Centre for Transport Studies
STOCKHOLM

Multi-unit common value auctions: An experimental comparison between the static and the dynamic uniform auction

Joakim Ahlberg – VTI

CTS Working Paper 2012:24

Abstract

It is still an open question whether the dynamic or the static format should be used in multi-unit settings, in a uniform price auction. The present study conducts an economic experiment in a common value environment, where it is found that it is more a question of whether the auctioneer wants to facilitate price discovery, and thereby lessen the otherwise pervasive overbidding, or if only the revenue is important. The experiment in the present paper provides evidence that the static format gives significantly greater revenue than the dynamic auction, in both small and large group sizes. But a higher revenue comes at a cost; half of the auctions in the static format yield negative profits to the bidders, the winner's curse is more severely widespread in the static auction, and only a minority of the bidders use the equilibrium bidding strategy.

Keywords: Laboratory Experiment, Multi-Unit Auction, Common Value Auction

JEL Codes: C91, C72, D44

Centre for Transport Studies
SE-100 44 Stockholm
Sweden
www.cts.kth.se

vti

KTH VETENSKAP OCH KONST

Multi-unit common value auctions: An experimental comparison between the static and the dynamic uniform auction

Joakim Ahlberg

VTI - Swedish National Road and Transport Research Institute, P.O. Box 55685, SE-102 15 Stockholm, Sweden
Tel: +46 8 555 770 23. *E-mail address*: joakim.ahlberg@vti.se

Abstract

It is still an open question whether the dynamic or the static format should be used in multi-unit settings, in a uniform price auction. The present study conducts an economic experiment in a common value environment, where it is found that it is more a question of whether the auctioneer wants to facilitate price discovery, and thereby lessen the otherwise pervasive overbidding, or if only the revenue is important. The experiment in the present paper provides evidence that the static format gives a significantly greater revenue than the dynamic auction, in both small and large group sizes. But a higher revenue comes at a cost; half of the auctions in the static format yield negative profits to the bidders, the winner's curse is more severely widespread in the static auction, and only a minority of the bidders use the equilibrium bidding strategy.

Keywords: Laboratory Experiment; Multi-Unit Auction; Common Value Auction

JEL codes: C91; C72; D44

1 Introduction

In many auctions, such as for CO_2 allowances, electricity, bonds, etc, the auctioneer wants to sell many items at the same time, and bidders are usually not content with buying just one unit. All units for sale have the same value for bidders in these auctions. That is, the profit is linear, or is a multiple of the number of units won. For some of them, as a first approximation, the value is also equal *across* bidders because the value of the unit often depends on some outside parameter, common to all bidders.[1] Such auctions are referred to as common value auctions. Even though the valuation of the items across bidders is identical in a common value auction, it is unknown at the time of bidding. Bidders' information only consists of a (privately known) signal.

When there are secondary markets, as in the emission permits market or the bond market, the price in the secondary market can be a good estimator of the price in the auction; that is, a common price signal for all bidders. But, private signals also exist. For example, when there are market-dominant participants in the auction, they could, due to their (demand) size, be price drivers. This is especially true when there is a fixed quantity for sale, and big participants need/want a large share of the supply. Then, their own demand is one type of private signal. Signals can also contain information such as (under hand) political information about change of rules, or technology changes which are not known to every participant in the auction.

Comparing the CO_2 allowance auctions in the USA and the EU, that is the Regional Greenhouse Gas Initiative (RGGI) and European Union Emission Trading Scheme (EU ETS), respectively, a striking difference is that the clearing price in the EU ETS is more than five times higher than in the RGGI. This discrepancy has a couple of different explanations; the fixed quantity, i.e. the shortage of units for sale, and the number of bidders, given the same supply. The two are correlated, and they are intertwined with the bidders' demand. The quantity cap in the RGGI has been non-binding, the reserve price has been met in the last six auctions, whereas, for the EU ETS, the clearing price fluctuates with the number of bidders; the more bidders, the higher the price.[2]

In the present study, we try to replicate the two allowance auctions mentioned, but without varying the cap (i.e. supply). The experiment makes use of two group sizes, the first includes a large group of bidders that more or less has the same relation between demand and supply as the EU ETS, and, second, a smaller group of bidders that has half the demand (and players) of the first group. For each group size, there are also two different demand sizes. Even though it is theoretically not the same to cut the number of bidders' demands in half as to increase the supply twofold, there is experimental evidence that, contrary to the predictions of a Nash equilibrium, bidding does not decrease in response to an increased number of bidders. See Kagel (1995) and Ahlberg (2011).

[1] For the CO_2 allowance auction case, the value is a proxy for the social abatement cost; in the electricity auction, the value comes from the electricity price; whereas in the bond case, the value is driven by the interest rate.

[2] Data from RGGI can be found at http://www.rggi.org/market/market_monitor and data from the EU ETS can be found at http://ec.europa.eu/clima/policies/ets/auctioning/second/index_en.htm.

The two allowance auctions above employ a static, sealed bid, uniform price auction. Both theoretical and experimental economic research suggests that a dynamic auction format is preferable to the static auction in conducting allowance auctions. In the theoretical literature, Milgrom and Weber (1982) show, in single-unit, affiliated value auctions, that the informational content in open auctions reduces the bidder's uncertainty about the (affiliated) value and thus, bidders are able to bid more aggressively in them. In the experimental literature, Kagel et al. (1987) report a pervasive bidding above value in the single-unit, IPV static auctions, which is, however, alleviated in the dynamic format. See also Kagel (1995).

In the common value (CV) environment, an essential advantage of dynamic, or open, bidding is that the bidding process reveals information about the other bidders' estimates of the value. Consequently, the winner's curse is likely to be mitigated in the open auction. The argument is that, by using tentative price information, bidders are better able to make more precise calculations about the value; thus the open auction facilitates price discovery.

The seminal closed-form equilibrium analysis of the winner's curse (WC) was made by Wilson (1969), and has since then been shown by Bazerman and Samuelson (1983) in various experimental environments. In the present experiment, we discriminate between bidding above the conditional expected value (of winning) and the more naive conventional expected value. The rationale is that bidding above the naive expected value has nothing, strictly speaking, to do with the WC; it will transmit negative profit in the mean. Whereas bidding in the WC interval, which is defined as bidding in between the two expected values and winning, *could* ensure a negative profit; it depends on how other players bid.

Both these arguments run in favor of open bidding, rather than sealed bidding. The open paradigm is also widely used by the Federal Communication Commission when selling radio frequencies in the USA. In IPV settings, some research, e.g. Klemperer (2002) and Engelmann and Grimm (2009), instead calls for caution due to the facilitative facilitating effect of the open format on collusion between bidders, since all bids, or quantities demanded, are visible for all participants still in the auction.

Multi-unit, common value experiments are rare, and the experiment in the present study contributes to the ongoing debate on open or sealed bid auction mechanisms inside the uniform price mechanism. One exception is the closely related experiment conducted by Ausubel et al. (2009), which is focused on troubled assets and liquidity needs. They find that, even though the formats rendered similar prices, the open format gave substantially higher (bidder) payoffs as well as reduced bid errors.

This study compares two different uniform price auctions; the static and the ascending clock auction, both in a common value environment. To address the above questions, both formats are used in two group sizes: 3- and 6-bidder groups. Letting the configuration of the larger groups (in own demand) be exactly two times that of the smaller groups, and letting the supply be equal in both groups, is effectively comparing a loose and a tight cap at the same time (if bidding does not adapt to the increasing number of bidders). The loose cap, represented by the 3-player groups, has the relation $\frac{1}{2}$ of supply (numerator) and aggregated demand (denominator), whereas the tight cap, or 6-player groups, has the relation $\frac{S}{D} = \frac{1}{4}$. Moreover, the two group sizes always have the relation $\frac{1}{2}$ between a large demander (numerator) and a small demander (denominator). The tight cap resembles the EU ETS auctions conducted in Great Britain (but which are open to participants throughout the EU).

The main results from the experiments are;

- The seller revenue is significantly greater in the sealed-bid format. But it comes at the cost of a considerably more negative profit for buyers, and nearly half of the auctions ended with a negative profit for the subjects.
- In line with this is the considerably smaller amount of WC in the open format, both bidding in the WC interval and experiencing a negative profit. There is also a notable quantity of bids above the conventional, naive, expected value, especially in the static format.
- The more bidders (the tighter the market), the greater the revenue.
- None of the formats seem to result in high bids that coincide with individual rationality. That is, there is overbidding; less than 1/5 of all subjects' first unit bid/dropout is at, or below, the expected value of the unit.
- The demand reduction, measured as the bid spread, is visible in both formats, but it is significantly lower in the dynamic auction.

We conclude that the dynamic auction seems to be a better choice in common value environments, especially if the players are without experience. It facilitates price discovery, and thereby alleviates the overly aggressive bidding. The choice between an open or a closed format may be more important than the choice of price mechanism, especially in common value settings.

The remainder of the paper is organized as follows. Section 2 provides an overview of some earlier research, section 3 introduces the experimental model and delivers the hypotheses. Section 4 presents the experimental results, while section 5 discusses them. Section 6 concludes the paper.

2 Earlier research on static vs. dynamic formats

The research on multi-unit, common value auctions is still embryonic. Much has been done in the independent private value (IPV) field, especially with single unit demand. Vickrey (1961) was the first to show that, in theory, the static second-price auction produced efficient outcomes in the IPV setting with single unit demand. Vickrey was also the first to state the revenue equivalence theorem that under certain conditions, any allocation mechanism will lead to the same revenue for the seller. Riley and Samuelson (1981) and Myerson (1981) then generalized the theorem. In contrast to this, laboratory experiments have proved that the dynamic second-price auction, the English auction, performs roughly as predicted by theory, whereas the static second-price auction does not. One rationale for that is that the transparency of the dynamic mechanism guides subjects; see for example Kagel (1995).

In the multi-unit case, the seminal (game theoretic) article is by Wilson (1979), who, in an auction of shares, found collusive equilibria with prices lower than if the unit was sold as an indivisible unit. Later, Ausubel and Crampton (2002) showed that the efficiency of the second-price, multi-unit auction may break down due to demand reduction. Demand reduction, which is the phenomenon of bidders reducing demand (on marginal units) in favor of a lower market-clearing price, has been shown in a number of experiments since then. In analyzing the difference between the static and the dynamic uniform auction [3] in a model with two bidders, with two-unit demand, Engelmann and Grimm (2009) see a larger share of demand reduction, especially extreme demand reduction, in the dynamic format versus the static in an IPV setting. Consistent with that, they also find that the static version outperforms the dynamic version in terms of collecting revenues as well as efficiency. Alsemgeest et al. (1998) also report lower revenues in the English clock auction as compared to the static version, due to demand reduction.

Vickrey (1961) also described an efficient mechanism in multi-unit settings in the IPV environment, nowadays called the Vickrey auction. Ausubel (2004) then came up with an open format that implements the same outcome as the multi-unit Vickrey auction in an IPV setting, and continues to be efficient in an affiliated value (AV) environment [4] which is not the static Vickrey auction. Manelli et al. (2006) experimentally compare the static Vickrey auction with the Ausubel auction, also known as the dynamic Vickrey auction, in both an IPV setting and an interdependent value (IV) setting, where the values are

[3] The uniform auction is a generalized second-price auction, meaning that the price paid is the highest losing bid.

[4] Affiliated value comes from Milgrom and Weber (1982), and roughly means that a high value of one bidder's estimate makes high values of the others' estimates more likely.

affiliated. They conclude that due to overbidding in both types of auctions, but slightly more in the Vickrey auction, the revenue from the Vickrey auction is greater, while the efficiency is lower in the Ausubel auction. But in the IV setting, they observe less overbidding and a trade-off between efficiency and revenue; the Vickrey auction is more efficient while the revenue is higher in the Ausubel auction.

Concerning the (pure) common value environment, much of the focus is on the winner's curse and very few studies focus on the multi-unit case. One, notably, is Ausubel et al. (2009), which experimentally tests alternative auction designs suitable for pricing and removing troubled assets. They make use of the same static and dynamic uniform auction as the present study and Engelmann and Grimm (2009) above, except that their dynamic format is an Ausubel descending clock auction. The units for sale are not identical, and they sell the units individually or as pooled units. And, for some sessions, bidders also know their liquidity needs. They find that the static and dynamic auctions resulted in similar prices. However, the dynamic auctions resulted in substantially higher bidder payoffs, which made it possible for the bidders to better manage their liquidity needs. The dynamic auction was also better in terms of price discovery, as well as at reducing bidder error.

3 The Model and Hypotheses

The experiment will take place inside a multi-unit, common value (CV) auction model where bidders have independent (private) signals. Four units will be sold in each round, and all bidders place the same value v on each unit in a given auction, i.e. subjects have flat demand curves. The common value v is an integer drawn from a uniform distribution on the interval $V = \{10, 90\}$, and the signal s_i is uniformly distributed around this value, and lies in the interval $S = \{v - 10, v + 10\} \subseteq \{0, ..., 100\}$, for $i \in \{1, 2, 3\}$ (3-player groups) or $i \in \{1, ..., 6\}$ (6-player groups).

This method for generating values comes from Kagel et al. (1987), where it is used in a single unit CV auction and can be contrasted to that used in Manelli et al. (2006). In the latter study, all bidders get different private information about the value, and the CV is calculated as the weighted average of all bidders' information. Thus, it is not a pure CV environment but an interdependent value environment. Ausubel et al. (2009) use different methods for generating values. In the first method, they let the CV for a security (or unit) be the average of eight iid random variables, uniformly distributed between 0 and 100, where a bidder's private information about the unit is the realization of one of the random variables. In the second method, the high-value ($U[50, 100]$) and the low value ($U[0, 50]$) random variables are grouped together in a pooled-unit auction. This is a pure CV environment but with non identical units.

One important implication of our (Kagel's) way of generating the common value is the three distinct signal regions to which it gives rise, with a different informational content. The most interesting region, which encompasses the larger mass of bids, lies in $\{20, 80\}$. (It is called *region 2.*) In this region, the signal is always an unbiased estimator of the true value, ex ante. The other two regions, regions 1 and 3, contain signals in the interval $s_i \in \{0, ..., 19\}$ and $s_i \in \{81, ..., 100\}$. The information that the signal is in one of these regions can be used to compute a more exact expected value than signals from region 2. That is, in region 1 (region 3), the signal is a downward (upward) biased estimator of the true value. And the lower (higher) the signal is in region 1 (region 3), the more downward (upward) biased it is. Signals at the endpoints can be used to compute an exact value.

Given signal s_i, the estimated valuation will be contained in $v_i \in [\{\max\{s_i - 10, 10\}, \min\{s_i + 10, 90\}\}$. Bidders can place a risk free bid by bidding the lower end-point in this interval.

Two group sizes are used; 3-player groups and 6-player groups. As hypothesized, the two treatment groups can be seen as either representing a loose and a tight cap, respectively, or just plainly as two different group sizes. Inside the smaller group, one bidder demands 4 units and two bidders 2 units each. The larger group has the same relationship between small and large demanders, that is two 4-unit demanders and four 2-unit demanders. Aggregated demand is thus 8 (16) in 3-player (6-player) groups. The supply in each auction is 4 units. Thus, we have the relationship $\frac{1}{2}$ $(\frac{1}{4})$ between supply and aggregated demand in small (large) groups.

In the static, the players bid in prices, whereas the dynamic is a quantity auction. In this quantity auction, the price is raised by means of a *price clock* and players respond with the quantities desired at the prevailing price. The quantity is restricted by an activity rule requiring monotonicity in quantities demanded, i.e. a dropout is irrevocable.

In the sealed bid auction, all bidders submit, once and for all, their bids, and then the auctioneer ranks the bids from high to low. The four highest bids are deemed to be winning bids, and the owners of these bids pay the fifth highest bid (b^5) for each unit won. (When there are ties, the winning bids are randomly determined.) Thus, if k_i is the number of units won in the auction for bidder i, $b_i \in \{0, ..., 100\}^l$ is the vector of bids for bidder i (where l $\in \{2, 4\}$ is the the demand), and B is the downward ranked vector of all bids. Then, the profit for each bidder is $\pi_i = k_i(v - B(5))$.

The dynamic ascending auction is a natural generalization of the English auction when selling more than one unit. In this auction, the price is gradually raised by means of an integer price-clock from zero to one hundred, and players start with full demand and yield units as the price rises. The auction ends when there are only four units demanded left in the auction, and all winners pay the price that prevailed when the fifth-to-last unit was surrendered. Thus, if $P(5)$ is defined as the price that prevailed when the fifth-to-last unit in the auction was surrendered, the profit-function is similar to the one above $\pi_i = k_i(v - P(5))$, but now the bid $B(5)$ has been changed to the clock-price $P(5)$.

In an IPV auction, with only one unit for sale, $B(2)$ and $P(2)$ would have the same value, if the distribution of the values and signals were continuous, by the revenue equivalence theorem. But we have two extensions from this: First, this is a common value auction and, second, there are four units for sale. Regarding the first extension, Milgrom and Weber (1982) showed that the dynamic auction is always at least as good for revenue as the static counterpart in a CV auction. But in the multi-unit case, the ranking is less clear, especially with CVs. From Vickrey (1961), we have that all weakly non-dominated equilibria have one thing in common; namely, that the bid/dropout on the first unit should be the expected valuation of the unit. (The first unit means the unit with the weakly highest bid/dropout.) For the subsequent units, the theory is still vague.

Thus, even though the dynamic auction is to collect weakly more revenue in contrast to the static auction, the experimental literature has supported the dynamic auction for a long period of time because of its price discovery and transparency qualities. This is important since there appears to be a competitive effect, what seems to be a myopic joy of winning, that works in the other direction. That is, many other experiments, starting with Kagel et al. (1987) in an affiliated private value setting, have shown a pervasive bidding above the value in static uniform auctions, whereas this is alleviated in the dynamic auction. This also carries over to CV settings, and Ahlberg (2011) showed, in another multi-unit, CV setting, substantial bidding above value in the static uniform auction. This overbidding affects the profit for the bidders, and often produces negative earnings. Thus,

Hypothesis 1 *The static auction will, at the expense of the bidder profit, deliver the highest revenue of the two formats.*

In a common value auction, there is also an adverse selection effect called the winner's curse (WC). It arises when bidders neglect the information a win will produce, and overbid as a result. The core of the WC is that the announcement of winning the auction leads to a decrease in the estimated value, if not accounted for when bidding. That is, even though the signal in region 2 is ex ante an unbiased estimator of the value, the largest of all bidders' signals is not. (The *max* function is convex and thus overestimates the value.)

Assume that values are uniformly distributed and the signals are uniformly distributed around the values. Then, if the value, and hence the signal, came from a continuous distribution, the conditional expected value for player i, with realized signal s_i, would be:

$$E_i(v|s_i > s_{-i}) = s_i - 10\frac{n-1}{n+1} \tag{1}$$

where s_{-i} is defined as the realized signals from the other players and n is the number of players. Thus, in 3-player (6-player) groups, the bidders must scale down their expected value by 5 (7) from the signal to avoid falling prey to the WC. We will use this measure when testing whether bidders account for this adverse selection effect. The hypothesis, partly from Ahlberg (2011) where there was a fairly large amount of WC in the static uniform auction, is that they do not; but, once more, to a lesser degree in the dynamic auction because of its inherent price discovery mechanism. (The survey, by Kagel (1995), of experiments with single-unit auctions also shows the presence of WC, to various degrees, for the inexperienced as well as professionals under a variety of circumstances.)

Hypothesis 2 *The winner's curse will be present in both auctions, but more so in the static form.*

From the above, we had:

Hypothesis 3 *The equilibrium strategy to bid or dropout at the conditional expected value of the first unit should be more likely in the dynamic format due to information revelation, but the problem may be to bid/dropout at the conditional expected value (equation 1) and not at the naive EV (s_i in region 2).*

From equation 1, we had that the conditional expected value decreases with the number of bidders. From the Nash equilibrium theory, when there is just one unit for sale, we also have that the bids will decrease with the number of bidders. But, in contrast to this, Kagel et al. (1995) show that bidders fail to respond to the Nash predictions in a single-unit, second-price auction with CV. Ahlberg (2011) also shows this in a multi-unit setting. We believe the experimental literature to have more bearing also in this case; thus, we have that:

Hypothesis 4 *Subjects' bids will not decrease in response to an increased number of bidders. Thus, instead of halving the supply, increasing the number of bidders, to construct a tighter market, will have the same effect. Hence, the tighter the market, or the more bidders, the larger the revenue.*

The phenomenon when bidders reduce demand in favor of a better price is called demand reduction. This happens in a uniform auction since, with a positive probability, bids may determine the price paid on all units. Thus, in every undominated equilibrium, bids other than on the first unit are lower than the expected value. The hypothesis of which of the two formats transmits more demand reduction than the other also hinges on how the dynamic auction behaves relative to the static auction. If we use the theory for interdependent values by Ausubel and Crampton (2002), the dynamic auction should, if there is no collusive behavior, diminish the demand reduction tendencies and thereby give smaller differences between the bids/dropouts. We will measure demand reduction as the spread in players' bids/dropouts.

Hypothesis 5 *Demand reduction, or bid-spread (dropout-spread), is likely to be in play, but to a lower extent in the dynamic auction.*

4 Experimental design

Table 1 shows the design of the auction. Each format will have two group

	3-player groups		6-player groups	
	small	large	small	large
Static auction	x	x	x	x
Dynamic auction	x	x	x	x

Table 1
Auction configuration

sizes, and each group size will have small and large demanders. The demand configuration in 6-player groups is exactly twice that of the smaller group, which, in turn, has two subjects who demand 2 units and one subject who demands 4 units.

In the experiment, students from KTH (the Royal Institute of Technology) were used as experimental subjects. They were from different Master of Engineering programs, and the experiment took place in September 2011.

The experiment is between subjects in a fixed matching procedure, i.e. they played against the same competitors and were placed in the same group and had the same demand throughout the session. The subjects were recruited for computer sessions where the given auction mechanism was iterated (unknown to the subjects) 10 times. [5] In each auction, the bidders had the opportunity to

[5] The decision not to communicate the number of rounds was made on the basis that

buy as many items as the bidder showed demand for. Before the auction began, the subjects got instructions and, in three trial periods, had the opportunity to become familiar with the interface. The information a bidder got in advance of each round was: the (updated) monetary balance, the own signal (as well as its distribution), own demand, total supply, and how many bidders there were in the auction from the start. Moreover, the subjects were equipped with a starting balance of 50 experimental currency. Bidder instructions are find in Appendix B and C.

In the static version, the subjects simultaneously submitted bids. Then, the software ranked them and made the necessary calculations. Following each auction period, bidders were provided with the true value, the price, the four highest bids along with adherent signals, the number of units won and own profit.

In the dynamic version, the price started with zero for 15 seconds and then increased at a rate of 1 per second.[6] Bidders responded with the quantities demanded at all prices, starting with full demand for all participants at time (price) zero. At any price, bidders were able to drop out on any number of demanded units. When bidder i, say, dropped out on 1 or more units, the clock stopped for 5 seconds and increased at a rate of 1 per second thereafter. Any other bidder dropping out during this brief pause was regarded as having the same drop-out price as the first, but later in time. (This five-second delay of time was implemented for every dropout.) Moreover, a dropout was irrevocable. The auction ended when demand equaled supply. If a dropout produced excess supply, the price was rolled back one increment and the bidder (who dropped out) got to buy as many units as were needed to clear supply and demand. The information on the screen during the bidding process was the prevalent price and the number of active bidders and own dropout prices (so far). Then, following each period, the computer screen showed the true value, the price, the four highest dropout prices along with adherent signals, the number of units won and own profit.

The software was developed in Asp.Net framework 2.0 using $c\#$ for back-end programming and MsSQL database.[7] The sessions lasted for about 40 to 70 minutes; the open format often took a little longer, but the number of subjects in the session was also a time driver. After each session, all earnings were exchanged into real currency. Each subject earned the same amount in

---

subjects would play differently knowing it was the last round. This could happen if, say, they had lost much money during the first nine rounds, and therefore wanted to gamble a bit.

[6] This may seem fast, but it is not; according to the subjects themselves. Moreover, it seems to be the common rate in similar experiments.

[7] We also use Ajax for front-end programming to improve the user experience and interact with the database for fast feedback of input/output.

SEK as the monetary balance on his/her screen. Subjects earned, in the mean, SEK 253 (€25) which included a show-up fee of SEK 100 (€10). The minimum earning was SEK 100 (€10), and the maximum earning was SEK 659 (€66).

5 Experimental results

The data description is found in Table 2, which shows, for each format, the number of subjects, how many rounds there were, and the number of unique observations, and the average profit.

	No. of subjects	No. of rounds	Unique observations
Static	64	140	626
Dynamic	65	149	653

Table 2
Data summary

All comparisons below use statistic tests based on aggregated data over all auction periods, if not stated differently. The non-parametric Wilcoxon(-Mann-Whitney) rank sum test has been the main tool, especially between treatments but also within treatments when there is no dependency between the variables. For some comparisons, within a treatment where there is dependency, the non-parametric Wilcoxon signed rank test is employed. We have also tested OLS and panel data (random effects) models with the profit and revenue (price) as the dependent variables. Profit is explained by signal, format, group-size, demand and round, while revenue is explained by value, format, group-size and round. There was only a marginal change in the results presented below and, thus, the conclusions still hold. (The OLS regression on bidder profit can be found in Appendix A.)

When doing the econometric tests, one interesting result was that the region did not matter; only the signal. That is, first it did; the profit was significantly lower (higher) in region 1 (3). But when controlling for the signal, the region became insignificant. Thus, we are using the whole set in the below analysis.

To get a first impression of the data, we plot the bids/dropouts in a scatter diagram. Figure 1 shows the high bid and the second highest bid for the static uniform auction, while figure 2 shows the last and second-to-last dropout prices in the dynamic uniform auction. In the graph for the dynamic format, if a subject has not dropped-out on a unit, the price is registered.

Since 95 percent of all units won, and 80 percent of all clearing prices, in the static auction come from first and second unit bids, the figure comprises

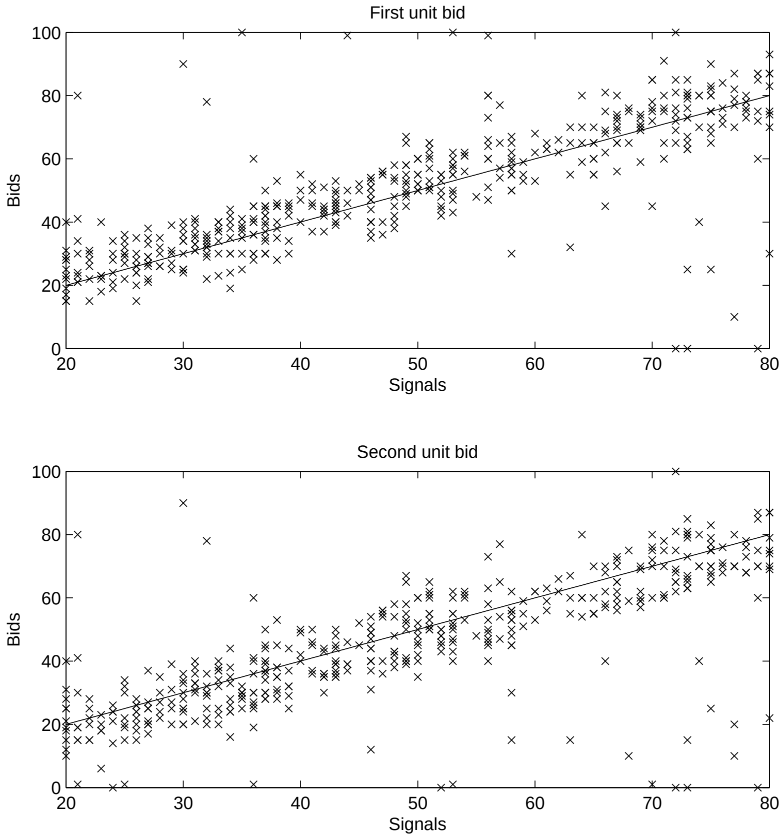

Fig. 1. First and second unit bids in the static uniform auctions.

almost all sales and prices (even though the sales (prices) become slightly overestimated because of the missing 5 (20) percent). But the first impression is nonetheless that there is substantial bidding above the signal for the first unit, with more than half of all first unit bids being greater than the signal. The second unit bid is, by its nature, lower, but it continues to be high for many subjects.

For the dynamic auction, the second to last dropout is when the aggregated demand in the auction shifts from six to five units. The last dropout is when the aggregated demand shifts to four units; that is, where the auction ends and, therefore, also the same as the clearing price in the auction. Thus, the dropouts are auction-specific, unlike the static auction, where the bids are subject-specific.

The first impression in the dynamic auction is that the clearing prices do not seem to be as high as in the static auction; a larger number of the last dropouts are below the signal, although there are quite a few above.

The auctions were not fully effective in that, in theory, the high signal holder(s)

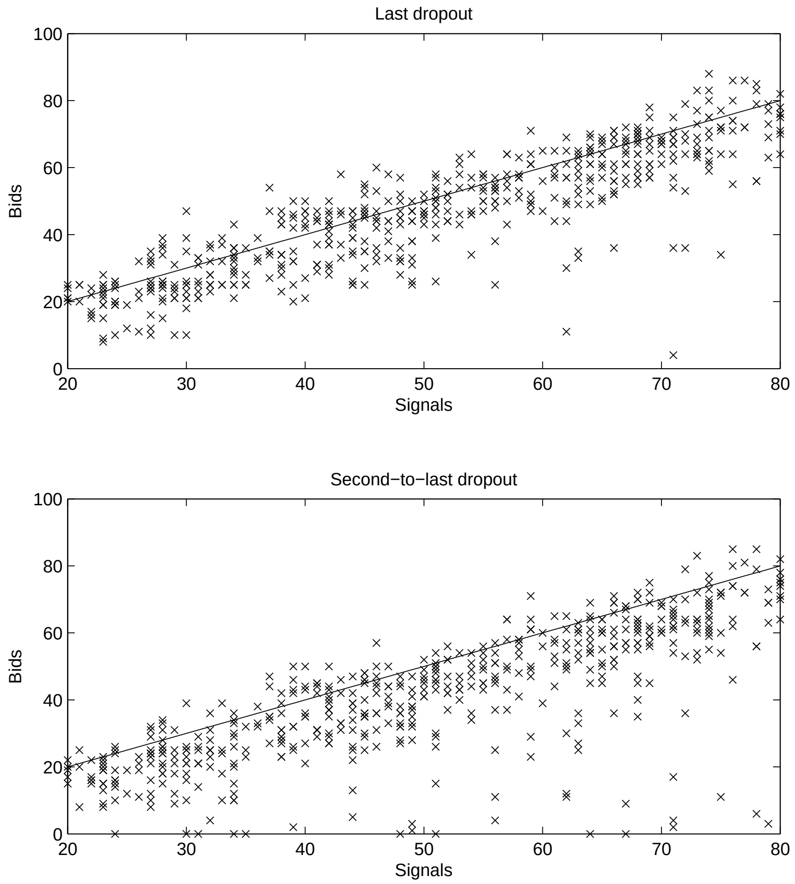

Fig. 2. Last and second-to-last dropout prices in the dynamic uniform auctions.

should always win units. If the signal vs. units won relationship is more closely examined, the result becomes the following: Given all subjects with the (weakly) highest signal within each auction round, 86 percent in the static auction won some units, as compared to only 77 percent in the dynamic auction. Instead looking at the (weakly) lowest signal within each auction round, 28 percent in the static auction now won units, as compared to 48 percent in the dynamic auction. Hence, close to twice as many subjects with the weakly lowest signal won units in the dynamic auction as compared to the static auction. Naturally, this affects the profit in the auction. But, it need not be exotic since it is often quite natural for the low signal holder to win units, e.g. when, in 3-player groups, a large demander has the weakly lowest signal. (Then, if the other two small demanders are engaged in demand reduction, the larger demander has a big chance of winning; even though she has the lowest signal.)

The first hypothesis examines the (seller) revenue and the (buyer) profit collected in each auction. Will the auction types give the same revenue in the mean? Or, correspondingly, will they produce an equal profit on average? We start with the profit.

Profit:

First, we look at winning bids only. Then, we have that, on average, the mean of the signal minus the value is almost the same; it only differs at the second decimal, it is 1.22 in the static and 1.29 in the the dynamic auction. Accordingly, in the mean, it was subjects with signals 1.22 (1.29) over the realized value who won the units.

But, even so, each column of table 3 shows the difference between the respective, (realized) value and price, signal and price, and the ratio of the two. Here, it is readily seen that the dynamical auction is superior in raising profit (when we are looking at winning bids only). On average, when looking at the

	$\overline{v-p}$	$\overline{s-p}$	$\frac{\overline{s-p}}{\overline{v-p}}$
Static auction	1.22	1.99	1.63
Dynamic auction	4.54	4.12	0.91

Table 3
Mean profit, pseudo profit and the ratio of the two.

values minus the prices (first column), it gives almost four times (3.72) as much profit as compared to the static auction. But the pseudo profit, which we define as the signal minus the price, was only 2 (2.07) times as large in the dynamic auction. (The p-values for the first two measures are below 0.01 between auctions.)

Thus, even though the value is on average 1.29 lower than the signal in the dynamic auction, the average profit is higher than the pseudo profit. Whereas, in the static auction, where the value is on average 1.22 lower than the signal, the average profit is lower than the pseudo profit. The two formats go separate ways in this respect which, in turn, makes the dynamic auction perform better for bidders. The last column shows the ratio between the actual and the pseudo profit, where it is seen that the static auction has nearly twice (1.79) as high a ratio as compared to the dynamic auction.

Now we turn to all bids, not just winning ones. Each auction format comprises both 3-player and 6-player groups. And inside each group size, 2/3 of the subjects demanded 2 units (small demanders) and 1/3 demanded 4-units (large demanders). In table 4, we see a highly significant ranking between the group

	All players	3-player groups	6-player groups
Static auction	0.67 (8.53)	5.55 (10.80)	−1.74 (5.82)
Dynamic auction	2.85 (10.71)	8.26 (14.53)	−0.28 (5.71)

Table 4
Mean bidder profit in each group size. (Standard deviations inside the brackets)

sizes in each auction format. Regarding the ranking between auction formats, we lose some predicting power when we split them up because of the poor significance between the auctions in 3-player groups (p-value = 0.1354), but in 6-player groups the p-value is 0.0026 and even lower for all players. Continuing

	3-player groups		6-player groups	
	small	large	small	large
Static auction	5.05 (8.29)	6.51 (14.50)	-0.95 (4.59)	-3.25 (7.46)
Dynamic auction	7.72 (12.05)	9.34 (18.62)	-0.06 (5.30)	-0.75 (6.50)

Table 5
Mean bidder profit for small and large demanders, in each group size.

to table 5, there is no significant difference in the inter-auction comparison for large demanders in 3-groups; otherwise, the significance is at least on the 10% level (ranging from 1 to 10) between auctions. From the standard deviations in the two tables, we have a possible explantation for the poor significance between the groups in question; it is quite high in those.

Thus, overall, we see that the dynamic auction was better at delivering profit to the subjects. When the auctions were split into the two group sizes, the ranking between formats became insignificant in 3-player groups, although the ranking of group sizes inside each format was significantly distinct. But, when the groups were divided into even finer parts, large and small demanders, the ranking between the auctions was partly recovered. But, we must not forget that there was some doubt about the effectiveness of the open auction since quite a large fraction of low signal holders won units, but it could also have a natural explanation (presented in the above subsection). (Effectiveness is not to be confused with efficiency, since all allocations are efficient in a CV auction.)

An interesting property from table 5 is that large demanders in 3-player groups seem to get more profit than do small demanders, but this does not carry over to 6-player groups; in these groups, the large demanders get less profit. Looking more closely at that phenomenon, only data from 6-player groups confirms that large demanders get less profit than small demanders (p = 0.0320). In 3-player groups, even if the data is pooled, there is no statistical difference between small and large demanders.

But, players with larger demand should, especially in 3-player groups, win more units due to their greater demand. Table 6 shows the number of units won, divided into group and demander size for the two auction formats pooled. (There is no significant difference in either group size or demand size between the two formats when comparing units won.) This is only confirmed in 3-player groups, the large demander won 1.8 units in the mean, while the small demander won just over 1 unit.

	3-player groups		6-player groups	
	small	large	small	large
Static & Dynamic	1.07	1.80	0.63	0.77

Table 6
Number of units won, pooled auctions.

Hence, large demanders in 3-player groups win 1.68 as many units as small demanders, but they do not earn more profit. If, then, profit per unit won is examined on the pooled set of auctions, table 7 is finally obtained, where the difference between mean profit per unit won is statistically significant for both group sizes at the 1 percent level.

	3-player groups		6-player groups	
	small	large	small	large
Static & Dynamic	6.15	4.49	-0.76	-2.52

Table 7
Mean profit per unit won, pooled auctions.

Thus, in both group sizes, when the auction formats are pooled, the profit per unit won is significantly lower for large demanders, although it was only in 3-player groups that large demanders won significantly more units per auction. As for the total profit per subject, it is only significantly lower in 6-player groups; but it holds for both auction formats. The rationale for this would be aggressiveness; large demanders act as (are) big participants and become price drivers. They outbid small demanders and thus, earn less profit per unit won, but, at least in 3-player groups, they win more units. (More on this in subsection 5.2.)

The fact that only large demanders in 3-player groups won significantly more units is probably explained by the fact that they were the sole large demanders in the auction, and thereby represented half of the aggregated demand. In 6-player groups, there were two large demanders, who together represented half of the demand, but alone only 1/4 of the aggregated demand. Consequently, since the market is much tighter in the larger group, the large demanders do not have the same price influence as they had in the smaller group sizes.

Ergo, the dynamic auction is the choice for the players. It is naturally better to be in a small group than in a large one, due to the tighter cap to which the bigger groups give rise. Furthermore, group size has more bearing than auction format; the 3-player groups in the static format give a significantly greater profit than 6-player groups in the dynamic auction. When it comes to demand size, there is more ambiguity about the ranking. But solely looking at 6-player groups, subjects with small demands earned less negative profit than large demanders. And, overall, small demanders earned more profit per unit won, but, at least in 3-player groups, they won less units.

Revenue:

Revenue is closely (negatively) affiliated to the profit in CV auctions, i.e. how much money each auction delivers to the auctioneer. The revenue is defined as how much money each round delivers, i.e. the price times four (units). Thus, we now measure between auction rounds, not between subjects.

When using this definition, we do not see any significant differences; neither between formats, nor between group sizes. But when controlling for value, by dividing all prices by the value of the unit, the p-values goes down. Table 8 shows that, overall, the static auction hands over more revenue than does the dynamic auction (p-value = 0.0169). The ranking also seems to extend down to group sizes, as can be seen in the table, but it is only in 6-player groups that the mean values differ significantly (p-value = 0.0090) from each other.

	Both groups	3-player groups	6-player groups
Static auction	1.05	0.92	1.18
Dynamic auction	0.93	0.86	1.02

Table 8
Mean revenue, divided with value.

But, on the horizontal level, i. e. intra comparison, there is no doubt about the natural hypothesis that the more bidders, the more revenue (p-values below 0.0001). Or the tighter the market, the larger (smaller) the revenue (profit).

For the revenue ranking hypothesis, the competitive effect had the largest bearing in the experiment. Participants engaged in overbidding, generally in 6-player groups which, especially in the static auction, led to negative profits in the greater part of all auctions. Table 9 shows the percentage of auctions with negative profits.

Result 1 *The static auction surrenders more revenue to the auctioneer than*

	3-player groups	6-player groups	Pooled groups
Static auction	0.23	0.71	0.47
Dynamic auction	0.19	0.45	0.31

Table 9
Fraction of auctions with negative profits.

the dynamic auction, as suggested by the hypothesis. Moreover, we saw the corollary that the profit was in favor of the dynamic auction.

5.2 Winner's curse

There are two types of overbidding; (i) bids which result in prices above the expected value of the objects, that is the signal ($E(v) = s$), and (ii) bids that result in prices above the conditional expected value ($E(v|s_i > s_{-i}) = s_i - 10\frac{n-1}{n+1}$), but below or equal to the expected value (or signal), that is, the winner's curse (WC) interval. In the experiment, even though the equilibrium bids are unknown in the auctions, there is always a potential risk that a player's bid becomes the price-setting bid. Thus, bidding above the conditional expected value could be costly.

Starting with the static auction format, 74 percent of the bids where subjects won one or more units were above $E(v|s_i > s_{-i})$. 44 of these were above $E(v)$; hence, taking the difference between the two intervals, we have that 30 percent of the winning bids were in the WC interval. The outcomes in the two group sizes were almost identical in bidding above the signal, category (i), but the outcomes for bids in the WC interval were significantly different. The outcome was 38 percent for 6-player groups as compared to only 25 for the smaller group size, which is seen in table 10.

There is much less overbidding in the dynamic form; as has been noted above as fewer auctions with negative profits. 31 percent of all bids are above $E(v|s_i > s_{-i})$ as compared to 74 in the static form. Bidding above $E(v) = s$ is also much lower, 21 percent as compared to 44 above. Thus, the percentage of bids in the WC interval is just 10 percent compared to 30 above for the static. Moving to group sizes, we note that the proportion between the two group sizes is almost identical to the static auction; but the level in the dynamic auction is just one third of the level of the static auction (table 10).

Bidding above $E(v) = s$ results in a negative profit in the mean, while bidding above $E(v|s_i > s_{-i})$ could, upon winning, give rise to a price that is greater than the estimated worth of the objects and, possibly, create negative profit. It is in this interval that the WC reigns. Looking more closely at winning bids in the WC interval, we get that in the static auction, actually 18 percent fall prey to the WC; 23 percent in 6-player groups and just 11 percent in 3-player groups. As for the dynamic auction, only 6 percent are accounted for in the WC and 8 (4) percent in 6-player (3-player) groups. Table 10 summarizes bids in this interval, where WCI is an abbreviation for the winner's curse interval and

	3-player groups		6-player groups		Both groups	
	Bids $\in WCI$	WC	Bids $\in WCI$	WC	Bids $\in$ WCI	WC
Static	0.25	0.11	0.38	0.23	0.30	0.18
Dynamic	0.08	0.04	0.12	0.08	0.10	0.06

Table 10
Frequency of (winning) bids in the WC interval, and actual WC.

WC for the actual winner's curse; that is, the negative profit following from bids in WCI. The dynamic auction has approximately one third of the entires of the static auction; hence, the format produces a much smaller number of bids in the WCI as well as actual WC. In both auctions, the larger group sizes produce 3/2 more bids in the WCI, but approximately 2 times as many WC cases. This is quite natural since the 3/2 more bids in 6-player groups are numerically larger than 3/2 more bids in 3-player groups.

If the group sizes were replaced by small and large demanders in the above table, all entries would be almost exactly the same, barely differing in two slots. This tells us that we have the same results, according to WC, as in table 10 between small and large demanders if groups are pooled. Hence, it is through the large demanders, or 6-player groups, that 2/3 of all WC is encountered.

The dynamic auction behaved as hypothesized, it mitigated much of the WC encountered by subjects in the static auction. It also lessened the pervasive bidding above both expected values. Hence, for bidders, it is the auction of choice, at least inside this model. Thus, the experimental literature has more bearing on behavioral prediction than the theoretical literature. The latter accounts for those players that scale down bids and do not bid above the conditional expected value, but it does not happen in this experiment, especially not in the static auction, with frequent overly aggressive bidding. Theory does not account for bidders who overbid as severely as do subjects in the static auction; it assume equilibrium play, or play that gives a weakly positive profit in the mean.

Result 2 *There was three times as much bidding in the winner's curse interval, as well as the experienced winner's curse, in the static auction estimated relative to the dynamic auction. The static format also had more than two times as much bidding above the standard, naive, expected value.*

The result shows that the dynamical auction shifts all bids downward toward more rational bidding even though the bids do not do fully converge to rational bidding. The subjects seem to better understand the laws of demand and supply in the open auction, and also seem to better grasp the idea of a pure common value.

5.3 Equilibrium bidding

Even though the equilibrium strategies are unknown in this game, we know that all weakly undominated equilibria have players who bid the conditional expected value on the first unit. And if we allow bids/drop-outs ±1 of $E(v|s_i > s_{-i})$ to also count as correct bids, we have that only six percent are using this strategy in the static auction (fifteen percent meet the naive expected value to bid ±1 of s); in the dynamic form, the corresponding numbers are sixteen percent (twenty percent meet the naive EV). Thus, there is a relatively larger amount of equilibrium play in the dynamic auction as compared to the static counterpart.

Result 3 *Compared to the static auction, the dynamic auction had more dropouts coinciding with individual rationality, i.e bidding below the expected value; much more for bidding below the conditional expected value.*

5.4 Bidding behavior in 3 *vs.* 6*-player groups*

The hypothesis of increasing the number of bidders instead of halving the supply to construct a tighter market seemed to be correct, considering the bidding behavior. Subjects' bids did not decrease in response to the increased number of bidders, contrary to the Nash equilibrium theory (for single unit demand). The null hypotheses that the bids are independent samples from the same distributions cannot be rejected between 3 and 6-player groups in any of the auctions (p-values: 0.5097 and 0.3077.) Moreover, in the revenue-section above, we saw that the more bidders, the higher the revenue.

Result 4 *Increasing the number of bidders instead of halving the supply, to create tighter markets, cannot be rejected as false. Moreover, the tighter the market, the larger the revenue.*

5.5 *Demand reduction*

The last hypothesis concerns demand reduction, which, measured here, translates more into bid/dropout spread; that is, how large is the difference between the first and the second bid, or, for large demanders, the difference between the first and the mean of the three lower bids. This is a crude measure since the above result gave us that roughly just 1/6 of the first unit bid was equilibrium bids, but it gives an indication of demand reduction.

In the comparison between the two auction types, there is a significant difference at the 1 percent level in that there is less bid spread in the dynamic auction; the mean of the spread is 6.43 in the dynamic auction, while it is 8.97 in the static auction. Moreover, it is of no importance if the formats are split into 3- and 6-player groups, or into small and large demanders; the result is approximately the same bid spread, and it is always significant at, at least, the 1 percent level.

This substantial difference partly originates from the fact (described above) that there is considerably more overbidding in the static auction. But the relatively lower spread in the dynamic auction is according to the theory of information dispersion by Wilson (1977); players need not take as much precaution as in the static format, since information about the common value is being updated during the bidding process.

Further elaborating on the bid spread, there is a much greater spread in 6-player groups as compared to 3-player groups. Pooling both formats provides the mean value of 5.44 in 3-player groups and of 8.75 in the larger group sizes (p-value < 0.001). Hence, not only does the bid spread chiefly emanate from the static auction, the larger part comes from the larger group size. But, there is no significant difference between small and large demanders.

Consequently, subjects behave according to the theory of demand reduction. The rationale is that bidders reduce their demand for a more favorable price.

Result 5 *There is a widespread demand reduction in both formats, and as predicted by the hypothesis, the spread was somewhat smaller in the dynamic format as compared to the static. Moreover, there was a significant difference between* 3- *and* 6-*player groups.*

6 Discussion

The results of the experiment in the present paper both contradict and are in line with existing theory. The first hypothesis of the revenue ranking contradicted the existing theoretical literature contention that open formats should deliver more revenue, not less. The present experiment also comes up with a different outcome than Ausubel et al. (2009) who established similar prices for the two formats. But, generally, it is in line with the experimental literature pointing at overly aggressive bidding in the static auction, manifested in that the better part of the auctions often ends up with negative profits for the subjects. And we have seen in this experiment that the dynamic auction cushions much of this bidding above value. Even if it still exists, it is more than halved as compared to the static auction.

Regarding the WC, we distinguished between bidding in the actual WC interval and just bidding above the conditional expected value. We have not seen this before, since experiments often report the latter interval. In the WC interval, subjects experienced three times as much WC, i.e. negative profit, in the static auction as compared to the dynamic format. (Consistently, there were also three times as many bids in the actual interval.) This shows the superiority of the dynamic auction over the static auction in guiding subjects to what the actual common value is in the auction.

The first explanation of the WC should probably be that players in this experiment were inexperienced. They came to the experiment without knowing what to expect. Nevertheless, all players had three dry runs before the experiment, in addition to ten rounds in the experiment. Therefore, subjects at least gained experience along the way. Another explanation is limited liability, meaning that subjects did not have to stand their own losses; they had their starting balance of 50, and had to leave when they went bankrupt. (It only happened 5 times, 3 in the static and 2 in the dynamic auction.) However, Kagel and Levin (1991) and Lind and Plott (1991) provide an experimental verification that limited liability forces did not account for the overly aggressive bidding reported in, at least, their set-up, which is similar to the set-up in the present paper, but with single-unit demand.

There was also much less demand reduction, or bid spread, in the dynamic auction. This is according to theory, but, at the same time, since there was no considerable equilibrium bidding on the first unit, it is hard to evaluate the demand reduction. Still, the variance in the static auction is twice as high as in the dynamic auction, and the standard deviation is also higher in the static auction. This tells us that subjects behave more uniformly in the dynamic form which is, probably, brought forth from the information revelation in the auction.

In IPV settings, some lab and field experiments have showed the superiority of the static uniform auction over the dynamic form, and have also underlined the caution that is warranted in using open formats in multi-unit settings. This does not need to carry over to common value settings. While the static form delivers more revenue than the dynamic form also in the present experiment, it comes at a pretty high cost for the subjects.

The other side of the coin is that, in CV settings, the static auction seems to bring forth an overbidding which is moderated in the dynamic auction. CV auctions are known to produce allocations with negative profits and, in these, the dynamic form could be an excellent guide to price discovery. Why there is this overbidding, especially in the static auction, is hard to tell; it seems as if there is some myopic joy of winning, see Holt and Sherman (1994). The competitive effect takes over the rationality. Consequently, the dynamic form has nice properties for a common value auction, especially for inexperienced bidders.

In both Kagel (1995) and Ausubel et al. (2009), we find strong advocates for the dynamical auction over the static one. The first is a survey of (partly) single-unit, common value experiments establishing that the dynamic form helps alleviate the overbidding in the static format. This also holds for experienced bidders. One of the problems, they argue, is that an increased number of bidders produces no change in bidding in second-price auctions [8]; which it should, according to the robust Nash equilibrium prediction. Subjects encountered the same problem in the present experiment, especially in the static auction; they did not seem to understand that the more bidders in the auction, the bigger the chance of being the price setter and/or bidding above value.

In the paper by Ausubel et al. (2009), the experiment, which is similar to ours, produces equal prices in the two formats, contrary to the present experiment, but, at the same time, they find that the open format is less prone to bidding error and to deliver much higher payoffs. The rationale is that the open environment helps subjects understand complicated settings and thereby reducing errors in finding, if not the optimum, a better outcome than the static auction can contribute to.

[8] The static uniform price auction is the extension of the second-price auction for multi-unit auctions, in the same way as the dynamical uniform auction is the extension of the English auction.

7 Conclusions

In deciding which of the two auction formats of the uniform price auction that were used in our controlled laboratory experiment that is preferred, one has to decide if (i) collecting the most revenue or (ii) avoiding the most negative bidder profit is the most important criterion in the choice process.

If revenue is the most important selection criterion, the static format is the best choice. It generally collects a significantly greater revenue, particularly in a bigger group size. As a result, the profit is greater in the dynamic auction, which holds true (weakly) even if the two formats are split into finer parts; first into large and small group sizes, and then, even finer, into large and small demanders. We also got the corollary that the tighter the market (or the more bidders), the greater the revenue.

On the other hand, if avoiding negative profit is more interesting as the selection criterion, the dynamic auction is better. It only has 1/3 of the actual WC of the static auction, and less than half of the bidding of the static auction above the conditional expected value. Moreover, almost half of all auctions in the static form terminated with a negative profit for the subjects, as compared to 3/10 in the dynamic form. Moreover, not only were there more auctions with a negative profit in the static form, the mean of the negative profit was also greater in it.

The weak equilibrium strategy to bid (either one of the two) EVs on the first unit, was also better in the dynamic auction. But both only had a few bids on the (extended) target. No auction format (at either of the two targets) had better than 1/5 of the bid in the zone.

As for the prevalence of demand reduction, we measured the bid spread and found that the subjects of both formats employed such strategies, but the spread was larger in the static auction. Both the variance and the standard deviation were significantly larger there. But since subjects in neither auction utilized the weak (individual rational) first unit bid strategy, and we know that there was considerable overbidding in the static auction relative to the dynamic auction, it is hard to draw any conclusions.

Auction format is just one feature that determines the outcome of an auction, and our results also illuminate the importance of being in a smaller group size. No matter the format, being in a small group size counts more in terms of bidder profits. But, given the group size, there were different findings for small and large demanders; in 3-player groups, the large demanders earned more profit than small demanders, whereas it was the other way around in 6-player groups.

The bottom line is that, especially for inexperienced players, and for common value settings, the dynamic auction seems to be a better format for price discovery, which mitigates the common overbidding that has been produced in static auction formats.

There is still lack of knowledge in multi-unit settings in general, and in CV settings in particular. The present experiment was carried out with inexperienced subjects, even though they gained experience along the way. But it would be interesting to see how experienced bidders performed in a similar setting. The conclusion from earlier experiments is that they continue to have problems with CV settings.

8 Acknowledgements

We would like to thank Lars Hultkrantz, Jan-Eric nilsson for valuable comments on the paper. Also, thanks to Jan-Erik Swärdh for important help with econometrics. This study has been conducted within the Centre for Transport Studies (CTS). The author is responsible for any remaining errors.

References

Ahlberg, J.: 2011, 'Multi-unit common value auctions: A laboratory experiment with three sealed-bid mechanism'. *Working paper.*

Alsemgeest, P., C. Noussair, and M. Olson: 1998, 'Experimental comparisons of auvctions under single- and multi-unit demand'. *Economic Inquiry* **36**(1), 87–97.

Ausubel, L. M.: 2004, 'An Efficient Ascending-Bid Auction for Multiple Objects'. *The American Economic Review* **94**(5), 1452–1475.

Ausubel, L. M. and P. C. Crampton: 2002, 'Demand Reduction and Inefficiency in Multi-Unit Auctions'. *Mimeographed, Department of Economics, University of Maryland.*

Ausubel, L. M., P. Cramton, E. Filiz-Ozbay, N. Higgins, E. Y. Ozbay, and A. J. Stocking: 2009, 'Common-Value Auctions with Liquidity Needs: An Experimental Test of a Troubled Assets Reverse Auction'. Papers of peter cramton, University of Maryland, Department of Economics - Peter Cramton.

Bazerman, M. H. and W. F. Samuelson: 1983, 'I Won the Auction but Don't Want the Prize'. *Journal of Conflict Resolution* **27**(4), 618–634.

Engelmann, D. and V. Grimm: 2009, 'Bidding behaviour in multi-unit auctions - An experimental investigation'. *Economic Journal* **119**(537), 855–882.

Holt, C. A. and R. Sherman: 1994, 'The Loser's Curse'. *The American Economic Review* **84**(3), 642–653.

Kagel, J. H.: 1995, *Auction: Survey of experimental research. In Kagel, J.H., Roth, A.E. (Eds.), The Handbook of Experimental Economics.* Princton University Press.

Kagel, J. H., R. M. Harstad, and D. Levin: 1987, 'Information Impact and Allocation Rules in Auctions with Affiliated Private Values: A Laboratory Study'. *Econometrica* **55**(6), 1275–1304.

Kagel, J. H. and D. Levin: 1991, 'The Winner's Curse and Public Information in Common Value Auctions: Reply'. *The American Economic Review* **81**(1), 362–369.

Kagel, J. H., D. Levin, and R. M. Harstad: 1995, 'Comparative static effects of number of bidders and public information on behavior in second-price common value auctions'. *International Journal of Game Theory* **24**, 293–319. 10.1007/BF01243157.

Klemperer, P.: 2002, 'What Really Matters in Auction Design'. *Journal of Economic Perspectives* **16**(1), 169–189.

Lind, B. and C. R. Plott: 1991, 'The Winner's Curse: Experiments with Buyers and with Sellers'. *The American Economic Review* **81**(1), 335–346.

Manelli, A. M., M. Sefton, and B. S. Wilner: 2006, 'Multi-Unit Auctions: A Comparison of Static and Dynamic Mechanisms'. *Journal of Economic Behavior & Organization* **61**(2), 304–323.

Milgrom, P. and R. Weber: 1982, 'A Theory of Auctions and Competitive Bidding'. *Econometrica* **50**(5), 1089–1122.

Myerson, R.: 1981, 'Optimal auction design'. *Mathematics of Operations Research* **6**(1), 58–73.

Riley, J. G. and W. F. Samuelson: 1981, 'Optimal Auctions'. *The American Economic Review* **71**(3), 381–393.

Vickrey, W.: 1961, 'Counterspeculation, Auctions, and Competitive Sealed Tenders'. *The Journal of Finance* **16**(1), 8–37.

Wilson, R.: 1977, 'A Bidding Model of Perect Competition'. *The Review of Economic Studies* **44**(3), 511–518.

Wilson, R.: 1979, 'Auctions of Shares'. *Quarterly Journal of Economics* **93**, 675–689.

Wilson, R. B.: 1969, 'Competitive Bidding with Disparate Information'. *Management Science* **15**(7), 446–448.

9 Appendix A

Variable	**OLS**	**Robust standard error**
3-player groups	Reference	
6-player groups	-8.83***	1.29
Dynamic auction	2.31***	0.97
Signal	0.08***	0.02
Large demander	-0.71	1.36
Intercept	3.91***	1.04
No of observations	1279	
R^2	0.149	

Notes: a; Dependent variable is profit.

b; ***, ** and * denote difference from zero at the one, five and ten percent significance level respectively.

Table 11
Regression on bidder profit

10 Appendix B

Bidder Instructions for the static, uniform, common value auction

10.1 Introduction

Hello and welcome. You will participate in an experiment on economic decision-making. The purpose is to study sales by bidding, i.e. through an auction.

You have the opportunity to win money through participation. The show-up fee is SEK 100 (€10), and by learning the rules of the game, you have the opportunity to earn more than that. On the other hand, you could also lose in the process. To ensure that you walk away with at least SEK 100 in your pocket, we give you a starting balance of SEK 50. If you lose this money, you will be excluded from the experiment. Your winnings, and the show-up fee, will be paid in cash after the experiment.

A rule that applies at all times is that all communication between participants is prohibited. If you have any questions, raise your hand and I will come to you and you may ask your question in a whisper. If I believe the question must be answered, I will repeat it to everyone and give the answer.

10.2 Design

Rounds: The experiment consists of several rounds. In each round, 4 identical objects, or units, are to be sold through an auction. (How many rounds to actually play will be unknown to you.)

The commodities: Each of you has a value associated with owning these units and would like to buy them. We call this the redemption value, which is the same for all units. How many units you want to buy, i.e. your demand, will be seen on your screen, and the number never changes during the game.

The redemption value: Before the start of each round, the value of the units is randomly determined through the program. It draws an integer from an array of possible values. The value can never be less than 10, and the maximum is 90. Therefore, the (value) v belongs to the set $\{10, 11, \cdots, 89, 90\}$. (All values in this range have an equal probability.) However, you will not know what this value is. Instead you will get private information about this value.

Information: Even if you do not know the true value, you will receive information that limits the set of possible values. This will be done through a private information signal that is randomly chosen from a range of values between the minimum value $v - 10$ and the maximum value $v + 10$. Therefore, (your signal) will belong to the set $\{v - 10, v + 10\}$. (All values in this range have the same probability.) Your signal will also be an integer.

Example: Suppose that the true value of the goods is 36, then your signal will be in the set $\{36 - 10, 36 + 10\} = \{26, 46\}$.

Opponents: You can either have two or five opponents. Your group-size will be seen on the screen.

Bids: After receiving your information, that is, after you have seen your signal, you should decide what you want to bid for those units that you demand. It is permissible to place equal or different bids for the units.

10.3 Instructions

Buy: Those who have placed the four highest bids purchase the units. This may be the same person or different people. If there are ties among the (winning) bids, the program will randomly choose the winner(s).

Price: The winners pay a price equal to the highest bid that did not win. That is, the highest bid that was rejected. Thus, all winners pay the same price for the units.

Example: 4 units are sold. Five people (A, B, C, D, E) have the five highest bids: 25 (A), 23 (B), 19 (C), 15 (D), 12 (E). A, B, C and D purchase the units and everyone pays 12.

Gain/Loss: The winners make a profit equal to the difference between the (redemption) value and the price. If the difference is negative, you make a loss.

Example of profit: You won one unit, and the price was 42. The value of the unit was 50. You made a profit of 8 ($50 - 42 = 8$).

Example of a loss: You won one unit, and the price was 65. The value of the unit was 61. You then made a loss of 4 ($61 - 65 = -4$).

Note If you do not have one of the highest bids, nothing happens. The profit is zero.

10.4 Practical execution

Bidding: You will come to a (web)page where you will see the signal you received, how many units you demand, and how many opponents you have. On basis of this, you place your bids. You bid in the empty boxes and each box represents one unit. Only integer bids from 0 and up to 100 are possible.

Money: You will see what your current balance is before every game starts on the screen. The starting balance is 50. If you lose your starting balance, the auction is over for you.

Lost starting balance: If someone (or some) lose her starting balance, she/they will no longer participate in the auction. This means that there will be one (or more) person(s) less in the auction. But the auction continues as usual without these people.

One round: After you have entered your bid in the fields, press the button "Add bids". When everyone has pressed the button, the bids are ranked. Those who have placed the highest bids purchase units at a price that is determined by the maximum rejected bid.

If there are more winning bids than units for sale, the program randomizes the winners. The balance is recalculated and a new round starts. On the screen, you will see what the value of the units was, the price, the winning bids (as well as the signals from those with winning bids in parenthesis), the units won, and own profits/losses.

The end: After a certain number of rounds, the experiment will end. Then press the logout button, and you will come to a page showing what you have earned in the experiment.

10.5 Summary

- You will play a certain number of rounds and in each round, 4 identical units are for sale.
- You will play against two or five opponents. You will see the number of opponents on the screen.
- In each round, all players in an auction will have the same redemption value for all demanded units.
- However, each player only gets an informational signal about the true value. Subjects may or may not see the same information as their opponents.
- One can place bids for as many units as one demands, one for each unit. It is permissible to place equal or different bids for the units.
- You start with SEK 50. If you lose this, the experiment is finished for you, and you are excluded from the experiment. But you can also earn more, depending how you and your opponents act.

11 Appendix C

Bidder Instructions for the dynamic, uniform, common value auction

11.1 Introduction

Hello and welcome. You will participate in an experiment on economic decision-making. The purpose is to study sales by bidding, i.e. through an auction.

You have the opportunity to win money through participation. The show-up fee is SEK 100 (€10), and by learning the rules of the game, you have the opportunity to earn more than that. On the other hand, you could also lose in the process. To ensure that you walk away with at least SEK 100 in your pocket, we give you a starting balance of SEK 50. If you lose this money, you will be excluded from the experiment. Your winnings, and your show-up fee, will be paid in cash after the experiment.

A rule that applies at all times is that all communication between participants is prohibited. If you have any questions, raise your hand and I will come to you and you may ask your question in a whisper. If I believe that the question must be answered, I will repeat it to everyone and give the answer.

11.2 Design

Rounds: The experiment consists of several rounds. In each round, 4 identical objects, or units, are to be sold through an auction. (How many rounds to actually play will be unknown to you.)

The commodities: Each of you has a value associated with owning these units and would like to buy them. We call this the redemption value, which is the same for all units. How many units you want to buy, i.e. your demand, will be seen on your screen, and the number never changes during the game.

The redemption value: Before the start of each round, the value of the units is randomly determined through the program. It draws an integer from an array of possible values. The value can never be less than 10, and the maximum is 90. Therefore, the (value) v belongs to the set $\{10, 11, \cdots, 89, 90\}$. (All values in this range have an equal probability.) However, you will not know what this value is. Instead, you will get private information about this value.

Information: Even if you do not know the true value, you will receive information that limits the set of possible values. This will be done through a private information signal that is randomly chosen from a range of values between the minimum value $v - 10$ and the maximum value $v + 10$. Therefore, (your signal) will belong to the set $\{v - 10, v + 10\}$. (All values in this range have the same probability.) Your signal will also be an integer.

Example: Suppose that the true value of the goods is 36, then your signal will be in the set $\{36 - 10, 36 + 10\} = \{26, 46\}$.

Opponents: You can have either two or five opponents. Your group-size will be seen on the screen.

11.3 Instructions

Auction Procedure: This auction is not a so-called price auction, i.e. an auction where you place bid(s) for the units. This is a quantity auction; that is, there is a price clock starting from 0 and ticking up to 100, and the players themselves choose when they want to yield their units. Each player starts with demanding all his/her units, but may yield one or more units at any time during the game.

Auction Time: The price clock starts at 0 for 15 seconds, then increases at a rate of 1 unit per second. Every time someone gives up one or more units, the price clock stops for 5 seconds. If someone else gives up one or more units during this short break, the same price is registered but later in time. The clock also stops for an additional 5 seconds.

Auction Stop: When the number of non-yielded units is equal to the supply of units, the auction automatically ends and all those who still demand units will win them. They will pay the price that cleared the market, for each unit won. That is, the last registered price.

Example: 3 players are asking for 2 units each; the supply is 4. Then, as soon as 2 units are yielded, the market clears, since demand is then equal to supply. The price that everyone pays for each of their units won is equal to the price that cleared the auction; that is, the price that prevailed when the second unit was yielded.

Excess Supply: If a bidder yields more than one unit, and thus gives rise to an oversupply, the clock will be rolled back one increment, and the player who made this happen may purchase the same number of units to clear the auction. All players who have won units may then also buy at the new price.

Example: Suppose that the price clock is at 49, and 5 demanded units remain in the auction. If a player then yields 2 units when the price clock turns to 50, the aggregated demand drops to only 3 units, while the supply is 4. Then, the player who yielded 2 units may only yield 1 unit, but the price is rolled back to 49. This price applies to everyone who won units.

11.4 Practical execution

Auction start: You will come to a (web)page where you will see how many units you demand, how many opponents you have, and your balance. When the auction starts you will also get your signal. From then on, you can yield units. You also have 15 seconds to think before the price clock starts.

Money: On the screen you will see your up-dated balance after each round. The starting balance is fifty. If you lose your starting balance, the auction is finished for you.

Lost starting balance: If someone (or some) loses her starting balance, she/they will not participate in the auction any more. This means that there will be one (or more) person(s) less in the auction. But the auction continues as usual without them.

One round: After each round, the balance is re-calculated and a new round starts. On the screen you will see what the true value of the units was in the round before, the price of the units, what price the price-clock registered for the four most recent (highest) yielded units (as well as the signal these players had in parenthesis), units won, and the profit/loss in the round.

Gain/Loss: The winners make a profit equal to the difference between the (redemption) value and the price. If the difference is negative, you will make a loss.

Example of profit: You won one unit and the price was 42. The value of the unit was 50. You made a profit of 8 ($50 - 42 = 8$).

Example of a loss: You won one unit and the price was 65. The value of the unit was 61. You then made a loss of 4 ($61 - 65 = -4$).

Note If you yield all your units, nothing happens. The profit is zero.

The end: After a certain number of rounds, the experiment will end. Then, press the logout button, and you will come to a page displaying what you have earned in the experiment.

11.5 Summary

- You will play a certain number of rounds, and in each round 4 identical units are for sale.
- You will play against two or five opponents. You can see the number of opponents on the screen.
- In each round, all players in an auction will have the same redemption value for all units.
- However, each player only gets an informational signal about the true value. Subjects may or may not see the same information as their opponents.
- When you see the signal, the auction has started. Then you demand all your units, but can yield a unit at any time. You can yield one, or more units, depending on what you think is the best. After fifteen seconds, the price clock starts.

- When demand equals supply, i.e. when there are only four units left, the auction ends automatically.
- You start with SEK 50. If you lose this, you are bankrupt, and you are excluded from the auction. But you can also earn more, depending how you and your opponents act.