

Collusion and the choice of auction: An experimental study¹

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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 are incentive compatible in FPSB only if the auction is repeated and bidders are patient enough. Our experiment partly confirms the theory: under overt collusion, stable cartels buy at a lower price in EN than in FPSB resulting in a lower average winning bid in EN. However, we also 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.

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

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1. INTRODUCTION

Two commonly used auctions are the English auction (EN) and the first-price sealed-bid auction (FPSB). Robinson (1985) argues 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 (e.g. Aoyagi (2003, 2007) and 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.

In our design we distinguish between tacit and overt collusion, although agreements are never binding. 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 (non-binding) cartel agreement allows them to coordinate on the collusive outcome more easily. Also, if the agreement involves side-payments, overt collusion guarantees those who are not designated to win a share of the supra-normal profits. 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).⁵

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). Overt collusion, whereby subjects can communicate prior to the auction, does lead to lower bids (Isaac and Walker (1985), Phillips *et al.* (2003), Sherstyuk and Dulatre, 2008). An explicit test of Robinson’s (1985) result is not yet provided however.⁶

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).

⁵ For instance, Fransecca and Normann, 2011, find that non-binding communication in a repeated Bertrand duopoly increases prices by ? percent.

⁶ Hu *et al.* (2010) is the only paper that compares the collusive properties of EN and FPSB. However, their environment differs crucially from Robinson’s in the sense that cartels are ‘strong’ (McAfee and McMillan, 1992): cartel agreements are binding; defection is not possible.

Results:

Overt versus tacit

One shot versus repeated

Our experiment supports 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 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. 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 (labelled ‘periods’). This allows us to test Robinson’s (1985) result in both a repeated and non-repeated framework.⁷ As in Robinson (1985), members of a group compete for a single object with a common value (of 10 points) in either EN or FPSB.

Table 1: Number of subjects (groups) per treatment

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

For both auctions we implement two 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 period, 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.⁸ 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.⁹

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

⁷ Collusive play in a finitely repeated-game setting is typically observed until the last couple of periods (Selten and Stroecker, 1983). In our experiment, end-game effects kick in as of period 36 (more on this below). Therefore, we consider the first 35 periods as being representative for infinitely repeated play, while the final 5 periods resembles single-period play. We report results both for (the average of) periods 36 – 39 and period 40. The four-period averages absorb possible correlations between the periods where end-game effects are observed.

⁸ This is, again, as in Robinson (1985). See, e.g. McAfee and McMillan (1992) for a (theoretical) analysis of partial cartels.

⁹ Here we follow Hu *et al.* (2010). 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 auction round was almost the same as in FPSB, the difference being that the highest bidder only became the provisional winner. In the next auction 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 auction round and when she did not submit a bid in the current auction 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 auction 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

In EN, both tacit and overt collusion are always incentive compatible in every period (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 single-period 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 overtly in the following way. 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 auction round 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. In case of tacit collusion, all bidders submit a bid of zero in the first auction round. 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. Because collusion is always incentive compatible in EN, it should not matter if the auction is repeated.

In FPSB it matters if subjects collude overtly or tacitly, and if the auction is repeated or not. If the auction is played once, neither tacit nor overt collusion is incentive compatible; it is a dominant strategy for each non-designated bidder to submit a bid. Both tacit and explicit collusion will break down and the single-period Nash equilibrium price of 9 will surface. This picture

changes if the auction is repeated. Friedman's (1971) theory of grim-trigger strategies can be used to obtain a measure for the likelihood that bidders collude in this case. 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 per-period 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.

Table 2: Critical discount factors for FPSB

Treatment	Tacit collusion				Overt collusion			
	Π^N	Π^C	Π^D	δ^t	Π^N	Π^C	Π^D	δ^c
TACIT	1/3	3 1/3	9	17/26 \approx 0.65	-	-	-	-
CARTEL	1/3	3 1/3	9	17/26 \approx 0.65	1/3	3 1/3	9	3/4 = 0.75

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

In TACIT, the value of sticking to the collusive strategy is $\Pi^C/(1 - \delta)$, where δ is 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 $\Pi^D + \delta\Pi^N/(1 - \delta)$. The critical discount factor follows:

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

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:

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

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.

Finally, given that in EN collusion is always incentive compatible, we expect more cartel activity 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.¹⁰ Table 3 reports the fraction of subjects in favor of cartel formation across auctions for different periods;¹¹ Figure 1 maps this fraction over time.

¹⁰ The concomitant analysis for TACIT necessarily involves the winning bids, which is postponed to Section 3.3 below.

¹¹ To determine when end-game effects start to play a role, we have estimated a random effects binomial logit model whereby we explicitly control for possible within-group correlations: $y_{jit}^* = \beta_0 + \beta_1 E_{it} + \varepsilon_{jit} + u_i$, $y_{jit} = 1 \Leftrightarrow y_{jit}^* \geq 0$, $j \in i = 1, 2, \dots, n^X$, $t = 1, \dots, 40$, where n^X is the number of subjects participating in CARTEL in auction $X \in \{\text{FPSB}, \text{EN}\}$, E is a dummy that equals 1 if, and only if, the observation concerns the final k periods, and y^* is a dummy with $y_{jit}^* = 1 \Leftrightarrow$ subject j in group i is in favor of forming a cartel in period t . Up to $k = 5$ the estimation results are quite stable for FPSB, revealing a significant end-game effect (for $k = 5$ the estimated coefficient for E is -0.33 with a (robust) standard error of 0.08) while there is never an end-game effect in EN (with $k = 5$, the estimated coefficient is 0.20 with a standard error of 0.13). Therefore, we treat the final 5 periods as “end periods”.

Table 3 Fraction of subjects in favor of cartel formation in CARTEL.

Period(s)	FPSB		EN
1 – 35	0.91	<	0.87
	∨		
36 – 39		>	
40	0.71	>	0.86

Notes: Significance levels follow from an exact, two-sided a Wilcoxon rank-sum test based on group averages. ** denotes statistical significance at the 1% level;

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

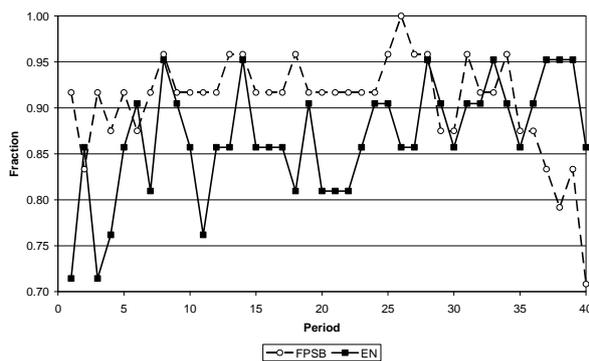


Figure 1 suggests that cartel formation becomes ever more likely in EN in the early periods. But as of period 5 the fraction of subjects in favor of cartel formation hovers around 87% right until the final round. In FPSB, the fraction of subjects willing to form a cartel is stable at about 92% up to the final 5 periods and goes down quickly after that. In sum:

Result 1

The fraction of subjects in favor of cartel formation does not differ significantly between EN and FPSB in periods 1 – 35. In EN, there is no end-game effect in cartel formation: The fraction of subjects in favor of cartel formation in period 36 – 39 or period 40 does not differ significantly from those in periods 1 – 35. In FPSB there is a strong end-game effect in cartel formation: The

fraction of subjects in favor of cartel formation in periods 36 – 39 or period 40 is significantly below that in periods 1 – 35.

The data clearly support the hypothesis that subjects will collude overtly if given the opportunity. In line with theory, this incentive is stronger in EN than in FPSB if the auction is not repeated. If the auction is repeated however, both auctions are equally likely to trigger cartel formation.

3.2 Cartel stability

A cartel is stable if, and only if, all bidders stick to the cartel agreement, that is, the non-designated bidders abstain from bidding. Figure 2 displays the fraction of non-designated bidders that do submit a bid over time. Table 4 compares these fractions between the two auctions for different time periods.

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

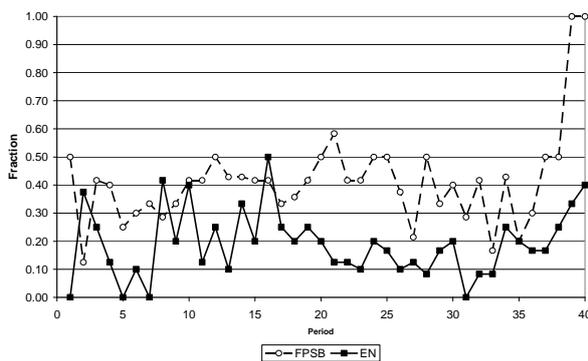


Table 4 Fraction of non-designated bidders submitting a bid in CARTEL.

Period(s)	FPSB		EN
1 – 35	0.34	>	0.18
		∨	
36 – 39		>	
	∧		∧
40	1.00	>	0.40

Notes: Significance levels follow from an exact, two-sided a Wilcoxon rank-sum test based on group averages. *, ** and ***, denotes statistical significance at the 10%, 5%, and 1% level, respectively;

In EN, the average fraction over the first 35 rounds is 18%, which is not significantly below the 34% of defectors in FPSB ($p = 0.148$). 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.¹²

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.¹³

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 2

Cartels are equally stable in EN and FPSB in periods 1 – 35. In EN, there is no end-game effect in cartel stability: The fraction of non-designated bidders that submit a bid in periods 36 – 39 or period 40 does not differ significantly from that in periods 1 – 35. In FPSB there is a strong end-game effect in cartel stability: The fraction of non-designated bidders that submit a bid in periods 36 – 39 or period 40 is significantly above that in periods 1 – 35.

3.3 *Winning bids*

¹² This result has been reported earlier in the experimental literature. See, e.g., Apestequia *et al.* (2007), Hinloopen and Soetevent (2008), and Bigoni *et al.* (2009).

¹³ As in footnote 11, whereby $y_{jit}^* = 1 \Leftrightarrow$ non-designated bidder j in group i submits a bid in round t .

Table 5 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 5: Winning bids

	FPSB		EN		TACIT		CARTEL	
Periods	TACIT	CARTEL	TACIT	CARTEL	FPSB	EN	FPSB	EN
1 – 35								
36 – 39								
40								

Notes: Significance levels follow from an exact, two-sided a Wilcoxon rank-sum test based on group averages. *, ** and ***, denotes statistical significance at the 10%, 5%, and 1% level, respectively;

Figure 3: Frequency distributions of winning bids for periods 1 – 35.

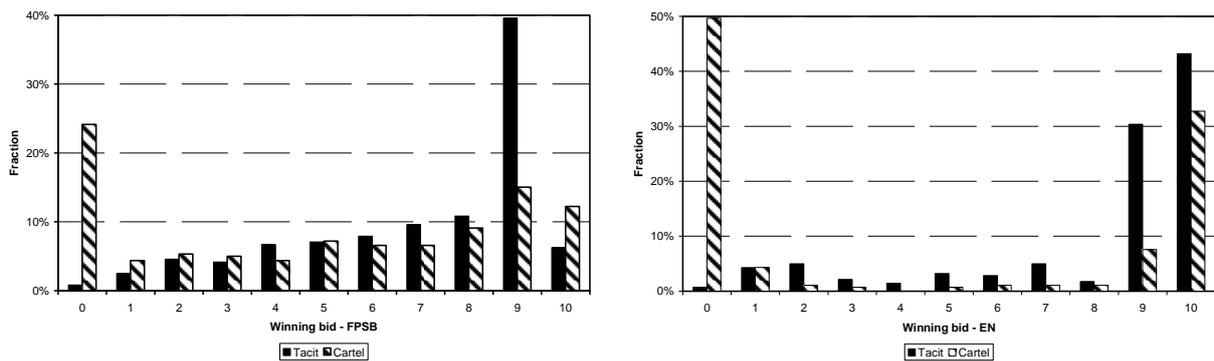


Figure 3 presents the frequency distribution of all winning bids for both treatments and auction formats. The first question we ask is if subjects collude tacitly if overt collusion is not possible. Recall that in both auctions, a winning bid of 9 emerges in the Nash equilibrium in weakly dominant strategies. 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 winning non-cartel bids in CARTEL is below 9. In sum:

Result 3

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 5: Winning cartel and non-cartel bids

		FPSB		EN	
Periods		Cartel	Non-cartel	Cartel	Non-cartel
1 – 35	TACIT	5.3	9.1	4.1	9.6
	CARTEL	3.5	9.4	2.1	9.6
36 – 39	TACIT				
	CARTEL				
40	TACIT				
	CARTEL				

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

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:

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

$j \in i = 1, 2, \dots, n^X$, $t = 1, \dots, 40$, where B_{it}^{XY} is the winning bid in group i in round t in auction $X \in \{\text{EN}, \text{FPSB}\}$ for treatment $Y \in \{\text{TACIT}, \text{CARTEL}\}$, 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 $Y = \text{CARTEL}$ 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:

Result 4

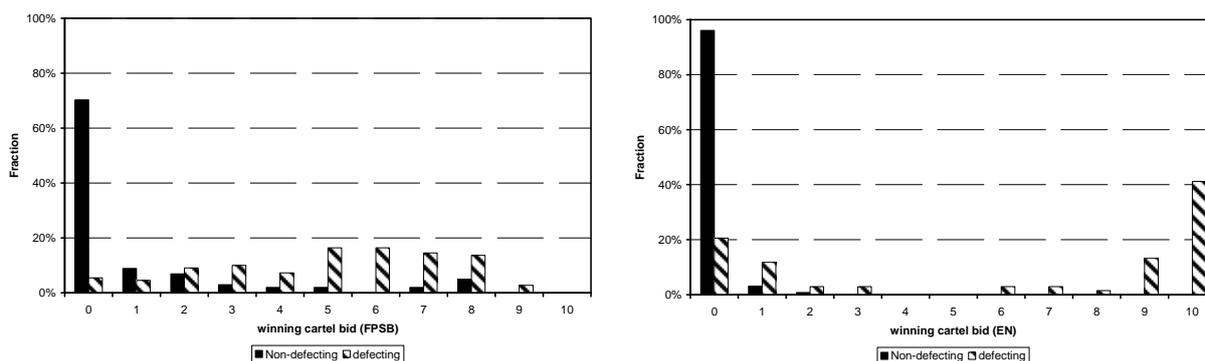
The average winning cartel bid is lower than the average winning non-cartel bid. The winning cartel bid in EN is lower than the winning cartel bid in FPSB. Only in FPSB does the winning cartel bid increase in the final rounds. The winning non-cartel bid increases in the final rounds in EN, and even more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

$$1 \text{ point} = \text{€ } 0.25$$

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

$$10 - \text{your winning bid}$$

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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