounds is significantly below that in earlier rounds.

3.2 *Cartel stability*

A cartel is stable if, and only if, all bidders stick to the cartel agreement, i.e., the non-designated bidders abstain from bidding. Figure 2 displays the fraction of non-designated bidders that do submit a bid over time. In EN, the average fraction over the first 35 rounds is 18%, which is not significantly below the 34% of defectors in FPSB ($p = 0.148$).[9] That is, cartels are equally stable in both auctions. Perhaps more surprisingly, bidders sometimes do defect: A significant fraction of cartels that form experience cartel defection.[10]

Figure 2: Fraction of cartel members defecting over time in CARTEL.



[9] Taking all rounds into account does not alter this conclusion.

[10] This result has been reported earlier in the experimental literature. See, e.g., Apesteguia *et al*. (2007), Hinloopen and Soetevent (2008), Bigoni *et al.* (2009), and Hu *et al.* (2009).

Result 3

Cartels are equally stable in EN and FPSB.

Again, the two auctions differ in terms of end-game effect. In EN, there appears to be no significant end-game effect in Figure 2. The concomitant random effects discrete choice binomial logit model confirms this observation.[11] In contrast, a clear end-game effect is observed in FPSB. This is somewhat surprising because cartel formation is already deterred in the final rounds. One could argue that cartels that nevertheless form in the final rounds have passed this hurdle and, therefore, are expected to be particularly stable. But the data show differently: In FPSB fewer cartels are formed in the final rounds, and those that do form experience more defection. In the final two rounds cartel defection is even certain. That is:

Result 4

In EN, there is no end-game effect in cartel stability: The fraction of non-designated bidders that submit a bid in the final rounds does not differ significantly from those in earlier rounds. In FPSB there is a strong end-game effect in cartel stability: The fraction of non-designated bidders that do submit a bid in the final rounds is significantly below that in earlier rounds.

3.3 *Winning bids*

Table 4 contains the average winning bids across treatments for both auctions, whereby the average cartel bids and non-cartel bids are reported separately as well.

Table 4: 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
TACIT	7.1	5.3	9.1	8.1	4.1	9.6
CARTEL	5.0	3.5	9.4	4.3	2.1	9.6

Notes: Cartel (non-cartel) bids in TACIT correspond to winning bids < (≥) 9.

[11] As in (3), whereby $y^*_{jit} = 1 \Leftrightarrow$ non-designated bidder *j* in group *i* submits a bid in round *t*.

Figure 3: Frequency distributions of winning bids.

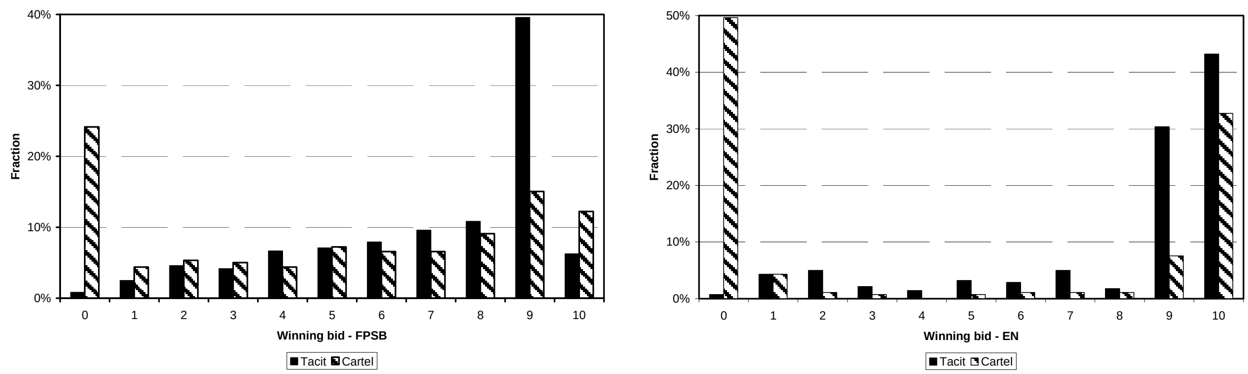


Figure 3 presents the frequency distribution of all winning bids for both treatments and auction formats. The first question we ask is if subjects collude tacitly if overt collusion is not possible. Recall that in both auctions, a winning bid of 9 emerges in the Nash equilibrium in weakly dominant strategies. Therefore, we treat all bids below 9 as proof of tacit collusion. Tacit collusion abounds in FPSB: 54% of all winning bids in TACIT are below 9 (with an average winning bid of 5.3). In contrast, in EN, subjects tacitly collude much less if overt collusion is not possible. Only 26% of all winning bids in TACIT is below 9 (with an average winning bid of 4.1).

Next, considering the effect of the possibility to collude overtly shows that in FPSB there is none: The average winning bid of 7.1 in TACIT does not differ significantly from the average winning bid of 5.0 in CARTEL (p = 0.245). Furthermore, subjects that do not collude overtly are also not inclined to collude tacitly: Only 2.5% of all winning non-cartel bids in CARTEL is below 9. In EN, it clearly matters if subjects can form cartels: The average winning bid of 4.3 in CARTEL is significantly below the average winning bid of 8.1 in TACIT (p = 0.047). Tacit collusion is again hardly observed if overt collusion is possible as only 2.8% of all wining non-cartel bids in CARTEL is below 9. In sum:

<u>Result 5</u>

In EN, the average winning bid decreases significantly if bidders can collude overtly. In FPSB, the average winning bid is not affected by this possibility. In both auctions, subjects almost never collude tacitly if overt collusion is possible.

Table 4 suggests that the average winning cartel bids are responsible for these results. Although cartels are equally likely and equally stable in EN and FPSB (results 1 and 3, respectively), in EN they appear to be better able to reduce the average winning cartel bid. This, in turn, reduces significantly the average winning bid in CARTEL compared to TACIT. We test for the success of cartels in bringing down the average winning (cartel) bid by estimating the following random effects model whereby we explicitly control for possible end-game effects:

$$\begin{aligned} B_{it}^{XY} &= \gamma_0 + \gamma_1 C_{it}^{XY} + \gamma_2 A_{it} C_{it}^{XY} + \gamma_3 A_{it} C_{it}^{XY} E_{it} + \gamma_4 (1 - A_{it}) C_{it}^{XY} E_{it} \\ &\quad + \gamma_5 A_{it} (1 - C_{it}^{XY}) E_{it} + \gamma_6 (1 - A_{it})(1 - C_{it}^{XY}) E_{it} + \varepsilon_{it}^{XY} + u_i^{XY}, \end{aligned} \tag{4}$$

$j \in i = 1,2,\ldots,n^X$, $t = 1,\ldots,40$, where B_{it}^{XY} is the winning bid in group i in round t in auction $X \in \{\text{EN, FPSB}\}$ for treatment $Y \in \{\text{TACIT, CARTEL}\}$, A_{it} is a dummy which equals 1 if, and only if, the observation concerns EN, and C^{XY} is a dummy with $C_{it}^{XY} = 1 \Leftrightarrow$ group i has formed a cartel in round t in treatment Y = CARTEL of auction X.

Table 5: ML-estimates of (4)

Constant	7.890^{**} (0.348)
C	-4.415^{**} (0.327)
A × C	-1.406^{**} (0.503)
A × C × E	0.171 (0.146)
(1 – A) × C × E	0.732^{**} (0.165)
A × (1 – C) × E	0.325^{**} (0.116)
(1 – A) × (1 – C) × E	0.277^{*} (0.110)
LR-test for random effects	$p < 0.001$

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

The estimates in Table 5 clearly support the observation that cartels manage to reduce the winning bid: On average, cartels pay 4.4 points less in FPSB. In EN, cartels are even more successful as they knock off on average an additional 1.4 points of their winning bid. In EN, the ability of a cartel to reduce the winning bid is not influenced by the repeated-game nature of the experiment: There is no end-game effect in the winning cartels bids of EN. In contrast, there is a significant end-game effect in FPSB: The ability of cartels to reduce the average winning bid is reduced in the final rounds. At the same time, in EN and even more so in FPSB, the winning non-cartel bids increase somewhat in the final rounds. To sum up:

<u>Result 6</u>

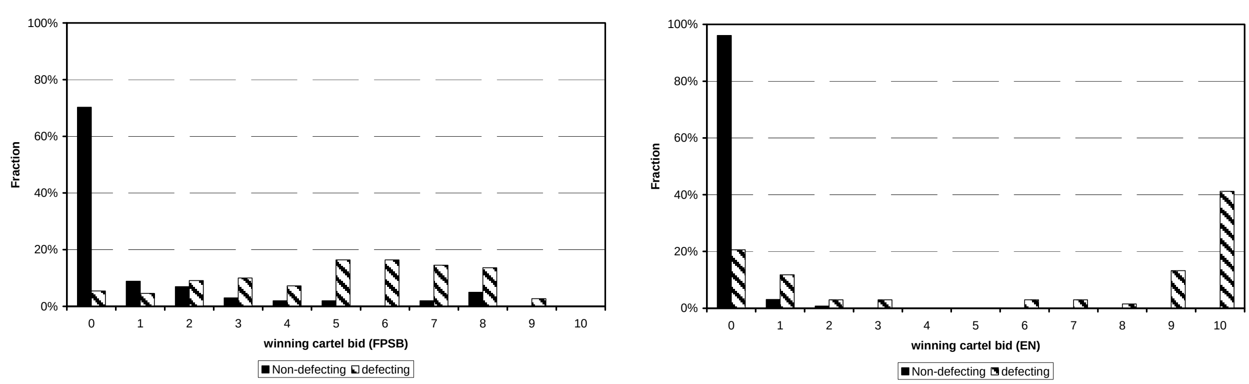
The average winning cartel bid is lower than the average winning non-cartel bid. The winning cartel bid in EN is lower than the winning cartel bid in FPSB. Only in FPSB does the winning cartel bid increase in the final rounds. The winning non-cartel bid increases in the final rounds in EN, and even more so in FPSB.

Finally, we address the question as to why cartels are more successful in EN than in FPSB. For that, we examine the bidding behavior of cartels whereby we distinguish between defecting and stable cartels. Table 6 contains the average winning cartel bids while Figure 4 displays the underlying frequency distributions.

Table 6: Average winning cartel bids in CARTEL

	Stable cartels	Unstable cartels			
		Overall	Winning bid non-designated bidder	Winning bid designated winner	Non-designated bidder wins
FPSB	2.4	5.3	5.3	5.2	69%
EN	0.1	6.1	8.5	6.0	16%

Figure 4: Frequency distributions of winning cartel bids in CARTEL



We observe that EN and FPSB differ markedly in terms of bidding behavior when distinguishing between stable and unstable cartels. First of all, the average winning bid in stable cartels is lower in EN than in FPSB. Second, non-designated bidders that win the auction do so with a lower bid in FPSB than in EN. And third, winning the auction as a non-designated bidder occurs less frequently in EN than in FPSB. To substantiate these observations we estimate (4) for winning cartel bids in CARTEL. The estimates are in Table 7, whereby D and DW are dummies with $D_{it} = 1 \Leftrightarrow$ a non-designated bidder in group i submits a bid in round t, and $DW_{it} = 1 \Leftrightarrow$ the designated winner in group i and round t wins the auction. These results confirm that:

Result 7

In EN, the designated winner submits a lower (final) bid than in FPSB in the case of a stable cartel. Non-designated bidders win the object for a higher price in EN than in FPSB. Non-designated bidders win less often in EN than in FPSB.

Table 7: Winning cartel bids.

	FPSB	EN
Constant	2.42^{**} (0.26)	0.23 (0.35)
D	2.14^{**} (0.19)	8.02^{**} (0.48)
D × DW	0.05 (0.20)	-2.47^{**} (0.49)
E	0.49^{**} (0.08)	0.02 (0.09)
LR-test for random effects	$p < 0.001$	$p < 0.001$

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

In EN, there are clear signs that the designated winner starts a bidding war in the case of cartel defection. Figure 4 shows winning bids up to 10 in EN. These high bids only emerge if a non-designated bidder enters the auction. This could be the result of the designated winner's punishment strategy: If someone outbids the designated winner, the latter may respond by starting a 'race to the top'.

Obviously, we do not observe a bidding war in FPSB. Although in FPSB the winning cartel bid is higher for unstable cartels, the difference is substantially lower than in EN. Moreover, in FPSB it does not matter for the winning bid in the case of cartel defection if it is the designated winner that wins the auction. This is because the designated winner cannot react to rivals' bidding behavior in an auction round.

These observations explain why cartels are more successful in EN than in FPSB in bringing down the winning bid. Because the designated winner can start a bidder war in EN, it makes sense for her to bid zero in the first round of the auction. If neither of the other bidders deviate, she secures the item for a price of zero. Figure 4 confirms that almost all subjects employ this strategy. In FPSB, the designated winner bids more than zero in about 30% of the cases. Such a strategy could be perfectly rational if a bidder believes that others may defect with some probability. The implication is that the winning bid submitted by the designated winner is lower in EN than in FPSB, and cartels that do not defect secure the item for a lower price.

4. CONCLUSIONS

We have examined experimentally the collusive properties of two commonly used auctions: EN and FPSB. Theory suggests that collusion is more likely to be stable in EN than in FPSB, suggesting that in EN the average winning bid is lower than in FPSB. Our experiment shows that this is indeed the case, but only if bidders collude overtly. This is not because subjects are more likely to join a cartel in EN than in FPSB, or because the likelihood of cartel defection is lower in EN. Rather, in EN, the designated winner submits a lower (final) bid than in FPSB so that stable cartels in EN buy at a lower price. Additionally, we observe strong end-game effects in FPSB but not in EN in the sense that in the final rounds of the experiment less cartel are formed, cartels that do form experience more defection, and stable cartels buy at a higher price. Our findings suggest that an auctioneer should use FPSB instead of EN if he has a strong indication that bidders have formed a cartel prior to the auction.

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 OVERT with the English auction.

Welcome!

You are about to participate in an auction experiment. The experiment consists of 40 rounds.

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.

Earnings

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 a single 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.

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.

Next, 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

Agreement

At the start 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.

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

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.

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.

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