Essays on auctions

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Citation for published version (APA):
Hu, X. (2010). *Essays on auctions*. Thela Thesis.

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Deterring Collusion using Premium Auctions

This chapter is based on Audrey Hu, Theo Offerman and Sander Onderstal. "Fighting collusion in auctions: An experimental investigation." Forthcoming in International Journal of Industrial Economics.

3.1 Introduction

Fighting collusion is a primary concern for auctioneers because bidders who manage to form a cartel can seriously harm the seller's revenue. Klemperer (2002) argues that collusion and other competition policy related issues like predation and entry deterrence are more relevant for practical auction design than risk-aversion, affiliation, and budget-constraints that play a prominent role in mainstream auction theory. Case law shows that collusion in auctions is not just a theoretical possibility: Krishna (2004) reports that in the 1980s, 75% of the US cartel cases were related to auctions.[1] Apparently, competition law enforcement does not sufficiently deter bidders to collude. In fact, Motta (2004) argues that "[i]t is better to try to create an environment that discourages collusion in the first place than trying to prove unlawful behavior afterwards."

The literature provides several ways for auctioneers to implement auction rules that discourage bidders to collude. It is well known that the auctioneer may impose a reserve price to do so (Graham and Marshall, 1987). Recent papers show that collusion-proof mechanisms exist under fairly general circumstances. These mechanisms raise as much revenue as a revenue-maximizing mechanism in the absence of collusion (Laffont and Martimort, 1997, 2000, Jeon and Menicucci, 2005, and Che and Kim, 2006, 2008).

These theoretical solutions have several practical limitations. The optimal reserve price and the collusion-proof mechanism require the auctioneer to know the distribution functions from which bidders draw their values. In addition, the auctioneer needs to know which bidders belong to which cartel. In practice, such information is difficult, if not impossible, to acquire.[2] For practical mechanism design, Wilson (1987) strongly advocates

[1] However, this high percentage does not necessarily suggest that the auctions cartels can be detected easily, as we do not know the number of those (tacit) collusions that have escaped public attention.

[2] Other limitations of proposed collusion-proof mechanisms are the following. Both Laffont and Martimort (1997, 2000) and Jeon and Menicucci (2005) require a risk-neutral, "benevolent" third-party to coordinate the side-payments for the coalition to function. Che and Kim's (2006) collusion-proof

the implementation of "detail-free" auctions, i.e., auctions of which the rules do not depend on the above mentioned peculiarities of the environment.

Therefore, we will focus on a more practical solution and search for an existing "detail-free" auction format that prevents collusion as much as possible. Among the existing auctions, the literature suggests using the first-price sealed-bid auction (FP) instead of the English auction (EN) (Robinson, 1985, and Marshall and Marx, 2007). The reason is that a cartel agreement is stable in EN, where no bidder has an incentive to deviate from the cartel agreement because the cartel will continue bidding up to the highest value of its members. In contrast, a cartel in FP has to shade its bid below the highest value in the group to make a profit, which gives individual cartel-members an incentive to cheat on the agreement and submit a higher bid than the cartel.

Still, there have been many FP auctions where bidders colluded, for instance by submitting identical bids (Scherer, 1980; McAfee and McMillan, 1992). Recent examples of collusion in FP include infrastructure procurement (Porter and Zona, 1993, and Boone et al., 2009) and school milk tenders (Porter and Zona, 1999, and Pesendorfer, 2000). Apparently, many cartels have been able to overcome the free-rider incentives in FP, possibly because repeated interaction renders collusion stable in FP (Blume and Heidhues, 2008, Abdulkadiroğlu and Chung, 2003, Aoyagi, 2003, 2007, and Skrzypacz and Hopenhayn, 2004). Motivated by these examples, we focus on the toughest possible case for auctioneers, the one where cartel members do not have to fear that there will be defection from within the cartel and where side-payments are possible between cartel members (a "strong cartel" in McAfee and McMillan's (1992) terminology, and a "bid submission mechanism" in Marshall and Marx's (2007)). Our choice to focus on strong cartels is also supported by experimental evidence. Phillips, Menkhaus and Coatney (2003) show that even groups of 6 bidders who

model does not rely on the special structures or bidder-types like the previous work. However, selling to the coalition is often not feasible in practice.

interact repeatedly are able to form stable coalitions when communication is allowed. In their communication treatment, Hamaguchi, Ishikawa, Ishimoto, Kimura and Tanno (2007) find that in procurement auctions subjects do not cheat on the agreement reached in the communication phase.

In this chapter , we compare how effective FP, EN, and a lesser known format based on a premium auction are in deterring collusion. In a premium auction, the auctioneer pays the runner-up a premium for driving up the price paid by the winner. In situations where the auctioneer fears collusion, a premium auction may make collusion less attractive because it encourages bidders outside of the cartel to compete for the premium.[3] In Europe, premium auctions are used to sell houses, land, boats, machinery and equipment. There are many variants of premium auctions, that differ in institutional details. In fact, in the Netherlands and Belgium, many of the larger cities have their own variant that they claim to be unique in the world.

Here, we consider a premium auction investigated in Goeree and Offerman (2004), the Amsterdam second-price auction (AMSA). This auction is one of the simpler formats and it has the advantage that its equilibrium is analytically tractable. AMSA consists of two phases. In the first phase, the auctioneer raises the price successively while bidders decide whether or not to drop from the auction. This process continues until two bidders remain. The price at which the last bidder dropped out defines the endogenous reserve price or bottom price for the second phase. In this phase, both remaining bidders independently submit sealed bids, which must be at least as high as the bottom price. The highest bidder wins and pays a price equal to the second highest bid. Both bidders of the second

[3] The literature identifies other situations where premium auctions may perform well relative to standard auction formats such as FP and EN. Goeree and Offerman (2004) show, both theoretically and in an experiment, that premium auctions may generate more revenue than standard auctions when bidders are asymmetric. Milgrom (2004) argues that the prospect of receiving a premium may attract "weak" bidders to a premium auction who would not have entered in a standard auction where they have no hope to beat the strong bidder.

phase receive a premium, which is a fraction $0 < \alpha < 0.5$ of the difference between the second highest bid and the bottom price.

Notice that there are some similarities between the use of premium auctions and shill bidding. With shill bidding, the seller invents fake bids or asks a confederate to submit fake bids to stir up the bidding. In contrast to the use of a premium in auctions, shill bidding is usually explicitly forbidden. For instance, eBay unambiguously prohibits shill bidding. The rationale provided by eBay is that family members, roommates and employees of the seller have a level of access to information on the good for sale that is not available to other bidders. This is an important difference with a premium auction, where the bidders who pursue the premium are not better informed than the bidders who are genuinely interested in the good. In addition, an important difference is that all the bidders who participate in a premium auction are exactly informed about the rules of the game, while in shill auctions the genuine bidders are not informed of the presence of a shill bidder. For such reasons premium auctions are legally more acceptable than shill bidding, even though they both intend to stir up the bidding.

In most countries collusion is forbidden, and, if it is detected, cartel-members receive a fine. In addition, players incur costs when they decide to set up a cartel. Instead of closely modeling such processes, we simply introduce a cost that bidders have to pay when they decide to collude. If the eligible bidders agree to form a cartel, they determine in a pre-auction knockout who will proceed to the auction and how much he has to pay to compensate the other members for not participating.

We examine two settings in which bidders can collude. In the symmetric setting, all bidders can collude, and in the asymmetric setting, only a subset can do so. In the symmetric environment, all bidders draw their values from the same distribution function. In the asymmetric one, we distinguish between "weak" and "strong" bidders. A strong bidder always has a higher value than a weak bidder. This form of asymmetry characterizes many situations in practice, where serious, genuinely interested bidders compete with fortune-hunters out for a bargain. Maskin and Riley (2000) motivated this setup with a reference to the “Getty effect”, after the wealthy museum known for consistently outbidding the competition. Only strong bidders have the opportunity to collude. The rationale for this choice is that in practice there is basically an infinite supply of bidders with a weak preference for the good, so it is prohibitively costly to try and include all of them in a cartel. On the other hand, there is usually only a limited number of seriously interested bidders, and for them it may be very interesting to prevent competition from each other.

The theoretical properties of this model are the following. In the symmetric case, collusion is equally likely in the three auctions, i.e., it is equally like that bidders form a cartel. In the asymmetric case, collusion occurs more often in EN than in FP despite the assumption that the cartel, if formed, is also stable in FP. In the stage game where the designated bidder of a cartel faces weak bidders, AMSA turns out to have multiple equilibria, which mainly depend on how aggressively weak bidders bid. If they remain “passive” and bid up to value, AMSA and EN are equally conducive to collusion, and both mechanisms are dominated by FP. However, in an “aggressive equilibrium”, AMSA outperforms both FP and EN in terms of fighting collusion.

Which equilibrium of AMSA is the most likely to be played remains an open question, which we address using a laboratory experiment. Another reason for using a laboratory experiment to empirically test our theoretical findings is that field data on cartels are difficult to obtain by its illegal nature. In the experiment, we compare AMSA with FP and EN. We observe the following results. In the symmetric setting, EN and AMSA are equally successful in fighting collusion. Both mechanisms outperform FP. In the asymmetric setting, AMSA triggers less collusion than the other two auctions, which perform equally poorly. Overall, our experiments suggest that AMSA is the superior choice to fight collusion. To the extent that the experimental results deviate from the theoretical predictions, we provide a coherent explanation for why they differ.

In single-unit auctions, collusion does not arise under standard experimental procedures.[4] The exception is provided in Lind and Plott (1991), who report attempts at collusion in one of their five common value auction sessions. There is surprisingly little experimental work that allows subjects to explicitly collude in single-unit auctions. The main exception is Isaac and Walker (1985) who gave bidders the opportunity to talk before they submitted their sealed bids in a first-price private value auction. In four out of their six series where a single unit was put up for sale, the four bidders managed to collude. Kagel (1995) discusses two unpublished studies that also study collusion in single-unit auctions. In one study, Dyer investigated tacit collusion in first-price private value auctions by comparing bidding in fixed groups and known identities with bidding in groups that were randomly rematched between auctions. His results were inconclusive. In the other study, Kagel, Van Winkle, Rondelez and Zander let subjects communicate prior to bidding in a first-price common value auction. When the reserve price was announced, subjects used a rotation rule and almost always submitted bids at the reserve price. With a secret reserve price, bidders were less successful in colluding and earned somewhat less than half the amount they made when the reserve price was announced and the amount that they made when there was no communication. More recently, Hamaguchi et al. (2007) study collusion in procurement auctions and the effectiveness of leniency programs. As in Isaac and Walker (1985), bidders could talk before submitting bids. They observe that virtually all bids are at the monopoly price, so that bidders clearly manage to collude. Our experiment goes a step further than the previous literature by examining how successful bidders are in forming cartels under different auction formats, and by studying the role of bidders outside the cartel who may render a cartel unattractive if they bid aggressively.[5]

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[4] See Kagel (1995) for an overview of experimental single unit auctions.

[5] In contrast, there is a vast experimental literature on collusion in multi-unit auctions. This literature includes Goswami, Noe, and Rebello (1996), Shertsyuk (1999, 2002), Kwasnica (2000), Kagel and Levin (2001, 2005), Phillips, Menkhaus and Coatney (2003), Sade, Schnitzlein and Zender (2006), Kwasnica and Sherstyuk (2007).

The remainder of this chapter is organized as follows. In Section 3.2, we describe the theoretical background of our experiments. Section 3.3 includes our experimental design. In Section 3.4, we present our experimental findings and section 3.5 concludes. The experimental instructions can be found in the Appendix of this chapter.

3.2 Theory

A seller offers one indivisible object in FP, EN, or AMSA to $n \geq 2$ risk neutral bidders, $s \geq 2$ strong ones and $w \equiv n - s \geq 0$ weak ones. Bidders who are active in the second phase of AMSA obtain a premium equal to a fraction $\alpha \in (0, 1/2)$ of the difference between the second highest bid and the reserve price. Weak bidders draw their value from the uniform distribution on the interval $[0, 1]$, while strong bidders' values are uniformly distributed on $[L, H]$, $H > L \geq 0$.[6] All values are drawn independently. We let $v^{[2]}$ denote the second order statistic of s draws from the uniform distribution on $[L, H]$.

Bidders interact in a three-stage game. In the first stage, strong bidders vote for or against forming a cartel. A cartel forms if and only if all strong bidders vote "yes". All bidders in the cartel incur a commonly known exogenous cost $c > 0$ if and only if the cartel is actually formed. If a cartel forms, in stage two, the strong bidders interact in a pre-auction knockout mechanism like the one described in McAfee and McMillan (1992). In this knock-out auction, all bidders independently submit a sealed bid. The highest bidder wins, he pays a fraction $1/(s-1)$ of his bid to each of the other $s-1$ strong bidders, and proceeds to stage three. In the third stage, in the case of a cartel, the designated strong bidder interacts in the auction (AMSA, EN, or FP) with the weak bidders.[7] The designated bidder can submit shill bids on behalf of the other cartel-members. This

[6] We shall assume $L \geq 1$ for the asymmetric case later on.

[7] Boone et al. (2009) describe how members of a Dutch construction cartel used a similar mechanism to determine the designated winner and his side-payments to the other cartel members.

realistic feature helps to conceal the fact that the strong bidders collude. When bidders do not form a cartel, stage two is skipped and all bidders compete in the auction in stage three. As solution concept, we use the perfect Bayesian equilibrium.[8]

In the first stage, a strong bidder will vote for collusion if and only if the (expected) benefits of collusion outweigh its costs c. Let us assume that the strong bidder with the highest value always wins, with or without collusion. Let P denote the price the designated strong bidder expects to pay in the actual auction. The following proposition characterizes when strong bidders will vote for collusion in stage one.

Proposition 6 *Suppose that the subgame after the voting stage has an equilibrium in which the auction always allocates the object to the strong bidder with the highest value (in both the collusive and the non-collusive case) and that the strong bidders' lowest type expects zero profit in the non-collusive case. Then, in the equilibrium of the entire game, a strong bidder, regardless of his value, votes in favor of the cartel if and only if*

$$c \leq \frac{1}{s}\left[E\left\{v^{[2]}\right\} - P\right]. \tag{3.1}$$

Proof. We let $F^{[1]}$ $[F^{[2]}]$ denote the distribution function of the first [second] order statistic of s draws from the uniform distribution on the interval $[L, H]$. Myerson (1981) shows that a strong bidder's expected pay-off from an auction can be expressed as

$$\pi(v) = \underline{\pi} + \int_L^v Q(x)dx$$

where $\underline{\pi}$ denotes the expected pay-off for the strong bidder's lowest type and $Q(x)$ the probability that a strong bidder with value x wins. Let $\underline{\Pi}$ be the expected pay-off for the strong bidder's lowest type in the case of collusion. Because the auction always allocates the object to the bidder

[8] When we speak about the equilibrium of an auction, we refer to the Bayesian equilibrium of the last subgame in which $w+1$ $[w+s]$ bidders participate if a cartel is [not] formed.

with the highest value (both in the collusive and the non-collusive case) and the strong bidders' lowest type expects zero profit in the non-collusive case, a strong bidder with value v is willing to join the cartel if and only if $c \leq \underline{\Pi}$. McAfee and McMillan (1992) show that in the knock-out auction, the following bidding function constitutes a symmetric Bayesian Nash equilibrium:

$$B(v) = \frac{s-1}{s} F^{[1]}(v)^{-1} \int_L^v (x - P)\, dF^{[1]}(x).$$

Given this equilibrium, $\underline{\Pi}$ can be expressed as

$$\begin{aligned}
\underline{\Pi} &= \frac{1}{s-1} \int_L^H B(v) dF(v)^{s-1} \\
&= \frac{1}{s} \int_L^H F(v)^{-s} \int_L^v (x-P)\, dF(x)^s dF(v)^{s-1} \\
&= \frac{1}{s} \int_L^H (x-P) \int_x^H F(v)^{-s} dF(v)^{s-1} dF(x)^s \\
&= \frac{1}{s} \int_L^H (x-P)\, s\,(s-1)\,[1-F(x)]\, F(x)^{s-2} dF(x) \\
&= \frac{1}{s} \int_L^H (x-P)\, dF^{[2]}(x) \\
&= \frac{1}{s} \left(E\left\{ v^{[2]} \right\} - P \right),
\end{aligned}$$

where F denotes the value distribution function of a strong bidders. The third equality follows by changing the order of integration. The other steps are straightforward. ■

Note the expected benefits of collusion for the strong bidders is the difference between the expected (net) payments without collusion (which is the expectation of the second highest value) and the price the designated winner expects to pay with collusion (which is P). This additional pie will be divided equally among the s strong bidders, which explains the expected benefits on the right-hand side of (3.1). The result that the willingness-to-pay for forming a cartel does not depend on a bidder's value follows from Myerson's (1981) revenue equivalence theorem. Given that two auctions always assign the object to the bidder with the highest value, the difference in expected utility for a bidder is determined only by the difference in expected utility for the bidder with the lowest value L. The following corollary follows from Proposition 6.

Corollary 1 *If two auctions always allocate the object to the bidder with the highest value in equilibrium (both in the collusive and the non-collusive case) and the lowest type expects zero profit in the non-collusive case, then the auction with the lower P is more conducive to collusion.*

Corollary 1 shows that we only have to compare the expected price the designated winner has to pay in FP, EN, and AMSA to predict which of the three auction formats is less prone to collusion.

We consider a symmetric and an asymmetric setting. In the symmetric one, $w = 0$ (there are no weak bidders), $H = 1$, and $L = 0$. The following proposition immediately follows from Corollary 1, because the three auctions are efficient (with and without collusion), the lowest type expects zero profit in the absence of collusion, and in all three auctions, the designated winner pays zero for the object in the case of a cartel.[9]

Proposition 7 *If $w = 0$, $H = 1$, and $L = 0$, collusion is equally likely in equilibrium in FP, EN, and AMSA.*

In the asymmetric case, $w \geq 1$ (there is at least one weak bidder) and $H > L \geq 1$ (a strong bidder's value is always higher than a weak bidder's). We will establish how the auctions rank in terms of incentives to collude on the basis of the equilibria of the subgame played in stage three. For FP, let $B^{FP}(v)$ [$b^{FP}(v)$] be a strong [weak] bidder's bid if his value is v.

[9] In the unique equilibrium of FP, a bidder with value v bids $B^{FP}(v) = v - v/n$, while EN has an equilibrium in weakly dominant strategies in which each bidder bids value. Goeree and Offerman (2004) establish that AMSA has an equilibrium in which a bidder with value v bids $\frac{v+\alpha}{1+\alpha}$ in both stages.

Using Maskin and Riley's (2003) uniqueness result, it follows that all non-collusive equilibria of FP in non-dominated strategies are characterized by

$$\begin{aligned} B^{FP}(v) &= v - \frac{v-L}{s}; \\ b^{FP}(v) &\in [0, v]. \end{aligned}$$

The following proposition describes collusive equilibria for FP for sufficiently high L.

Proposition 8 *Suppose that strong bidders form a cartel. If $w \geq 1$ and $L \geq \frac{w+1}{w}$, then in any equilibrium of FP in non-dominated strategies, the designated strong bidder bids $B^{FP}(v) = 1$ and always wins the auction.*

Proof. For weak bidders, bids above their value are weakly dominated. Therefore, none of the weak bidders bids more than 1 in equilibrium so neither does the designated strong bidder. Therefore, the proof is established if we show that the designated strong bidder will never bid less than 1 in equilibrium. Now, suppose his lowest equilibrium bid equals $b < 1$. Then a weak bidder with value $v_w \in (b, 1]$ best responds by submitting a bid in the interval (b, v_w), while those with a value below b bid less than b. Therefore, the designated winner's expected profit given his value v equals $U(b, v) = (v - b)\, b^w$ if he bids b and $v - 1$ if he bids 1. Note that, for all $v \in [L, H]$, $\frac{\partial U(b,v)}{\partial b} = b^{w-1}\,(wv - (w+1)\, b) > 0$ if $L \geq \frac{w+1}{w}$ so that $(v - b)\, b^w < v - 1$. A contradiction is established because bidding $b < 1$ is not a best response for the designated winner. An equilibrium in which $B^{FP}(v) = 1$ can be readily constructed by letting all weak bidders bid value. ■

So, if $L \geq \frac{w+1}{w}$, the expected payment by the designated winner equals

$$P^{FP} = 1.$$

For EN it is always a weakly dominant strategy to bid value. So, in the case of collusion, the designated winner expects to pay the highest value among the weak bidders:

$$P^{EN} = \frac{w}{w+1}.$$

The following proposition establishes an equilibrium for AMSA in the absence of collusion.[10]

Proposition 9 *Let $w \geq 1$ and $L \geq 1$. Suppose that the strong bidders do not form a cartel. The following bidding strategies constitute an equilibrium outcome of AMSA in non-dominated strategies. In the first phase, a strong bidder with value v remains in the auction up to $\frac{v+\alpha H}{1+\alpha}$. The weak bidders all drop out at any price between their value and L. In the second phase, a strong bidder with value v bids $\frac{v+\alpha H}{1+\alpha}$.*

Proof. We begin by solving the second phase given the strategies in the first phase. If $s > 2$, let v_3 denote the value of a strong bidder whose bid in phase one equals the bottom price $X = B_1(v_3)$. Otherwise, $v_3 = L$. Moreover, v_2 denotes the other strong bidder's value. The second phase expected payoff of a strong bidder with value v who bids $B_2(\hat{v}) \geq X$ can be expressed as:

$$\pi(\hat{v}|v) = \frac{1}{H - v_3} \times \left(\begin{array}{c} \int_{v_3}^{\hat{v}} (v - B_2(v_2))dv_2 + \alpha \int_{v_3}^{\hat{v}} (B_2(v_2) - X)dv_2 \\ +\alpha(B_2(\hat{v}) - X)(H - \hat{v}) \end{array} \right).$$

The first (second) [third] term on the RHS refers to the bidder's value minus his payment if he wins (the premium if he wins) [the premium if he

[10] For weak bidders the strategy to bid value weakly dominates bidding below value.

loses]. The FOC is:

$$\left.\frac{\partial\pi(\hat{v}|v)}{\partial\hat{v}}\right|_{\hat{v}=v} = \frac{1}{H-v_3}\times \left(\begin{array}{c} v - B_2^a(v) + \alpha(B_2^a(v) - X) \\ +\alpha B_2^{a\prime}(v)(H-v) - \alpha(B_2^a(v) - X) \end{array}\right) = 0$$

from which we obtain the optimal bidding strategy for strong bidders. It is readily verified that the SOC $sign\left(\frac{\partial\pi(\hat{v}|v)}{\partial\hat{v}}\right) = sign\,(v-\hat{v})$ is satisfied. Because a strong bidder with value L has not reason to bid more than $\frac{L+\alpha H}{1+\alpha}$, a weak bidder surely has no reason to do so. Therefore, he has no reason to deviate from the above bids. ■

As we discussed before, the designated bidder can submit bids on behalf of the other strong bidders. In FP and EN, these shill bids do not affect the equilibrium outcome. In AMSA, however, the designated bidder may discourage weak bidders from pursuing the premium by keeping at least one of the shill bidders in the auction as long as weak bidders continue bidding. The possibility of shill bids makes it harder for AMSA to outperform the standard auctions. The following proposition shows that the AMSA may have several equilibria, which depend on how "aggressively" weak bidders bid.

Proposition 10 *Let $w \geq 1$ and $L \geq 1$. Suppose that the strong bidders form a cartel. The following bidding strategies constitute an equilibrium outcome of AMSA in non-dominated strategies. In the first phase, the strong bidder and his shill bidder remain in the auction up to his value. The weak bidders all drop out at any price between their value and L. In the second phase, the strong bidder bids value and the shill bidder bids the bottom price.*

The above proposition holds true because a weak bidder has no incentive to bid more than L, the lowest bid submitted by a strong bidder. If he does, he will outbid some types of strong bidders and end up paying more for the object than his value. It is easy to see that the strong bidder has no reason do deviate either. We say that weak bidders bid aggressively [passively] if they bid up to L [value] in the first phase, which is the highest [lowest] bid which is consistent with Propositions 9 and 10. Let P_{agr}^{AMSA} [P_{pas}^{AMSA}] denote the designated winner's expected payment in the aggressive [passive] equilibrium in the case of a cartel. Then:

$$P_{agr}^{AMSA} = L$$

and

$$P_{pas}^{AMSA} = \frac{w}{w+1}.$$

Table 1 ranks the three auctions in terms of likelihood of collusion for the two equilibrium extremes of AMSA. Corollary 1 and the expected equilibrium payments in FP, EN, and AMSA imply that in equilibrium, collusion is (weakly) less likely in AMSA than in EN. If $L \geq \frac{w+1}{w}$, collusion is more likely in EN than in FP, while the ranking of AMSA relative to FP depends on which of the equilibria in AMSA is played in the case of collusion. If the passive [aggressive] equilibrium is played, collusion is more [less] likely in AMSA than in FP.

Table 1
Ranking of auctions w.r.t. likelihood of collusion: the asymmetric case

		Expected (net) payment	
Ranking	Auction	No collusion	collusion
1	AMSA: passive equilibrium	$E\{v^{[2]}\}$	$w/(w+1)$
1	EN	$E\{v^{[2]}\}$	$w/(w+1)$
2	FP	$E\{v^{[2]}\}$	1
3	AMSA: aggressive equilibrium	$E\{v^{[2]}\}$	L

Notes: This is the ranking for $w \geq 1$ and $L \geq (w+1)/w$. A higher ranking (=lower number) refers to a higher likelihood of collusion in the sense that there is a larger range of cartel costs c for which collusion is profitable in equilibrium.

3.3 Experimental Design and Procedure

The computerized experiment was conducted at the Center for Experimental Economics and political Decision making (CREED) of the University of Amsterdam. A total of 180 students from the undergraduate population of the University were recruited by public announcement and participated in 9 sessions. Subjects earned points in the experiment, that were exchanged in euros at a rate of 5 points for €1. On average subjects made €25.70 with a standard deviation of €7.45 in sessions that lasted between 100 and 140 minutes.[11] Subjects read the computerized instructions at their own pace. Before they could proceed to the experiment, they had to correctly answer some questions testing their understanding of the rules. Before the experiment started, subjects received a handout with a summary of the instructions (see Appendix).

We employed a between-subjects design, in which subjects participated in one of three treatments only, FP, EN, or AMSA. The treatments only differed in the auction rules. In FP, subjects simultaneously submitted sealed bids for the good for sale. The highest bidder bought the good for sale and paid a price equal to the own bid (in all auctions, tied bids were randomly resolved by the computer). In EN, a thermometer showing the current price started rising from 0. Bidders decided whether or not to quit at the current price. When all but one bidder had pushed the quit button, the thermometer stopped rising and the remaining bidder bought the good at the current price. In AMSA, the auction process consisted of two phases. In the first phase, a thermometer started rising from 0. The thermometer stopped rising when all but two bidders had pushed the quit button. This price was called the bottom price for phase two. The two remaining bidders proceeded to the second phase where they simultaneously submitted sealed bids at least as high as the bottom price.

[11] At the end of the first session, we found out that subjects earned less than we had expected. Therefore, we provided them with an unannounced gift of €5 that was added to the total that they had made in the experiment. We kept the same procedure in the other sessions.

The highest bidder bought the good for sale at a price equal to the second highest sealed bid.

In all auctions, the winner earned a payoff equal to the own value minus the price paid. In addition, in AMSA the two bidders of the second phase each earned a premium equal to 30% of the difference between the lowest bid in the second phase and the bottom price. We now describe the features that were the same in each treatment.

The experiment consisted of three subsequent parts: a symmetric environment without collusion, a symmetric environment with collusion, and an asymmetric environment with collusion. The three parts consisted of 6 periods, 8 periods and 10 periods, respectively. Subjects received the instructions of a subsequent part only after the previous part had been completed. In each period, subjects were assigned to groups of 6. We randomly rematched subjects between periods within a matching-group of 12 subjects. In each session, we ran two independent matching-groups simultaneously, unless we did not have sufficient subjects in which case we ran one group. In each treatment, we obtained data on 5 independent matching-groups of 12 subjects each.

We started part one without collusion because we wanted the subjects to gain experience with the auction rules before they proceeded to the more complicated game where they were allowed to collude. At the outset of part one, subjects received a starting capital of 50 points. In addition, they earned and sometimes lost points with their decisions. In each period, a good was sold in each group of subjects. We communicated to the subjects that each subject received a private value for the good for sale, which was a draw from a U[0,50] distribution. Draws were independent across subjects and periods. Subjects were only informed of their own value. We kept draws constant across treatments for the sake of comparability of the results.

In part two, subjects were allowed to collude. In each period, subjects were first informed of the costs of cooperating, which were the same for all subjects.[12] Then subjects simultaneously voted whether or not to cooperate. Only if all 6 players voted for cooperation, the group actually cooperated. When a group cooperated, each bidder paid a cost of cooperation. This cost varied across periods, but it was constant across treatments to make results comparable. Group-members were informed of the total number of votes for cooperation in their group. If the group cooperated, all 6 bidders simultaneously submitted sealed bids in a knock-out auction for the right to be the designated bidder. The highest bidder became the designated bidder and automatically bought the good for zero in the auction. The designated bidder paid his bid in the knock-out auction, which was equally shared by the 5 other bidders. If the group did not cooperate, subjects did not incur the costs of collusion and the good was sold with the same auction rules as in part one.

Part three introduced asymmetry between bidders. In each period, three out of six bidders in a group were assigned the role of weak bidder and the three others the role of strong bidder. Weak bidders received a value from U[0,50], while strong bidders received a value from U[70,120]. Roles and values were assigned privately and independently across subjects and periods. In part three, only strong bidders had the possibility to collude. At the outset of the period, all bidders were informed of the costs that strong bidders would incur if they actually cooperated. A period started with strong bidders voting to cooperate or not. If all three strong bidders voted for cooperation, strong bidders did cooperate. Only strong bidders were informed of the outcome of the voting process. Therefore, weak bidders were not sure whether or not they faced a cartel. When strong bidders cooperated, they paid the cost of cooperating and proceeded to a knock-out auction, where they submitted sealed bids for the right to be designated bidder. The highest bidder won and paid a price equal to the own bid. This price was equally shared by the other two strong bidders. Then the designated bidder proceeded with the weak bidders to the main auction

[12] In the instructions we avoided the word collusion, because many subjects are unfamiliar with its meaning.

to bid for the good for sale. In the main auction, the designated bidder submitted shill bids on behalf of the other strong bidders and serious bids on the own behalf. Designated bidders did not share the profits (and premiums) that they made in the main auction. In case the strong bidders did not collude, all bidders immediately proceeded to the main auction with the same auction rules as in the previous parts.

During EN and the first phase of AMSA, other bidders in the group were immediately informed when one of their rivals had dropped out and, in part three, whether this bidder was weak or strong. At the end of a period, all bidders were informed of all bids in the group, and, when applicable, the strength of the bidder making the bid. Table 2 summarizes our experimental design.

Table 2
Experimental design

characteristics treatments					
treatment	price paid by winner	premium?	group-size	matching-group size	# matching-groups
FP	b_1	no	6	12	5
EN	b_2	no	6	12	5
AMSA	b_2	$0.3*(b_2-b_3)$	6	12	5
other features that were the same in all treatments					
part	collusion? who?	bidders' types	valuations	# periods	cost collusion
1	no	6 symmetric	U[0,50]	6	no
2	yes, all	6 symmetric	U[0,50]	8	0,5,2,3,7,6,4,1
3	yes, only strong	3 weak and 3 strong	weak: U[0,50] strong: U[70,120]	10	2,20,12,16,14, 6,10,8,18,4

Notes: b_i refers to the i-th highest bid. The column cost collusion reports the costs per period, from the first period to the last one.

We deliberately chose to build up the strategic complexity throughout the experiment. In the first part, subjects became familiar with the auction rules. In the second part, they were introduced to the possibility of collusion. By varying the costs of collusion, we encouraged them to vote for collusion when costs were low and to vote against collusion when costs were high. This way they rapidly gained experience with how profitable collusive bidding is compared to competitive bidding. Finally, in part three we introduced asymmetry between the bidders after they had become familiar with the auction rules and the possibility of collusion. To some extent our design mimics a natural process where bidders are engaged in a new series of auctions and then start spotting opportunities for collusion after time progresses. The main difference between our design and a natural process outside the lab is that we force our subjects to think about the possibility of collusion. However, we do not think that our designs triggers too much or too little collusion compared to a more natural process. Because subjects experience collusive auctions as well as competitive auctions, they can make well informed choices after a limited amount of time. Our design choices make it easier for subjects to learn. The enhanced possibilities for learning may compensate for the lack of experience that our subjects have in participating in auctions.

In any case, the most important goal of our experiment is to compare behavior between treatments. Since the sequencing is the same for any treatment, there is no reason to expect a bias in the comparison of the auction formats.

3.4 Results

We present the results in three parts. Before we start we want to make the caveat that all our results depend on the particular parameters that we employ in our experiments. However, there is no reason to expect that our parameter choices bias the qualitative comparison between the auctions. In Subsection 3.4.1, we compare the three auction formats at the aggregate level. In Subsection 3.4.2, we take a closer look at individual bidding behavior and in Subsection 3.4.3 we provide a coherent explanation of the main results.

Table 3
Collusion

		part 2		part 3	
		group colludes	votes collusion	group colludes	strong bidders' votes collusion
FP	realized	42.5%	81.9%	56.0%	79.3%
	Nash	75.0%	75.0%	70.0%	70.0%
EN	realized	26.3%	75.8%	53.0%	81.0%
	Nash	75.0%	75.0%	90.0%	90.0%
AMSA	realized	30.0%	75.0%	40.0%	68.7%
	Nash	75.0%	75.0%	--	--
	Nash passive	--	--	90.0%	90.0%
	Nash aggressive	--	--	40.0%	40.0%

3.4.1 Between auction comparisons

We evaluated the three auction formats on the basis of how they scored with respect to deterring collusion, raising revenue, and pursuing efficient outcomes. Table 3 presents the percentages of bidders who voted in favor of collusion together with the theoretical predictions that depend on the costs of collusion. In part two, where all bidders were symmetric, theory predicts that the auctions are equally vulnerable to collusion. The data show that the votes on collusion were very close to Nash in EN and AMSA. In FP, we observed moderately more votes for collusion than predicted. Notice that the proportions of cases where groups actually colluded were substantially smaller than the theoretically predicted ones. This is due to the fact that subjects did not exactly follow the theoretical threshold rule. Combined with the unanimity rule for collusion, this led to much fewer occasions where the groups actually colluded.

In part three with asymmetric bidders, AMSA triggered considerably fewer votes for collusion than FP and EN did. The proportion of votes for collusion in AMSA was about halfway the level predicted by the aggressive and the one predicted by the passive equilibrium. Remarkably, EN and FP performed about equally poorly in preventing collusion, while theory predicted that FP should trigger less collusion. We will come back to these results in Subsection 3.4.3 after we have dealt with individual behavior.

In part three, theoretical predictions on when bidders collude vary with the treatments. The EN auction and the passive equilibrium of AMSA predict that collusion is only prevented for a cost of 20. In FP, players should not collude for costs higher than or equal to 16, and in the aggressive equilibrium of AMSA, players should not collude for costs of 10 and higher. Therefore, for a cost level of 20 and cost levels below 10 the predictions were the same for all treatments. Table 3 pools across all levels of costs of collusion, also the ones for which the theoretical predictions are the same. Figure 3.1 provides an view on the relationship between costs of collusion and votes for collusion. It is striking that in part three votes for collusion were very similar across treatments for cost levels below 10 and at 20, as theory predicts. The difference in votes was indeed produced in the theoretically relevant cost set {10, 12, ..., 18}.

We now investigate to what extent these qualitative results were statistically significant. To take account of the panel data structure of our experiment, we estimated the following logit model with random effects. Let $y_{i,t}$ represent the vote of individual i in period t; $y_{i,t} = 1$ if i voted for collusion in period t and $y_{i,t} = 0$ if i voted against. We introduce the underlying latent variable $y^*_{i,t}$:

$$\begin{aligned} y^*_{i,t} &= \gamma + \beta_{cost} * cost_t + \beta_{value} * value_{i,t} \\ &\quad + \beta_{dumam} * dumam_i + \beta_{dumfp} * dumfp_i + \alpha_i + \varepsilon_{i,t} \end{aligned}$$

$$\begin{aligned} y_{i,t} = 1 \quad if \;\; y^*_{i,t} > 0 \\ y_{i,t} = 0 \quad if \;\; y^*_{i,t} \leq 0 \end{aligned}$$

Here, γ represents the constant; $cost_t$ refers to the costs of collusion in period t; $value_{i,t}$ to the value of i in period t; $dumam_i$ is a dummy that

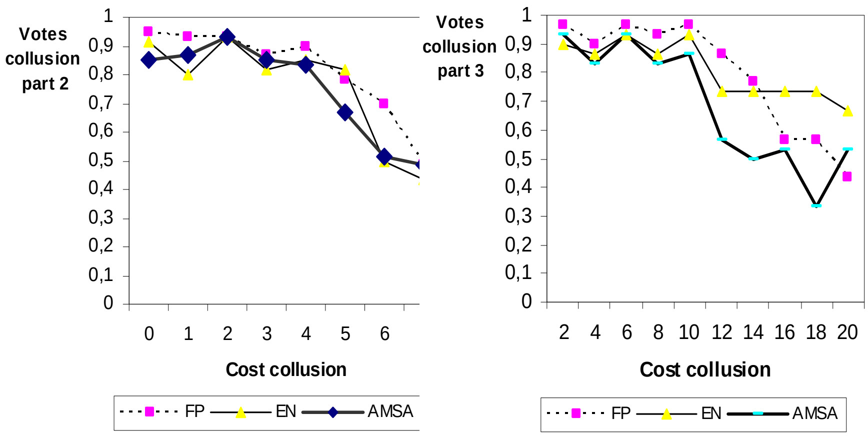

FIGURE 3.1. **Votes for collusion**. *Notes*: for each cost of collusion level the proportion of strong bidders' votes for collusion is displayed (vote collusion=1 if individual voted for collusion). Left panel: part2; right panel: part 3.

equals 1 if i participated in AMSA and 0 elsewhere, and $dumfp_i$ is the corresponding dummy for FP. In addition, we included "group dummies" in the regressions to correct for matching-group specific effects (not reported) and "period dummies" to correct for timing effects. Table 4 reports the treatment effects compared to the omitted treatment EN.

It turns out that in part two (the symmetric case), FP attracted significantly more votes for collusion than EN ($p = 0.01$) and AMSA ($p = 0.00$, Wald test). EN raised slightly more votes for collusion than AMSA did, and the difference is significant at $p = 0.05$. In part three (the asymmetric case), we observe less collusive votes in AMSA than in FP ($p = 0.01$, Wald test) and EN ($p = 0.00$), whereas there is no statistical difference between FP and EN ($p = 0.30$). As expected, there was a clear significant negative effect of the cost of collusion on the inclination to vote for collusion in both regressions reported.

Table 4
Random effects logit model on vote for collusion

	part 2	part 3
	estimate (s.e.)	estimate (s.e.)
dumam	-1.12 (0.57)**	-2.61 (0.71)**
dumfp	2.00 (0.73)**	-0.76 (0.73)
cost	-0.41 (0.05)**	-0.17 (0.03)**
value	-0.03 (0.01)**	-0.01 (0.01)
dump1	0.64 (0.25)**	-0.21 (0.38)
dump2	0.98 (0.38)**	-0.20 (0.34)
dump3	0.53 (0.29)*	-0.15 (0.36)
dump4	0.04 (0.23)	0.89 (0.62)
dump5	0.89 (0.29)**	1.06 (0.54)**
dump6	0.16 (0.34)	0.28 (0.48)
dump7		-0.25 (0.34)
dump8		-0.38 (0.54)
constant	3.71 (0.54)**	5.45 (1.08)**
Wald-test dumam−dumfp=0	-3.12 (1.01)**	-1.85 (0.67)**
-logL	602.21	393.45

Notes: standard errors in parentheses. ** (*) denotes significance at 5% (10%) level; the omitted treatment is EN; dumam equals 1 for AMSA and 0 otherwise; dumfp equals 1 for FP and 0 otherwise; for part 2, dump1, …, dump6 equal 1 for periods 8, …, 14, respectively, and 0 otherwise; for part 3, dump1, …, dump8 equal 1 for periods 17, …, 24, respectively, and 0 otherwise.

A remarkable result is that in part two the period dummies are always positive and significantly so in 4 of 6 cases. This suggests that subjects learned in the sense that they more easily voted for collusion after they obtained some experience with the game. In contrast, there does not seem to be a systematic pattern in the period dummies in part three. Interestingly, the coefficient for value is significantly negative in part two. There, subjects were more inclined to vote for collusion when they received lower values. This is in contrast to theory, which indicates that the decision to vote for collusion does not depend on value. Possibly, subjects with low values realized that they would not have a fair chance in a competitive auction, which made them more inclined to vote for collusion. The coef-

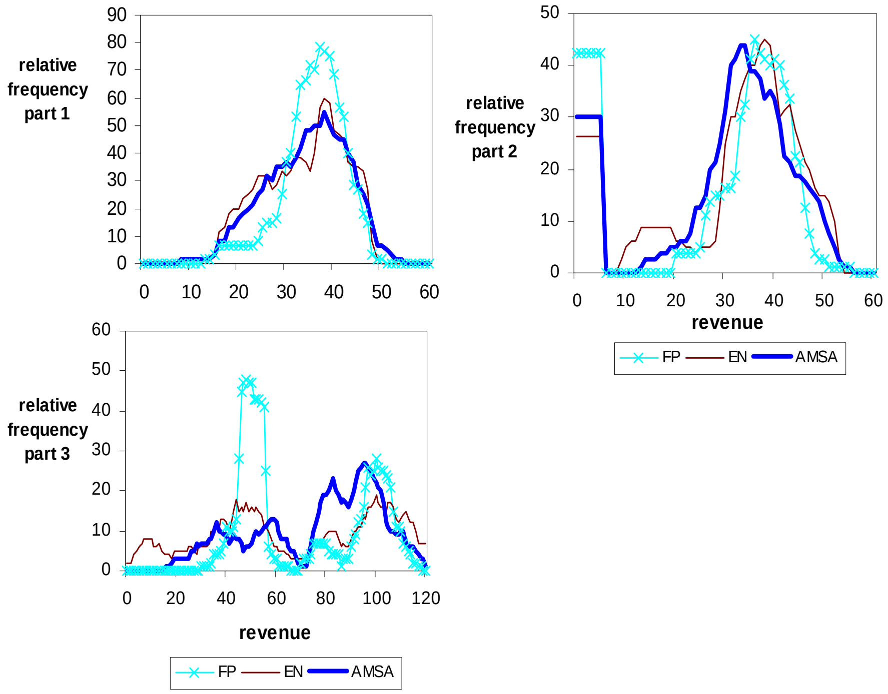

FIGURE 3.2. **Revenue**. *Notes*: for each revenue level the percentage of outcomes that fall in the interval [revenue-5, revenue+5] is displayed. Upper-left panel: part 1; upper-right panel: part 2; lower panel: part 3.

ficient for value ceases to be significant in part three, though, which may be a sign that subjects learned across the two parts.

We now turn to the comparison of revenues between the treatments. Figure 3.2 shows revenue histograms for parts one, two and three. In part one, revenue was on average somewhat higher and less dispersed in FP than in EN and AMSA. The histogram of revenues in AMSA was almost identical to the one in EN. In agreement with the finding that subjects colluded more often in part two of FP, the upper-right panel shows a larger spike at 0 in FP than the other two formats. Thus in the symmetric setup, the possibility to collude counteracted the usual revenue dominance

Table 5
Revenue

		part 1	part 2	part 3
FP	realized	35.7 (5.7)	21.3 (18.8)	70.9 (25.2)
	Nash	34.9 (6.1)	9.5 (16.6)	63.7 (21.4)
EN	realized	33.5 (8.1)	26.4 (17.7)	68.0 (33.8)
	Nash	35.8 (7.5)	9.8 (17.3)	45.2 (20.5)
AMSA	realized	34.3 (8.0)	24.9 (17.5)	76.8 (25.3)
	Nash	35.7 (5.5)	9.6 (16.8)	--
	Nash passive	--	--	45.0 (19.4)
	Nash aggressive	--	--	86.1 (14.5)

Notes: standard errors in parentheses.

of FP over EN found in previous experimental auctions.[13] The lower-left panel shows that the largest differences in revenues were observed for asymmetric bidders. Here, a bimodal distribution resulted in FP, with the largest number of outcome close to 50 and most of the other outcomes close to 100. In contrast, the revenue histograms for EN and AMSA were much more spread out. EN was the most vulnerable auction in terms of raising very low revenues.

Table 5 reports the average revenues in the experiment in comparison with the theoretical revenues given the values and collusion costs employed in the experiment. In part one, FP generated the highest revenue, followed by AMSA and EN. The differences were small, though, and all quite close to the theoretically expected levels. The second part reveals that in the case of symmetric bidders and potential cartel formation, EN and AMSA both raised higher revenues than FP. In all treatments, revenues were much higher than the theoretical predictions. Because unanimity was required for a cartel to form, the number of actual cartels was much lower than predicted by theory, and, as a consequence, actual revenue was higher. In the third part, AMSA performed best while EN and FP raised similar revenues. Here, EN performed much better than theoretically predicted.

[13] See Kagel (1995).

The revenue of AMSA was closer to the revenue expected in the aggressive equilibrium than the revenue in the passive equilibrium.

To investigate the significance of the revenue comparisons, we estimated a random effects model that took the interaction in the experiment into account. Let $r_{i,j,t}$ represent the revenue of group i ($i = 1$ or $i = 2$) in matching-group j in period t:

$$\begin{aligned} r_{i,,j,t} &= \gamma + \beta_{cost} * cost_t + \beta_{dumam} * dumam_j \\ &\quad + \beta_{dumfp} * dumfp_j + \alpha_j + \varepsilon_{i,j,t} \end{aligned}$$

Here, γ denotes the constant; $cost_t$ represents the costs of collusion in period t; $dumam_j$ ($dumfp_j$) is a dummy that equals 1 if the matching-group j was run in AMSA (FP) and 0 elsewhere.

Table 6 reports the results compared to the omitted treatment EN. In part one, only the difference in revenue between FP and EN is significant at p=0.08. In part two there are no significant differences between the treatments. In the asymmetric situation of part three, it becomes attractive for sellers to employ the AMSA format, as it raised roughly 10% more revenue than FP and EN. The difference in revenue between AMSA and FP is significant at p=0.08 (Wald test) and the difference in revenue between AMSA and EN is significant at p=0.04. The difference between FP and EN is not significant (p=0.50). In both regressions there is a significant effect of costs of collusion. With higher costs of collusion, groups colluded less and more revenue was raised.

Table 6
Random effects model on revenue

	part 1	part 2	part 3
	estimate (s.e.)	estimate (s.e.)	estimate (s.e.)
dumam	0.80 (1.34)	-1.49 (4.34)	8.76 (4.35)**
dumfp	2.12 (1.20)*	-5.15 (4.36)	2.90 (4.30)
cost		2.31 (0.79)**	1.39 (0.35)**
dump1	-5.88 (2.07)**	-10.07 (3.20)**	0.09 (6.08)
dump2	2.92 (0.97)**	3.66 (4.11)	6.98 (5.46)
dump3	-1.17 (1.34)	3.72 (4.19)	4.68 (6.42)
dump4	-4.75 (1.20)**	6.15 (3.36)*	-9.25 (5.40)*
dump5	-3.93 (1.73)**	-9.73 (3.53)**	-17.23 (4.56)**
dump6		9.44 (4.30)**	-4.37 (5.97)
dump7			6.53 (5.69)
dump8			3.54 (7.44)
constant	35.67 (1.16)**	17.95 (4.34)**	53.65 (6.22)**
Wald-test dumfp−dumam=0	1.32 (1.16)	-3.66 (4.33)	-5.86 (3.37)*
R^2 within	0.18	0.28	0.20
R^2 between	0.44	0.11	0.29
R^2 overall	0.18	0.26	0.21

Notes: (robust) standard errors in parentheses. ** (*) denotes significance at 5% (10%) level; the omitted treatment is EN; dumam equals 1 for AMSA and 0 otherwise; dumfp equals 1 for FP and 0 otherwise; for part 1, dump1, …, dump5 equal 1 for periods 2, …, 6, respectively, and 0 otherwise; for part 2, dump1, …, dump6 equal 1 for periods 8, …, 14, respectively, and 0 otherwise; for part 3, dump1, …, dump8 equal 1 for periods 17, …, 24, respectively, and 0 otherwise.

Table 7 presents revenue in parts two and three conditional on whether a cartel was established. In part two, conditional on a cartel not being formed, the results were very similar as the ones for part one. Thus, the different revenue results in parts one and two are mainly attributed to the differences in votes for collusion between the treatments. In part three, both in the cases where collusion occurred and the cases where collusion did not occur, actual revenues were very close to the theoretical predicted outcomes in EN and FP. The result that, pooled across all cases, revenue in EN was much higher than theoretically expected must thus be attributed to the fact that this auction was much less conducive to collusion than predicted. Overall, revenue in AMSA was higher than the other two formats

Table 7
Revenue conditional on (no) collusion

		part 2	part 3	
		no collusion	no collusion	collusion
FP	realized	37.0 (5.2)	97.8 (9.6)	49.8 (5.8)
	Nash	36.1 (5.3)	96.7 (5.6)	50.0 (0.0)
EN	realized	35.8 (9.2)	99.0 (12.7)	40.5 (19.9)
	Nash	36.7 (9.1)	101.3 (11.9)	39.2 (8.6)
AMSA	realized	35.6 (7.2)	93.8 (10.5)	51.3 (18.6)
	Nash	37.3 (6.7)	98.6 (7.8)	--
	Nash passive	--	--	38.8 (7.5)
	Nash aggressive	--	--	70.0 (0.0)

Notes: in part 2 realized and theoretical revenues in case of collusion equal 0 by definition; the Nash predictions are computed on the basis of the actual voting behavior. Standard errors in parentheses.

despite the fact that AMSA realized less revenue in the absence of collusion. Conditional on collusion, AMSA dominated EN, but raised similar revenues as FP did. Therefore, the results that AMSA revenue dominated FP and EN must be attributed to bidders being less inclined to vote for collusion. Note that the observations are closer to the Nash predictions than in Table 5, with AMSA in part three being closer to the "passive" equilibrium than the "aggressive" one.

Finally, we point the spotlight on efficiency. Table 8 includes the average efficiency of the auctions in each part.[14] Theory predicts that all auctions are 100% efficient because in equilibrium, the bidder with the highest value always wins the object. In all three parts, EN was more efficient than FP, and AMSA was less efficient than FP and EN. The efficiency differences were substantial in parts one and three. Running similar regressions as the ones reported for revenue, we find that the differences in efficiency in part one between FP and AMSA and EN and AMSA are both significant at the 5% level. In part three, the differences between EN and AMSA and FP and EN are significant at the 10% level. All other differences in efficiency are not significant at conventional levels. So while AMSA tends

[14] We define efficiency as $(v_{\text{winner}} - v_{\min})/(v_{\max} - v_{\min})$, where v_{winner}, $v_{\min}$, and $v_{\max}$ represent the value of the winner, the lowest value among the bidders and the highest value among the bidders, respectively.

to outperform FP and EN in terms of cartel formation and revenue, the auctioneer may still prefer EN if efficiency is considered the important criterion.

Table 8
Efficiency in %

	part 1	part 2	part 3
FP	95.4 (13.9)	96.0 (12.6)	92.7 (15.3)
EN	95.4 (16.0)	97.0 (13.1)	96.1 (11.9)
AMSA	86.7 (27.1)	94.4 (18.3)	90.9 (21.5)

Notes: standard errors in parentheses.

3.4.2 Individual bidding behavior

In this section, we take a close look at subjects' bidding behavior before we turn to an explanation of the main results. First, we deal with how subjects behaved in the knock-out auctions once they had decided to collude. Figure 3.3 shows average bids conditional on value in parts two and three. In part 2, the Nash predictions trace average bids in FP very well, as can be observed in the upper-left panel. In EN, submitted bids fall below the Nash prediction while in AMSA bidders tended to overshoot compared to Nash. Nevertheless, deviations from Nash were rather small when symmetric bidders bid in the knock-out auction.

The other panels of Figure 3.3 display how strong bidders bid after they voted to collude in part three, where the theoretical predictions depended on the employed auction format. Like in part two, actual average bids in FP were very close to the theoretical prediction. In contrast, in EN strong bidders submitted substantially lower bids than predicted. It was as if bidders preferred to leave the task to exploit the right to be designated bidder to others in this treatment. In Subsection 3.4.3, we will provide an explanation of this remarkable result. In AMSA, average knock-out bids were above the amounts that were predicted by the aggressive equilibrium but below the amounts of the passive equilibrium.

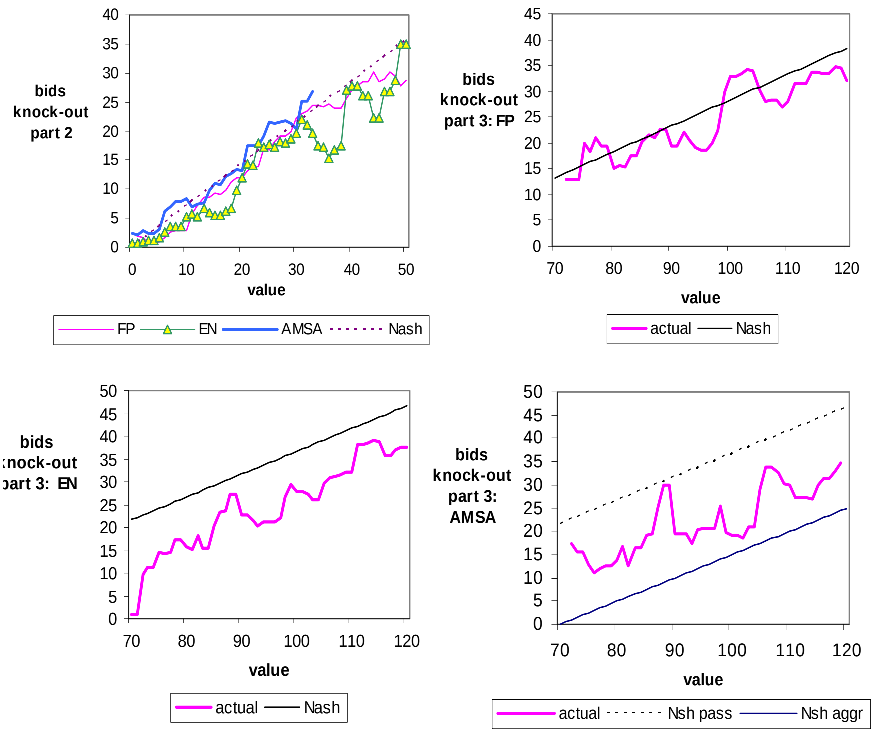

FIGURE 3.3. **Bids knock-out auction**. *Notes*: for each value the average of knock-out bids that fall in the interval [value-2, value+2] is displayed. Upper-left panel: part 2 all auctions; upper-right panel: part 3 FP; lower-left panel: part 3 EN; lower-right panel: part 3 AMSA.

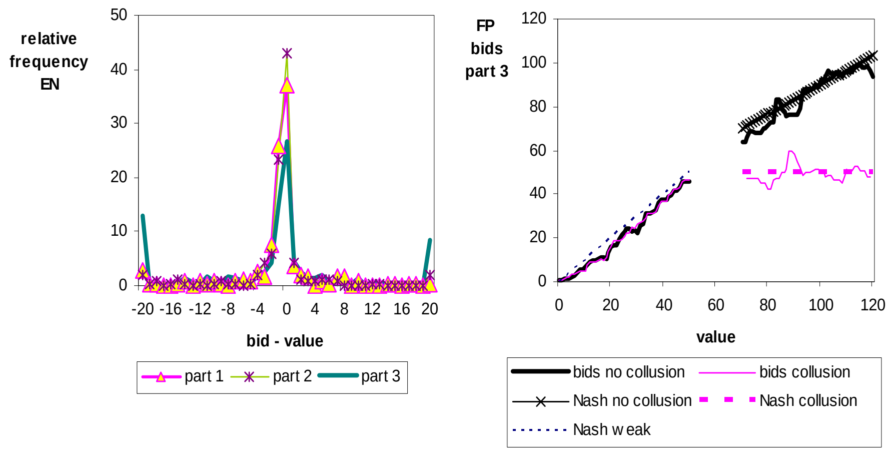

FIGURE 3.4. **Bids in FP (part 3) and EN**. *Notes*: the left-panel shows the histogram of deviations from value (bid-value) in main-auction EN; the right-panel presents for each value the average of main-auction FP bids that fall in the interval [value-2, value+2].

We now turn to the bids submitted in the main auction. For EN, the left-panel of Figure 3.4 provides the histograms for the deviations of bids from value in all three parts. Most submitted bids were equal to value, and only few deviated more than two points from value. Only in part three a small minority of bids deviated substantially from value. Most of these deviating bids were submitted by weak bidders, who either gave up from the start or who chose to drive up the price for the strong bidders.

In the first two parts of FP, bidders' behavior agreed with the general picture coming from symmetric private value auctions. Bidders submitted bids that were on average slightly higher than Nash. The right-panel of

Figure 3.4 shows average bids together with theoretical predictions for the much less investigated asymmetric case. Average bids were remarkably close to the theoretically predicted ones, both for weak and for strong bidders.

Figure 3.5 tells a somewhat different story for the first two parts of AMSA. In the first phase of these auctions, bidders on average exited a bit sooner than predicted by Nash, while the subjects that went on to the second phase with low values submitted higher sealed bids than expected (upper-left panel). A similar pattern was observed in Goeree and Offerman (2004). One possible explanation is that subjects differ in their risk-attitudes. The AMSA format automatically selects the risk-averse types to drop in the first phase while the risk seeking ones tend to continue to the second phase. Alternatively, low-valued subjects who proceeded to the second phase may have decided to submit high bids to rationalize their risky bidding in the first phase. Occasionally, low-valued bidders thus became the winner of the auction, which agrees with the poor efficiency performance of this format. A similar picture emerged in part three of AMSA. Again, in the first phase weak bidders behaved rather cautiously, on average exiting only somewhat higher than their value (lower-left panel). Those weak bidders that continued to the second phase tended to take high risks (lower-right panel).

Conditional on collusion, bidders faced a coordination problem in part three of the AMSA auction. In the experiment, the passive equilibrium, predicting that weak bidders bid up to value, and the aggressive equilibrium, predicting that weak bidders submitted bids equal to 70, attracted bidders' attention. To classify the collusive cases, we divided the interval between the prediction of the passive equilibrium (i.e., the highest value of the weak bidders) and the prediction of the aggressive equilibrium (i.e., 70) in three equal parts. If the realized revenue was to the left of the middle interval, it was classified as being close to the passive equilibrium and if it was to the right of the middle interval, it was classified as being close to the aggressive equilibrium. A substantial part of 50% of the col-

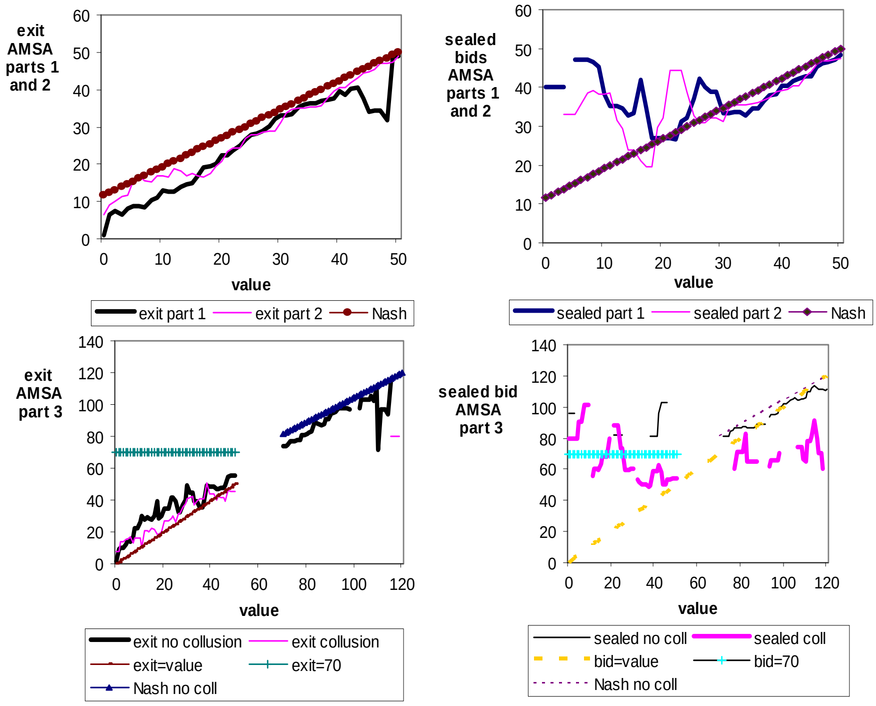

FIGURE 3.5. **Bids in AMSA**. *Notes*: for each value the average of main-auction sealed bids in AMSA that fall in the interval [value-2, value+2] is displayed. Upper-left panel: AMSA exit first phase parts 1 and 2; upper-right panel: AMSA sealed bids second phase parts 1 and 2; lower-left panel: AMSA exit first phase part 3; lower-right panel: AMSA sealed bids second phase part 3.

luding groups ended up being close to the passive equilibrium, while 25% finished close to the aggressive equilibrium. The remaining 25% of the collusive cases was in between the passive and the aggressive equilibrium.

According to both equilibria, the designated bidder should be tough and keep the shill bidders in the auction as long as the weak bidders had not yet exited. Only if a designated bidder plays tough, the bottom price is not determined by weak bidders. In agreement with this feature of the equilibria, designated bidders played tough in 72.5% of the cases and received higher profits if they did so. That is, the designated bidder's profit on the transaction equalled 48.9 (at an s.e. of 25.3) for tough play and it equalled 35.7 (at an s.e. of 28.3) when they let their shill bidders drop before the weak bidders did.[15]

3.4.3 Explanation of the main results

In this section, we provide an explanation for the main results on collusion. In part two, theory predicted that the auctions were revenue equivalent and that, as a consequence, the auctions would be equally conducive for collusion. Instead, we observed that FP triggered significantly more votes than the other two formats.[16] We think that the key to explaining these differences is given by the revenues actually raised in part one. There, bidding was most competitive in FP, while AMSA and EN raised similar profits. FP-bidders experienced that the main auction was not so profitable, which made collusion more attractive compared to the other two formats. In fact, when revenue equivalence breaks down in the way it did in part one, the theoretical predictions on collusion change in the direction that we actually observed.

[15] In AMSA, the profit on the transaction equals the own value minus price paid plus premium in case the bidder bought the good and it equalled the premium or 0 in case the bidder did not buy the good.

[16] In addition, EN was significantly more conducive to collusion than AMSA, but the difference in collusive votes between these two auctions was rather small.

Table 9
Prospects for designated bidder part 3

Part 3	profit transaction winner collusion	price paid by designated bidder	% cases designated bidder buys product
FP	49.6 (19.3) n=56	50.3 (5.6) n=52	92.9%; n=56
EN	61.8 (26.5) n=53	40.9 (19.6) n=33	96.2%; n=53
AMSA	42.3 (26.1) n=40	51.6 (17.9) n=33	82.5%; n=40

Notes: standard errors in parentheses.

The main results in part three were that AMSA proved less conducive to collusion than the other auctions, and that, rather unexpectedly, FP performed equally unsuccessful in fighting collusion as EN did. Table 9 presents some statistics that provide an explanation for these results. The table lists for each auction how much profit the designated bidder actually made on the transaction in the main auction, at which price the designated bidder bought the good for sale, and what the probability was that the designated bidder actually bought the good in the main auction.[17] On all these criteria, AMSA offered the worst prospects for the designated bidder. Given that collusion was most unattractive in AMSA, it makes sense that bidders voted more often against collusion in this format.

What remains puzzling though was that FP did not attract less collusive votes than EN did, even though the statistics in Table 9 show that the prospects for the designated bidder were worse in FP. We think that two features may have contributed to this result. The first one is that, even though the designated bidder made on average a higher profit in EN than in FP, this occurred at a higher variance. Subjects who disliked risk may have been more reluctant to become designated bidder in EN. This was also reflected in the knock-out bids shown in Figure 3.3. Bids in the knock-out auction were close to the theoretically predicted ones in FP, while they were considerably below the theoretical bids in EN. We think

[17] For AMSA, the profit on the transaction was defined in footnote 15. In EN, it was equal to the own value minus the price paid in the main auction if the designated bidder won the auction and 0 otherwise; in FP, it was equal to value minus own bid in case of winning and 0 otherwise.

that perhaps an even stronger force behind this result may have been designated bidders' lack of control in the EN auction. In the FP auction, it was easy for a bidder to predict how much profit was available in the main auction. Bidders knew that a bid of 50 or 51 would win the main auction almost surely. Therefore, a colluding strong bidder could easily anticipate the profit to be made in FP, which may have led to more confident bidding in the knock-out auction and more confident voting for collusion in the voting stage. In contrast, in EN the price that the designated bidder was going to pay completely depended on the behavior of weak bidders. As Figure 3.6 shows, this price was much more volatile in EN than in FP. The extra ambiguity in EN that designated bidders faced in the main auction may have discouraged voting for collusion.[18]

It is important to remember that in our experiment the cartel was stable by design in all auctions. This feature of our experiment diminishes the relevance of our results for one-shot auctions. When some bidder cheats on the cartel agreement, bidders may retaliate within a one-shot EN auction but not within a one-shot FP auction. Therefore, when bidders do not have the possibility to retaliate in the future, EN auctions may be more prone to collusion than FP auctions (Robinson, 1985; Marshall and Marx, 2007). Instead, our results are relevant to situations where bidders interact repeatedly as in bidding for projects in the construction industry. In such situations, there is ample evidence that even in FP auctions bidders refrain from cheating on the cartel, presumably out of fear for future retaliation (Scherer, 1980; McAfee and McMillan, 1992; Porter and Zona, 1993; Porter and Zona, 1999; Pesendorfer, 2000; Boone et al., 2009).

3.5 Concluding Discussion

In this chapter, we studied the collusive properties of EN, FP and AMSA using a laboratory experiment. We did so in two settings. In the first one,

[18] Notice that in AMSA designated bidders were faced with a similar lack of control as in EN, so this factor also worked against collusion in AMSA.

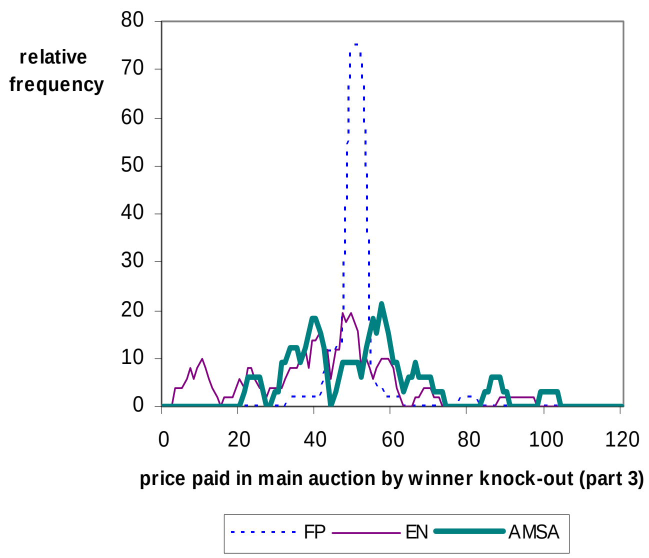

FIGURE 3.6. **Prices paid in main auction by designated bidder part 3**. *Notes*: for each price paid in the main auction the percentage of outcomes that fall in the interval [price-2, price+2] is displayed.

bidders were symmetric and all could participate in the cartel. Here we observed that FP triggers more collusive votes than the other formats. This result is consistent with the finding that without collusion, the FP auction was the most competitive one. Therefore, the incentive to collude was highest in this format. Interestingly, with the possibility to collude, the revenue dominance of FP over EN usually reported in experimental private value auctions completely disappears.

In the second setting, both strong and weak bidders competed for the good for sale. Only strong bidders were eligible for collusion. In theory, FP should outperform EN in preventing collusion, because in the former a designated bidder could not afford to bid below the higher end of the support of the weak bidders, which makes collusion relatively less attractive. In contrast to this prediction, we observed that EN triggered about as much collusion as FP did. We think that there are two reasons behind this result. First, the designated bidder ran a higher risk in EN when he had to beat the weak bidders in the auction. Second, the designated bidder faced less ambiguity in FP than in EN. That is, in FP the designated bidder could easily anticipate the amount of profit that he would almost surely make in the main auction, whereas in EN the actual price paid in the main auction varied substantially. Consistent with these explanations is our finding that in EN strong bidders tended to submit low bids in the knock-out auction, as if they preferred to leave the right to be designated bidder to others.

According to theory, AMSA is less conducive to collusion than the other formats only if weak bidders bid sufficiently aggressively in the case of collusion. In the experiment, bidders focussed sufficiently on the aggressive equilibrium to make collusion unattractive. AMSA triggered less collusion than the other auctions did.

3.6 Appendix

INSTRUCTIONS EXPERIMENT[19]

Welcome to this experiment on decision-making! You can make money in this experiment. Your choices and the choices of the other participants will determine how much money you will make. Read the instructions carefully. There is paper and a pen on your table. You can use these during the experiment. Before the experiment starts, we will hand out a summary of the instructions.

THE EXPERIMENT

You will earn points in the experiment. At the end of the experiment, your points will be exchanged in euros. Each point will yield 20 cent. You will start with a starting capital of 50 points.

The experiment consists of three parts. The three parts are linked to one another, so it is important that you understand the instructions of current part before you proceed with the experiment. Only when a part is completely finished you will receive instructions for the next part. The first part lasts for 6 periods. Your earnings in the first part will be the sum of your earnings in these 6 periods plus the starting capital. Your earnings in the experiment will equal the sum of your earnings in all three parts.

Each period you will be allocated to a group of 6 persons to whom a product is to be sold. The composition of the group varies from period to period. This means that you will be involved in an auction with different players in each period.

VALUE OF THE PRODUCT

For each participant, the product has a different value lying between 0 points and 50 points. Every number between 0 and 50 is equally likely. The value assigned to one participant does not depend on the values of the

[19] These are the instructions for treatment AMSA. Other instructions are available upon request.

other participants. This means that your value is probably different from those of others. At the start of a period, you will be informed about your own value, which will not be revealed to the other participants. Likewise, the other participants' values are not revealed to you.

SALE OF THE PRODUCT: PHASE 1

Each period consists of two phases. In the first phase, the "temperature of a thermometer" will rise point by point. The level of the temperature indicates the price of the product. In the first phase, all six participants have the possibility to push the button "QUIT". By pushing the QUIT button, a participant indicates that he or she will not buy the product in this period. When four participants have pushed the QUIT button, the first phase is finished. The level of the temperature where the fourth bidder pushed QUIT is called the "BOTTOM PRICE". The four participants that have pushed the QUIT button in the first phase do not receive any payoff in this period.

If accidentally two (or more) participants push the QUIT button at the same time then chance will determine which one of these participants will continue. The temperature in the thermometer will never rise higher than the upper bound of the value interval: 50 points. If the thermometer reaches the upper bound, the computer will automatically push the QUIT button for you.

When a participant pushes the QUIT button in the first phase, the other participants (no matter whether they have pushed the QUIT button or not) can observe the price at which he or she chooses to quit in the current period.

SALE OF THE PRODUCT: PHASE 2

In the second phase, the two participants that have not quit will submit their "ultimate bid". The participant with the highest ultimate bid buys the product. The price that this participant pays is NOT equal to the own ultimate bid, but to the ultimate bid of the OTHER PARTICIPANT!

The ultimate bid has to be larger than or equal to the bottom price determined in phase 1. If accidentally both bidders submit the same ultimate bid, then chance will determine which of these two bidders buys the product. It is not allowed to submit an ultimate bid higher than 50.

The buyer will not literally receive a product. He or she will receive an amount equal to the value of the product minus the price of the product (in points).

SALE OF THE PRODUCT: PREMIUM

Both bidders of the second phase will receive a premium that depends on the extent to which the bottom price from the first phase is actually increased. To calculate this premium, the difference between the lowest ultimate bid in the second phase and the bottom price is determined. Each bidder of the second phase receives a premium of 30% of this difference (in points).

EXAMPLE

The procedure to sell the product will now be illustrated with an example. THE NUMBERS IN THE EXAMPLES ARE ARBITRARILY CHOSEN.

The temperature of the thermometer starts rising from 0. At a price of 22, 25, 30, the first, second, and the third bidder pushes the QUIT button respectively. The temperature keeps rising until the fourth bidder pushes the QUIT button at a price of 32. This is the end of the first phase. The two remaining bidders submit an ultimate bid higher than or equal to 32 in the second phase. Assume that the fifth bidder bids 42 and the sixth bidder bids 45, and then the results are as follows:

The sixth bidder buys the product at a price of 42. Both the fifth and the sixth bidder receive a premium of 30% of 42-32 (=the lowest ultimate bid minus the bottom price): this yields an amount of 3 points to either of them.

The sixth bidder also obtains the gains from trade. The gains from the trade equal her or his value for the product minus the price paid for the product.

GAIN AND LOSS

Notice that the highest bidder in a period can make a loss. If the highest bidder pays a price higher than her or his value for the product, and if this is not compensated by the premium, he or she makes a loss. Just as any gain is automatically added to the amount earned up to that period, any loss will automatically be subtracted.

RESULTS OF THE PERIOD

At the end of a period, the results of the period will be communicated. You will be told whether you had the highest bid and how much payoff you have earned. All bidders in a group will also be informed about the two ultimate bids submitted in the second phase.

Then a new period will be started. In the new period, again a product will be sold. Each participant receives a new value for the product. Your value for the product in the one period will not depend on your value for the product in any other period

If you are positive that you have understood the instructions, please click 'Next' below for the test questions.

THE NUMBERS IN THE QUESTIONS ARE ARBITRARILY CHOSEN.

(1) Assume that in the second phase your ultimate bid equals 48 while the other bidder has an ultimate bid of 46. What is the price that you will have to pay for the product?

(2) Assume that in the second phase your ultimate bid equals 46 while the other bidder's ultimate bid equals 36. The bottom price from the first phase equals 16. What is the premium for each of the bidders in the second phase?

(3) Is the following statement correct: in each period you will be matched with the same other players

END

You have reached the end of the instructions. If you wish to read some parts of the instructions again, please click 'Finished', then you will return to the beginning of the instructions. When you are ready to start the experiment, please push the button READY. If by then not all the participants have pushed READY, you will return to the beginning of the instructions. When all participants have pushed READY, the experiment will start. When the experiment has started, you will NOT be able to return to these instructions. Before the experiment is started, a summary of the instructions will be handed out.

If you still have questions, please raise your hand!

INSTRUCTIONS: PART 2

The second part of the experiment lasts for 8 periods. Your earnings of part 1 will be transferred to the first period of part 2. As the general rules in the second part are quite similar to those of the first part, we will focus on the differences between the two parts in the following.

At the beginning of every period in the second part, you are given AN OPTION TO VOTE FOR COOPERATION with the other players in your group at a given cost. You will know the cost of cooperation before each period starts; your value for the product will be communicated to you at the same time. The cost of cooperation differs in each period. Within a period, each player faces the same cost of cooperation. The gain or loss a participant makes in each period is immediately subtracted from or added to his or her total earnings.

DECISION TO VOTE FOR COOPERATION

ALL BIDDERS are asked if they would like to vote for the cooperation. A bidder can either click the YES button on the screen if he or she would like to cooperate with the other bidders; or click the NO button if he or she thinks otherwise. Only in the situation where all six bidders vote for the cooperation, will the group of bidders cooperate.

Also, note the bidders are obliged to pay the costs of cooperation only when the cooperation ACTUALLY takes place. That is, if one or more bidders vote against cooperation, then the group will not cooperate and consequently no bidder has to pay the costs for cooperation.

When all bidders have made their choice about cooperation, you will be informed about how many bidders have voted against cooperation and whether the cooperation will take place in your group.

COOPERATION

If a group cooperates, ONLY ONE BIDDER among the six obtains the right to enter the main auction. This bidder is called the DESIGNATED BIDDER.

The following procedure will determine who will be the designated bidder in a group: each bidder has to submit a bid for the right to be the only bidder in the main auction. For each participant, the bid submitted cannot be higher than 60 points. If the bid you submit for the right is the highest among the six, you will then become the designated bidder of your group at a price equal to your own bid. To compensate all the other five bidders who will not be preset at the main auction, your payment will be EQUALLY shared by them. Likewise, if your bid is not the highest among the six, you will receive a fifth of the bid of the highest bidder. In exchange, you will not compete for the product in the main auction. The bids submitted have to be an integer between 0 and 50 points. If two or more bidders submit the same bid, then chance will determine which of these bidders will receive the product.

As the designated bidder will effectively be the only ACTIVE bidder in the main auction, we will skip the course of the main auction and directly reward the product to the designated bidder at price 0. The results will be communicated at the end of the cooperation phase. You will be told whether you have had the highest bid, how much profit you have made and how high the other five bids are. To summarize, the payoff of a designated bidder equals his or her own value minus the bid he or she submitted for the right to be the designated bidder and minus the costs of cooperation.

The payoffs of the other bidders equal the designated bidder's bid by 5 minus the costs of cooperation.

NO COOPERATION

If one or more bidders vote against cooperation, then the group will not cooperate. In this case, the rules will be the SAME as in part 1. That is, all bidders will compete in the same way for the product as described in the instructions of the previous part.

EXAMPLE

The procedure to sell the product will now be illustrated with an example. THE NUMBERS IN THE EXAMPLES ARE ARBITRARILY CHOSEN.

Bidders A, B, C, D, E and F are allocated in one group for the current period. The cost of cooperation is 2; the bidders' values for the product are 0, 10, 20, 30, 40 and 50 points respectively. All six bidders choose to vote for the cooperation, so the group will cooperate.

The next step is to determine the designated bidder: bidder A, B, C, D, E and F each submits one bid for the right to be the designated bidder. Their bids are 0, 5, 15, 20, 25, and 30 respectively. Hence, bidder F gets the right to be the designated bidder at a price equal to his or her own bid, namely 30 points. Bidders A, B, C, D and E will not participate in the main auction and will equally share bidder F's payment (each bidder 6 points). After the costs of cooperation are subtracted, their pay-off is 4 points.

As the designated bidder (bidder F) will effectively be the only ACTIVE bidder in the main auction, we will skip the course of the main auction and directly reward the product to bidder F at price 0. Therefore, bidder F's payoff is equal to 50 (his value) minus 30 (his payment to the other bidders) minus 2 (the cost of cooperation), which equals 18.

OTHER ASPECTS

All other aspects of part 2 will be the same as they were in part 1. In particular, the same procedure will be used to determine the values. That is, each participant will receive in each period a different value between 0 and 50 points, and every number between 0 and 50 is equally likely.

If you are positive that you have understood the instructions, please click 'Next' below for the test questions.

THE NUMBERS IN THE QUESTIONS ARE ARBITRARILY CHOSEN.

(1)Assume that four out of six bidders in your group push the YES button when they are asked to vote for cooperation. Will your group cooperate?

(2)Assume that four out of six bidders in your group push the YES button when they are asked to vote for cooperation. You were among the players who voted for cooperation. Will you pay the costs for cooperation?

(3)Assume that your group cooperates; your bid for the right to buy the product at a price of 0 equal to 28 while the other bids submitted are 12, 20, 24, 25, and 30. The cost for cooperating equals 2 in this period. What is your payoff in this period?

(4)Assume that your group cooperates; your bid for the right to buy the product at a price of 0 equals 30 while the other bids submitted are 12, 20, 24, 26, and 28. The cost for cooperating equals 2 in this period. Your value for the product equals 40. What is your payoff in this period?

INSTRUCTIONS: PART 3

The third part of the experiment lasts for 10 periods. Your earnings of parts 1 and 2 will be transferred to the first period of part 3. As the rules in the third part of the experiment are quite similar to the rules in the second part, we will focus on the differences between part 2 and 3 in the following instructions. An important aspect where part 3 differs from part two is that TWO TYPES of roles are assigned to the participants: the role of STRONG BIDDER and the role of WEAK BIDDER.

STRONG AND WEAK BIDDERS

The role of each type of bidder is determined by chance at the start of each period. Hence, a participant who receives the role as weak bidder in one period may be asked to play as a strong bidder in the next period and vice versa. In part 3, each group consists of three players who receive the role of the strong bidders and three players who receive the role of weak bidders. Like in parts 1 and 2, players will be re-matched into a different group when a new period starts.

VALUE OF THE PRODUCT

In the third part of the experiment, the strong bidders and the weak bidders have different intervals from which the values are drawn. For the strong bidders, the value of the product lies between 70 points and 120 points, and every number between 70 and 120 is equally likely. For the weak bidders, the value of the product lies between 0 and 50 points, and every number between 0 and 50 is equally likely.

Again, the value assigned to one participant does not depend on the values of the other participants. Hence, your value is probably different from those of the others. At the start of a period, you will be informed about your own role and your own value, which will not be revealed to the other participants. Likewise, the other participants' values and roles are not revealed to you.

DECISION TO VOTE FOR COOPERATION IN PART 3

Different from part 2, the option of cooperation is offered to the STRONG BIDDERS ONLY. The costs of cooperation are the same for each strong bidder but they differ from period to period; the weak bidders never have to bear such costs because they are excluded from cooperation. Both the strong bidders and the weak bidders will be informed about the strong bidders' costs of cooperation before each period begins.

In the third part of the experiment, all participants who receive the roles as strong bidders are asked to vote for the cooperation with the other two strong bidders in the same group. Each strong bidder can either click the YES button on the screen if he or she would like to cooperate with the other strong bidders; or click the No button if he or she thinks otherwise.

Only in the situation where all three strong bidders vote for cooperation, will the strong bidders of a group cooperate. Strong bidders pay for the costs of cooperation only when cooperation ACTUALLY takes place. In other words, if one or more strong bidders vote against cooperation, cooperation will not take place and consequently no bidder has to pay the costs for cooperation. The results of voting are communicated after all three strong bidders in the group have made their choice (Yes or No). The strong bidders will be informed about how many of them have voted against cooperation and whether the cooperation will take place. The weak bidders will not receive this information.

COOPERATION AMONG STRONG BIDDERS

If the strong bidders cooperate, ONLY ONE STRONG BIDDER among the three obtains the right to enter the main auction, bidding against the three weak bidders for the product. This strong bidder is called the DESIGNATED BIDDER.

Apart from bidding for his or her own, the designated bidder also bid on behalf of his or her fellow strong bidders in the same group, who according to the rules, are not allowed to participate in the main auction.

The following procedure will determine who will be the designated bidder in a group: each strong bidder submits a bid (number of points) for the right to be the designated bidder. The strong bidder with the highest bid will be the designated bidder (in case of ties among the highest bidders, the winner is selected by chance from them). The designated bidder will pay an amount equal to the own bid to compensate the other two strong bidders in the group. This amount will be EQUALLY shared by the other two strong bidders. Bids to become the designated bidder have to be at least 0 points and they cannot exceed 120 points. When all strong bidders submitted their bids, the results will be communicated. All strong bidders will be informed about if they have submitted the highest bid, and how high all three bids submitted are. (Weak bidders will not receive this information.)

SALE OF THE PRODUCT WITH COOPERATING STRONG BIDDERS: PHASE 1

Unlike part 2, there are altogether four active bidders involved in the main auction: the designated bidder and the three weak bidders, who will bid for the product for sale in a similar way as introduced in part 1. The difference is that the designated bidder has to bid on all three strong bidders' behalf in the third part. The designated bidder is free to set the bids for the other two strong bidders in any way that he or she likes, as long as these bids do not exceed his or her own bid (so the strong bidders who are not present will not become the winner of the auction). That is, when bidding in the first phase, a designated bidder must push the QUIT button for the other two strong bidders before he or she pushes his or her own QUIT button. Notice that the designated bidder may push the QUIT button for the other two strong bidders at a price of 0, but he or she may also decide to wait before letting one or two of the other strong bidders quit.

In the third part, the temperature of the thermometer may rise until 120 points before the computer will automatically push the QUIT button for any bidder who has not pushed the button then. When a participant pushes the QUIT button in the first phase, the other participants in the same group (including the strong bidders who are NOT ACTIVE in the main auction) will not only observe the QUIT price of this participant like in the first two parts, but also the role of this bidder (i.e. a weak bidder or a strong bidder). If a strong bidder pushes the QUIT button, all the other bidders will observe a blue colored bid together with the letter "b" next to the thermometer. If a weak bidder pushes the QUIT button, all the other bidders will observe the yellow colored bid together with a letter "w" next to the thermometer. From this, both of the remaining bidders in phase 2 can infer the other bidder's role.

SALE OF THE PRODUCT WITH COOPERATING STRONG BIDDERS: PHASE 2

In the second phase, the two participants that have not quit in the first phase will submit their "ultimate bid" for the product. The participant with the higher ultimate bid between the two buys the product at a price equal to the lower ultimate bid. An ultimate bid in phase 2 has to be an integer between the bottom price determined in phase 1 and 120 points. This restriction holds for both weak bidders and strong bidders, which means that for the weak bidders whose value is between 0 and 50, the upper limit of bids is higher in part 3 (120 points) than in part 1 and 2 (50 points).

Both bidders who enter the second phase earn a premium that is determined in the same way as in the previous parts. It is possible that a designated bidder enters the second phase with one of the other strong bidders on whose behalf the designated bidder is bidding for (when all the weak bidders quit before the designated bidder lets the second strong bidder quit). In such a case, we will SKIP the course of the second phase (so the designated bidder DOES NOT have to submit any ultimate bid) and directly reward the designated bidder with the product at the bottom price. In other words, we equate the lower ultimate bid (which is the product price for the winner in the second phase) to the bottom price. As a result, no premium is rewarded to both bidders (i.e. the designated bidder and the strong bidder the designated bidder bids for). Therefore, the designated bidder's gains from trade in this period equals his or her value minus the bottom price determined in the first phase minus the price paid for the right to be the designated winner minus the cost of cooperation of this period.

NO COOPERATION

If one or more strong bidders vote against cooperation, then the strong bidders will not cooperate. In this case, all bidders will compete in the same way for the product for sale as described in the instructions of part 1. The only difference is that from now there are weak and strong bidders, and that both types of bidders may bid higher than they were allowed in parts 1 and 2 (up to a maximum of 120 points). When a participant pushes the QUIT button, the other participants in the same group can observe the QUIT price of the participant and the role of this bidder (i.e. a weak bidder or a strong bidder). Note that you get the same information as in the case that strong bidders vote for cooperation.

EXAMPLE

The following example illustrates the procedure. THE NUMBERS IN THE EXAMPLE ARE ARBITRARILY CHOSEN.

Strong bidders A, B and C and weak bidders D, E, and F are allocated in one group for the current period. The cost of cooperation is 10. The strong bidders A, B, C's values are 80, 90 and 110, respectively. The weak bidders D, E, F's values are 10, 30 and 50, respectively. When asked to vote for cooperation, all three strong bidders (bidders A, B and C) vote 'yes'. Hence, the strong bidders cooperate.

Next, the three strong bidders submit a bid for the right to be the designated bidder. Bidders A, B and C bid 10, 20 and 30, respectively. As a result, bidder C receives the right and pays a price equal to 30 (the own bid). This amount is shared by bidders A and B: each receives an amount of 15 points. In total, bidders A and B make: 15 (share) - 10 (cost cooperation) = 5 each.

Weak bidders do not observe the results of cooperation.

In the main auction, bidder C has to bid for him or herself as well as for bidders A and B. Assume that in the first phase the weak bidders D, E and F push the QUIT button at prices of 8, 31 and 49, respectively. The strong bidder pushes the QUIT button at 50 for one of the other strong bidders. This terminates the first phase. Because all weak bidders quit in the first phase, the second phase is skipped. The result is that bidder C buys the product at a price of 50. In total, her or his payoff equals 110 (value) - 50 (price product) - 30 (own bid for designated bidder) - 10 (cost cooperation) = 20. The weak bidders do not earn any payoff in this example.

If you are positive that you have understood the instructions, please click 'Next' below for the test questions.

(1)Assume that you are a weak bidder in the current period. Are you going to have the option to cooperate with the other weak bidders?

(2)Assume that the cost of cooperating equals 5 points and that all strong bidders vote for cooperation. You are a strong bidder who bids 16 to become the designated bidder, while the other two bids submitted are 8 and 18. What is your payoff in this period?

(3)Assume that the cost of cooperating equals 5 points and that all strong bidders vote for cooperation. You are a strong bidder who bids 20 to become the designated bidder, while the other two bids submitted are 8 and 16. You become the designated bidder who competes against the weak bidders for the product. You push the QUIT button for one other strong bidder at a price of 10. Then the three weak bidders push the QUIT button at prices of 40, 60 and 65. Thus the bottom price is 65. You are told the second phase is to be skipped. What is your payoff in this period if your value equals 105?