The Design of Recurrent Procurement Auctions

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CCP Working Paper 24-04
This version: 21 August 2024

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ISSN 1745-9648

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August 22, 2024

Abstract

In a procurement setting, when firms exit markets due to high costs, competition wavers, and the remaining bidders bid less aggressively, resulting in higher prices. The auctioneer's problem could conceivably be modulated by a reserve price mechanism that uses the lowest bid from the previous period. In a single market, when bidders set the cap in the next period, they can pull back their bids and keep that bid cap from biting. If instead, bidders from another market set the cap, the incentive for strategic bidding is removed, and competition can potentially be restored. Using a controlled setting, we show how dynamics in reserve price setting influence bid shading and entry in multi-round auctions. We find that, without a bid cap, dampened competition does lead to higher prices after bidders exit. Imposing a dynamic bid cap solves this issue of higher prices but knocks more people out of markets, leading to widespread failure of auctions. Surprisingly, bidding behavior remains similar across bid cap institutions during the first round. In subsequent rounds, bidding becomes deceptively more competitive in auctions with bid caps, but unexpectedly resulting in destroying markets.

Keywords: dynamic games, auctions, experiments, procurement, pricing, market structure
JEL Codes: C73, C91, D44, H57, L11

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1 Introduction

Auctions are widely used by governments to buy different types of goods and services. The main feature of this mechanism is competition, which should drive discipline among bidders to keep procurement costs low for the buyer. The most common format used is the sealed bid, first price auction, or low price (LP) auction. Here, bidders compete for the contract to sell, and the seller with the lowest asking price wins, getting paid their winning bid. In order to maximise profit, sellers need to consider the trade-off between the cost of bidding aggressively and its increased probability of winning. However, when bidding to sell the same object is done repeatedly, inefficient firms tend to exit the market over time, resulting in a dampened level of competition. With fewer sellers competing for the contract, bidding becomes less aggressive and prices are expected to rise.

Consider the case of government hospitals, spread across different locations, keeping a certain set of essential drugs in their inventory at all times. The hospitals would then regularly ask for competing offers from suppliers for each of these drugs. Sellers are heterogeneous, and some are relatively more efficient than others. These sellers have idiosyncratic costs that can change from year to year. It is likely that over time some firms will realise that they are not competitive. These firms leave, and the number of bidders participating in auctions drops. Sellers who stay quickly find out that they need not bid as aggressively as before, resulting in higher auction prices. A way to possibly mitigate this effect is to use a reserve price mechanism to keep prices low even when there are fewer sellers competing. Suppose that the auctioneer's reserve price is set as the lowest bid in the previous period. One can imagine that this bid cap can put a strong downward pressure on prices over time. This approach imposes a bid cap endogenously by making it a function of bidder behaviour. This type of bid cap can be vulnerable to manipulation and can inadvertently help bidders tacitly collude in order to keep prices high. An alternative approach would be to set the bid cap as the lowest bid in the previous period in a different market. The idea is to address the issue of endogeneity and restore prices to competitive levels, as if there were no bid caps. Examining these two institutions against the case where there is no bid cap is motivated by policy questions encountered by Bokhari et al. (2023).The authors find that the average prices were, in fact, lower due to the bid cap, but also find evidence that at least 1 in 3 auctions for regulated drugs failed. They also present evidence of significant heaping of prices just below the bid cap, indicating some ability to manipulate the policy. This policy mechanism is not common in practice, if used at all [1].

Imposing a static reserve price in repeated first-price auctions improves auctioneer revenue. In a static setting, because the distribution of transaction prices is truncated with a reserve price, the search over subsequent auctions becomes less valuable, and bidders shade

[1]Similar mechanisms exist throughout procurement settings, see Bucciol et al. (2020), the average pricing system (APS) in Medicare for Group B drugs and medical devices, but none with a dynamic feature

their bids less with respect to their values. However, the introduction of dynamics into the mechanism may leave markets vulnerable to strategic bidding by sellers Kanoria & Nazerzadeh (2021). The salience of a regulated price has been speculated to serve as a focal point that allows bidders to tacitly collide, a common issue associated with such an intervention Scherer (1967). In this version of the story, sellers can bid less aggressively to keep prices high. They shade their bids more to maximise their expected utility across periods, making the contract more expensive for the auctioneer. When endogeneous dynamics are introduced, one would expect bidders to pull back their bids to improve their profits in subsequent auctions. When this happens, the downward pressure on prices is less severe, keeping more sellers in the market, and reducing the likelihood of failed auctions. When bidders fail to collectively inflate bids and instead compete aggressively to win the current auction, they end up pricing themselves out of subsequent periods and winning in auctions only when they get a favourable cost draw. Seller attrition can end up being more severe than when there is no bid cap, and failures become more likely. Although the system can have favourable price outcomes, the implication is that markets end up being destroyed.

Our study examines how the dynamics in setting the reserve price affects bidder entry and exit in markets, the likelihood of failed auctions, and bidding behaviour over time. We examine the implications of two bid cap institutions in controlled settings using laboratory auction markets. We compared and contrast outcomes against the case where there is no bid cap imposed in the markets, and between institutions. Surprisingly, we find that our results show that bidders compete aggressively despite the endogenous bid cap and end up pricing themselves out of subsequent rounds. Over time, bidding behaviour becomes less competitive, as expected from the no bid cap case resulting in higher prices, and both institutions effectively address this issue. As a general result, we observed a clear trade-off between lower auction prices and extensive auction failure. Our choice of studying the behaviour of laboratory auction markets reflects an attempt at continuity with previous experimental studies, as well as previous empirical work evaluating a closer related policy regulating auction markets for medicines.

This paper proceeds as follows. Section 2 discusses related work. Section 4 looks at the theoretical predictions for the static case and our behavioural predictions when dynamics are introduced. Section 3 discusses our experimental design. Section 5 present the data from the experiment and analysis of the results. The last section concludes.

2 Related Literature

In auction markets, standard partial equilibrium theory predicts that a non-binding price control will not have an effect on price. However, the focal point hypothesis of Scherer (1967) argues that when a price ceiling is not binding, that is, above the equilibrium, the regulated price can serve as a focal point, keeping prices higher than what they should be. Using a laboratory setting to study this issue, Isaac & Plott (1981) found that the behaviour of auction markets over several periods with "static" price controls is better approximated by standard predictions than by the focal point hypothesis. However, they also found that a non-binding price control does affect price but not necessarily creating a focal point. The authors did not identify which feature of the environment induced such a result, but speculate that additional uncertainty created by removing the price control could have played a role in encouraging additional search activity by participants. An auctioneer's choice of reserve price can involve search theoretic considerations similar to reservation wage offers in labour markets, i.e., the highest bid in an auction will only be accepted by the auctioneer if it exceeds the reserve price, as observed by Ashenfelter (1989). From the bidder's perspective, it is optimal to bid up to their values in a one-shot auction, but in a sequential setting, bidders shade their bids relative to their values because of the possibility of winning at more favourable prices in subsequent auctions. Carare (2012) finds that imposing a static reserve price truncates the distribution of transaction prices, lowering bidders' expected surplus and because of a lower value of search over future auctions, bidders will shade their bid by a lower amount. Renewed interest in behaviour-based pricing strategies driven by the rise of e-commerce and online retailers motivated Kanoria & Nazerzadeh (2021)'s theoretical examination of auction markets with a dynamic reserve price. They find that in second-price auctions, if the auctioneer updates a common reserve price based on bidding history, then this may create incentives for bidders to shade their bids. They then show that incentive compatibility can be restored by using personalised reservation prices based on historical bids from other bidders.

In the literature on independent private value auctions, wide-spread deviations from the risk-neutral Nash equilibrium (RBNE) are well documented. This puzzle of overbidding in experiments, initially observed by Coppinger et al. (1980), has been explored and debated over the years. General bidding models using risk aversion (Cox et al. (1983, 1985, 1988)), regret theory (Rabin (2000)), quantal response equilibrium (Goeree et al. (2002)), and level-k behaviour (Crawford & Nagore (2007)) have been proposed to explain this finding. Common knowledge of rationality, that is, when all bidders believe that they are competing with similarly rational subjects, can plausibly contribute to such behaviour among bidders. The competition to win could then overwhelm the ability to manipulate the bid cap.

A real world application of a dynamic reserve price mechanism in pharmaceutical markets is studied by Bokhari et al. (2023). They conducted an empirical investigation of a procurement policy in the Philippines for essential drugs. Using a triple difference design, they found a causal effect that the policy reduced prices. In other dimensions of competition, their findings are not as rosy. The dataset they used recorded only winning bids, and one can infer that the auction failed and was re-run at an inflated reserve price if the transaction price recorded is higher than the applicable bid cap. They found that about 1 in 3 auctions resulted in the winning bid higher than the bid cap, and inferred that failed auctions could be widespread. Bidders in auctions for regulated drugs have won significantly more at prices just under the applicable bid cap. Due to the limitation of their data, this finding could be conditioned on the number of bidders. Such an insight could be useful to better understand if this was due to coordination among the sellers or a severely diminished level of competition in the markets because there are no sellers willing to bid.

We hope to contribute to the existing literature in the following ways. First, we extend the findings of Isaac & Plott (1981) and Carare (2012) by looking at the behaviour of laboratory auction markets with a dynamic reserve price rather than the static version. Second, our experiment provides evidence relevant to the theoretical predictions of Kanoria & Nazerzadeh (2021) and extends their findings on second-price auctions to first-price sealed bid auctions. Lastly, we contribute to the literature insight about the trade-off between auction price regulation and the likelihood of failed auctions. By doing so, we add to the growing body of knowledge related to the regulation of auction markets, where a strong link between evidence and policy is needed, but often lacking.

3 Experimental Design

Real-world procurement auctions and their outcomes before and after imposing a dynamic bid cap policy motivate our choices in designing the experiment. Bokhari et al. (2023) studies such auctions, finding a systematic reduction in prices and evidence of widespread auction failures. We want to look at the behaviour of laboratory auction markets with a dynamic bid cap to measure changes in transaction prices and bidder entry relative to a baseline of auctions without a bid cap. We explore two variants of the mechanism, one with endogenous features and another that delinks the bid caps from behaviour of bidders in a market. Therefore, the experiment requires three treatments using the Low Price (LP) auction: one without a dynamic reserve price, i.e. no bid cap, (NBC), one using a dynamic reserve price in a single market (SBC), and the third using a dynamic reserve price with multiple markets (MBC). Participants will interact through a computerised system. The winner of these auctions will be determined by the lowest bid submitted. Using a between-subjects design, each participant is exposed to only one of the three conditions and plays multi-round auctions. Each treatment will have 3 sessions. In each session, there is a hypothetical buyer and up to 5 competing sellers. In each session, subjects participate in 10 sequences of up to three auction rounds per sequence. In each sequence, each participant will receive a fundamental cost to provide the product to the buyer. In each auction round, the actual cost will be equal to this fundamental cost plus a round-specific random draw. The fundamental cost will be redrawn for each sequence from a uniform distribution in the range [100, 200]. Then in each auction round, the second component is then redrawn from a uniform distribution in the range [-15, 15]. Participants will only be told their actual cost for the round.

In round 1 of each sequence, everyone is told their realised cost and everyone participates. In each subsequent round, participants are told their realised cost for that round and will be allowed to choose whether or not to participate in the auction for that round. If they choose to participate, they will pay a 2 ECU fee to do so, whether they win or not. If they choose not to participate in a round, they will not be able to participate for the remaining rounds in that sequence, but they will be able to rejoin in the subsequent sequence. If they choose not to participate, there will be an alternative uncompensated activity for them to engage in while waiting for the experiment to continue. After deciding to participate, subjects are informed of the number of competitors participating. Each competitor will have received a realised cost using the same method, with all draws being independent.

In the first treatment, there is no bid cap imposed between rounds. In the second treatment, inside a sequence, there will be a bid cap on possible bids that can be submitted based on the winning bid in the prior round. There will be no cap placed on bids in round 1 of a sequence, but there will be in rounds 2 and 3. This cap will be reset between sequences, so after one sequence ends and a new one begins, in the first auction round of a new sequence, there will be no bid cap.

For the third treatment, each participant will be randomly assigned to a group. Each group will be randomly matched with another group. Inside a sequence, there will be a bid cap on possible bids that can be submitted based on the winning bid in the matched group in the prior round. This means that there will be no cap placed on bids in round 1 of a sequence, but there will be in rounds 2 and 3. This cap will be reset between sequences, so after one sequence ends and a new one begins, in the first auction round of a new sequence, there will be no bid cap.

In addition to a 200 Philippine Peso (PhP) fee for showing up, participants will be paid after adding the earnings from all rounds at the conversion of 1 ECU to 10 PhP. Overall, subjects earned an average of PhP 967.91 in NBC sessions, PhP 517.74 in SBC sessions, and PhP 562.21 in MBC sessions, inclusive of a PhP 200 show-up fee. Bankruptcy rules were put in place to deal with the possibility of bidders going bankrupt. First, all subjects start the experiment with an initial balance of 50 ECUs. If they lose so much money that their balance reaches zero, then they were declared bankrupt and asked to leave the experiment with only their show-up fee. Alternate participants were recruited for each session who went through the instuctions at the same time as the other subjects and replaced those who were declared bankrupt. Alternates are given 50 ECUs upon replacing bankrupt subjects. Participants were recruited through online ads posted in public access student social media groups and invited to sign up for a session. No demographic information was asked of the participants. The software for the experiment was programmed using oTree Chen et al. (2016).

4 Equilibrium Predictions

We consider n sellers competing for a contract to sell a good or provide a service to a buyer. Each seller $i \in 1, ..., n$ gets a fundamental cost draw c_i from uniform $[\underline{f}, \overline{f}]$. In each round

$t \in 1, ..., T$, a seller receives a second draw from uniform $[-\delta, \delta]$ to form their actual private cost s_{it}. In effect, the actual cost in each round is independently drawn from a trapezoidal distribution over the interval $[c_i - \delta, c_i + \delta]$. This means that a given seller will know the actual cost of winning in any given period, but only knows that it is within δ above or below the fundamental cost. This also means that in each round, a seller cannot be certain but can draw inference if they have likely drawn a higher or lower cost than others. In each round, sellers try to win the contract such that they maximise their expected payoffs. They pay a nominal participation fee to submit a bid in each round but can decide to withhold participation after the first round.

4.1 Low Price (LP) Auction

In period t, each seller i submits a price bid of b_i, and given these bids, the ex post payoff function of seller i is

$$\Pi_i(b_i, b_{-i}) = \begin{cases} b_i - c_i & \text{if} \quad b_i < b_j \quad \forall j \neq i, \\ 0 & \text{otherwise.} \end{cases} \tag{1}$$

4.1.1 Equilibrium with n sellers

We look at the case where bidders are symmetric in expectation in that the actual costs are independently drawn from the same distribution, $F_i = F, \forall i$. First, suppose that bidder i's signal $S_i \sim F(\cdot)$ with realization $s_i \in [\underline{s}, \overline{s}]$, where $F(\cdot)$ is continuous, and her cost is $c_i(s_i) = s_i$. Assume that bidders $j \neq i$ use identical bidding strategies $b_j = b(S_j)$ that are strictly increasing, continuous, and differentiable functions of cost, then we consider the problem facing bidder i. Bidder i's expected payoff, as function of her bid b_i, and her signal s_i is:

$$U(b_i, s_i) = (bi - s_i) \cdot Pr[b_j = b(S_j) \geq b_i, \forall j \neq i] \tag{2}$$

Bidder i then chooses b that solves:

$$\max_{b_i} (b_i - s_i)\big(1 - F(b^{-1}(b_i))\big)^{n-1}$$

The first order condition is:

$$(b_i - s_i)(n-1)\big(1 - F(b^{-1}(b_i))\big)^{n-2}\big(-f(b^{-1}(b_i))\big)\frac{1}{b'(b^{-1}(b_i))} + \big(1 - F(b^{-1}(b_i))\big)^{n-1} = 0$$

At the symmetric equilibrium, $b_i = b(s_i)\ \forall i$ so the FOC reduces to a differential equation:

$$b'(s) = \big(b(s) - s\big)(n-1)\frac{f(s)}{1-F(s)} \tag{3}$$

Using the boundary condition $b(\bar{s}) = \bar{s}$, this can be solved to obtain:

$$b(s) = s + \frac{\int_s^{\bar{s}} \big(1 - F(\tilde{s})\big)^{n-1} d\tilde{s}}{\big(1 - F(s)\big)^{n-1}} \tag{4}$$

Given signal s, bidders use strategy $b(s)$, where it is optimal to bid some positive value above cost. Observe further that this deviation from cost is decreasing in the number of bidders. The formal derivation and examples are given in Appendix D and Appendix E. When bidders are asymmetric with costs drawn from independent, but not necessarily identical distributions, it is possible for a bidder to have the lowest cost and another to have the lowest willingness to pay [2].

4.1.2 Equilibrium Bid Functions with a Trapezoid Distribution

Now suppose that the bidders are still symmetric in that $F_i = F,\ \forall\ i$, but $S_i \sim F(r)$ where bidder i's signal has realisation drawn from $[c_i - \delta, c_i + \delta]$. Given that both c_i and δ are uniformly distributed with different supports, the resulting probability distribution is trapezoidal. The shape is illustrated in Figure 1.

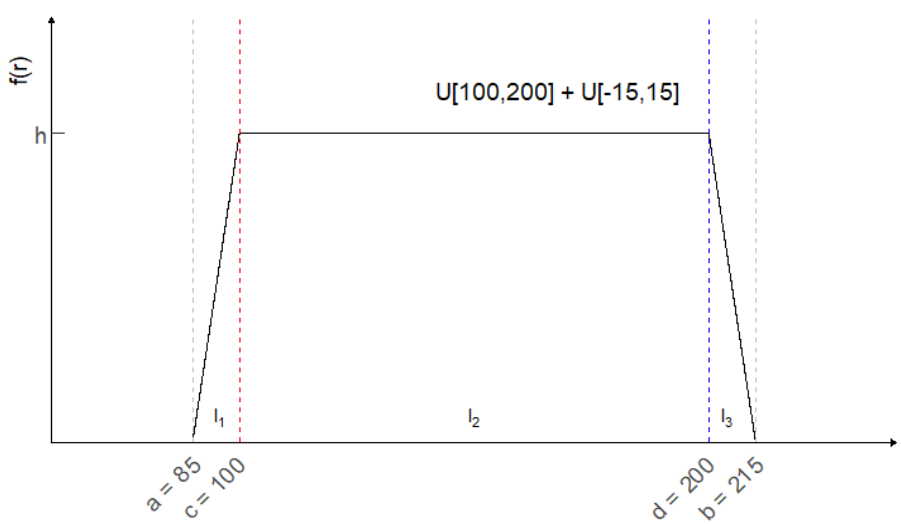

Figure 1: Trapezoid probability density function

The distribution is defined by four parameters, the minimum a, the maximum b, the lower mode c, and the upper mode d, where $a \leq c \leq d \leq b$. Substituting the expression for the cdf derived by Kacker & Lawrence (2007) into Equation 4, we get the equilibrium bid function for

[2] For more details on this, see Myerson (1981).

our environment as Equation 5. We simplify the expression by defining line segments between a, c, d, b as $l_1 = (c-a)$, $l_2 = (d-c)$, and $l_3 = (b-d)$, where $w \equiv l_1 + l_2 + l_3 = (b-a)$. The formal derivation of the pdf and cdf are given in Appendix F. All relevant cases are consistent with the standard theory that bidders choose to bid some positive amount above cost in equilibrium. We provide worked out examples in Appendix G.

$$b(r) = \begin{cases} r + \dfrac{\displaystyle\int_r^c \left(1 - \frac{(\tilde{r}-a)^2}{l_1(w+l_2)}\right)^{n-1} d\tilde{r}}{\left(1 - \dfrac{(r-a)^2}{l_1(w+l_2)}\right)^{n-1}} & \text{if} \quad a \le r < c, \\[2em] r + \dfrac{\displaystyle\int_r^d \left(1 - \frac{l_1 + 2(\tilde{r}-c)}{w+l_2}\right)^{n-1} d\tilde{r}}{\left(1 - \dfrac{l_1 + 2(r-c)}{w+l_2}\right)^{n-1}} & \text{if} \quad c \le r < d, \\[2em] r + \dfrac{\displaystyle\int_r^b \left(\frac{(b-\tilde{r})^2}{l_3(w+l_2)}\right)^{n-1} d\tilde{r}}{\left(\dfrac{(b-r)^2}{l_3(w+l_2)}\right)^{n-1}} & \text{if} \quad d \le r \le b. \end{cases} \tag{5}$$

4.2 Behavioral Response to Dynamic Reserve Price

Without any restriction to the auctioneer's reserve price, bids become less competitive as high-cost bidders exit and fewer bidders are left in the market to compete. Using a mechanism where the reserve price is made endogenous by setting it equal to the winning bid of the same auction market in the previous period, we consider two possible outcomes. The first is that bidders learn to bid less aggressively to prevent the bid cap from closing them out of the subsequent auction. Sellers end up shading their bids more and inflating the price.

Suppose that this is the outcome. Another bid cap mechanism can address the endogeneity by setting the reserve price of a market as the winning bid in the previous period of a different auction. Here bidders in an auction should have no ability to manipulate the bid cap they will face in the subsequent auction, and we expect sellers to compete aggressively and prevent the increase in auction prices over time.

There may be an alternative outcome from the endogeneous bid cap. For the collusive outcome to be sustained, the participating bidders must be convinced that this is a sustainable strategy for everyone. If this tacit coordination is not maintained and at least one bidder decides to bid aggressively and compete, then the other sellers would switch to competing as well. This leads to the other possible outcome, which is that sellers end up bidding at least as aggressively as if there were no bid caps. If everyone believes that all other players understand that the tacit collusive strategy is unlikely to be sustained, the increased bid shading will not be observed.

5 Results

A set of summary statistics for key variables of interest is given in Table 1. Average values are provided by session and treatment. For auction prices, entry of bidders, and failure rates, we present averages by round. When comparing the average bids and costs of round 1, the similarity between treatments is striking. Average costs are similar by construction. Round 1 average bids in NBC and MBC auctions are similar as expected. However, sellers in NBC auctions were expected to be bidding higher under the collusive prediction. Instead of increased shading in bids, we find bidders competing aggressively.

Table 1: Summary Statistics

Treatment†	Session	*Avg Cost*‡	*Avg Bid*‡	Avg Price			Avg Bidder #			Failed (%)		
				r1	r2	r3	r1	r2	r3	r1	r2	r3
NBC	3	*149.54*	*153.79*	120.10	128.35	157.65	5.00	2.73	2.56	-	3.33	3.33
	8	*152.27*	*156.62*	117.65	124.11	139.95	5.00	3.00	2.50	-	0.00	0.00
	10	*151.87*	*153.77*	114.35	130.88	150.16	5.00	2.57	2.33	-	0.00	5.00
	All	*151.27*	*155.04*	117.73	126.99	147.98	5.00	2.82	2.49	-	1.11	2.22
SBC	2	*148.47*	*148.92*	118.17	106.31	105.75	5.00	1.31	0.74	-	20.00	50.00
	4	*152.37*	*157.79*	119.93	113.18	113.22	5.00	0.97	0.77	-	43.33	70.00
	5	*152.25*	*156.31*	122.40	122.64	123.40	5.00	1.01	0.79	-	30.00	50.00
	All	*151.30*	*155.01*	120.19	113.72	114.27	5.00	1.08	0.76	-	32.86	58.57
MBC	1	*149.33*	*152.33*	117.60	107.57	116.46	5.00	0.92	0.56	-	43.33	73.33
	7	*151.70*	*155.54*	124.57	114.55	116.48	5.00	1.36	0.89	-	20.00	56.67
	9	*148.83*	*152.23*	118.17	115.80	120.75	5.00	1.03	0.59	-	33.33	73.33
	All	*149.95*	*153.37*	120.11	113.03	117.69	5.00	1.11	0.71	-	32.22	67.78

Note: †NBC- No bid cap, SBC- Single market dynamic bid cap , MBC- Multi-market dynamic bid cap
‡Averages of round 1 auctions. Costs and bids are of all participating sellers.

In subsequent rounds, auction prices rise in the NBC auctions, while in both the SBC and MBC cases, prices have stayed low. Prices in the no bid cap case increase up to 148 on average by round 3. In contrast, both SBC and MBC auction prices are much lower and stay below 120 in subsequent rounds. Looking at the average number of bidders, we see attrition in all three treatments. This is because high cost sellers exit the market after round 1. However, the loss of bidders in the SBC and MBC auctions is much more pronounced. When there is no bid cap, the bidder count drops to about 3 bidders in round 2 and in the last round, 2 bidders on average. For both bid cap institutions, an average of just one bidder remains in the auction immediately after round 1. We get a better understanding of this attrition and average bidder counts when we look at the auction failure rates. Examining the auctions in rounds 2 and 3 where subjects are given the option of entering the auction, we find, quite surprisingly, that a large proportion of auctions end up failing with a dynamic bid cap. In NBC auctions, only about 1-2% on average fail. With the SBC, about 33% of the auctions fail in round 2 and 59% end up failing in round 3. We initially get the same proportion of auctions that fail in the MBC institution, but a larger number of auctions fail in round 3 at about 68%.

5.1 Bidding Behaviour

Figure 2 gives a scatter plot of bids and their corresponding costs across the three treatments with nonlinear regression lines fitted through the respective data sets. Reference lines are provided as the 45 degree line and the equilibrium bid function in the LP auction. We show round 1 auctions where the environments can be compared along these two dimensions. Bidding in rounds 2 and 3 becomes also a function of the level of competition. For these we use our regressions to gain insight to bidders' behaviour. Trend lines show a visually obvious similarity of bidding behaviour in all three institutions. Throughout the range of cost draws, trend lines stay very close to each other, overlapping in most parts. Bids are clustered above the cost and below the predicted levels for the LP auction. This means that bids are more aggressive relative to standard equilibrium predictions. We note that the observed behaviour in NBC auctions is consistent with overbidding among subjects in other laboratory experiments with independent private valuations. A long series of experiments find that bidders tend to bid more aggressively than the risk neutral equilibrium predictions[3]. General bidding models such as risk aversion, regret theory, level-k, and quantal response equilibrium have been proposed to rationalise such a finding. The tacit collusion prediction that would have resulted in higher round 1 bids with the SBC treatment did not show up in the results. Instead, behaviour that is identical to that in NBC auctions comes clearly through the summary table and figure. A possible explanation is that subjects have common knowledge of rationality, expecting that competing sellers also form beliefs that, despite the endogenous feature of the mechanism, a collusive equilibrium is not easily sustained. Such level-k thinking of what opponents expect other players to bid can drive up competition to win, overwhelming the ability to influence the bid cap. Under conditions where coordination is easier to maintain, strategic behaviour would be more likely. The robustness of this explanation needs to be further investigated and is one of the ways forward for extensions of this study. In the MBC mechanism, we see what is expected in that bidding is similar to the NBC bids, since there is no ability to influence bid caps by shading bids more.

Table 2 gives the results of several regression specifications on bids in each round to determine the overall structure of bidding behaviour. Variables used include the realised cost of the bidder, dummies for auctions using the single market bid cap (SBC) and the multimarket bid cap (MBC), and a dummy for whether the round is in the second half of the

[3] See Sections 1.1 and 1.2 of Kagel & Levin (2017) for a survey of experiments exploring this finding

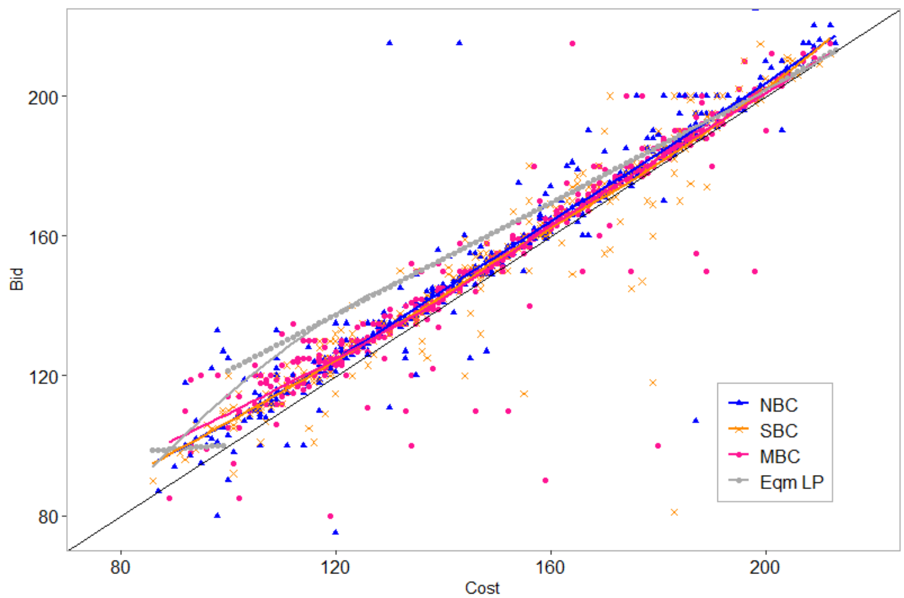

Figure 2: Scatterplot of Bids vs Cost (Round 1 Auctions)

experiment. Specifications examine differences in behaviour between institutions over time. These regressions support our first result.

RESULT 1. There is no significant statistical difference across treatments for round 1 bidding. In rounds 2 and 3, we find that bidding behaviour in NBC auctions becomes increasingly less competitive relative to both SBC and MBC auctions.

We find a clear break in the nature of bid functions between round 1 and the other rounds. For NBC, the bid function in round 1 is approximately $0.9s_i + 9$ shown in column (1). In round 2, it becomes $0.5s_i + 68$, shown in column (3), and in round 3 it is $0.5s_i + 86$, shown in column (6). This break holds after controlling for the number of bidders. The slope and intercept are different in round 1 but only the intercept is different between rounds 2 and 3. Bidding behaviour under the bid cap institutions becomes increasingly more competitive than in NBC seen in the coefficients of indicator variables SBC and MBC in columns (3)-(5) and (6)-(8).

5.2 Seller Earnings

Reported statistics in Table 1 show that the average price in NBC auctions starts around 118 on average in round 1 but rose to 147 in round 3. Prices in SBC and MBC auctions begin with a slightly higher level of about 120 on average but do not go up in rounds 2 and 3, ending lower than the initial average levels. The rise in auction prices for NBC auctions is consistent with what theory tells us. A seller's bidding function would predict higher bids with fewer competing sellers. Markets become less competitive, and sellers who remain in

Table 2: Regressions on Bidding Behaviour

	Bid							
	Round 1		Round 2†			Round 3†		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Cost	0.964***	0.964***	0.549***	0.569***	0.582***	0.484***	0.524***	0.519***
	(0.013)	(0.013)	(0.040)	(0.041)	(0.041)	(0.069)	(0.066)	(0.066)
No. of Bidders				−2.932**	−2.458**		−11.012***	−11.383***
				(1.174)	(1.166)		(2.048)	(2.066)
SBC	−0.069	−0.033	−21.993***	−25.448***	−24.017***	−34.408***	−50.997***	−50.979***
	(1.021)	(1.017)	(3.139)	(3.413)	(3.392)	(6.112)	(6.572)	(6.563)
MBC	−0.403	−0.403	−19.375***	−22.391***	−21.489***	−25.278***	−39.731***	−40.436***
	(0.947)	(0.944)	(2.870)	(3.098)	(3.068)	(6.022)	(6.318)	(6.333)
H2		2.440***			7.982***			4.873
		(0.804)			(2.266)			(3.758)
Constant	9.157***	7.936***	68.458***	75.199***	67.833***	86.268***	110.390***	109.327***
	(2.126)	(2.157)	(5.822)	(6.385)	(6.639)	(9.668)	(10.217)	(10.237)
Observations	1,240	1,240	428	428	428	259	259	259

Note: †Failed auctions are excluded.
*p<0.1; **p<0.05; ***p<0.01

the markets realise that they can bid less aggressively. This gives us the expected problem faced by the auctioneer in these multi-round auctions. With the imposition of a dynamic bid cap, both the SBC and MBC cases seem to resolve this issue. Table 3 shows that the expected surplus of participants in both variants of the bid cap is almost always a loss, while participants earn a surplus in the NBC auctions. Table 4 shows that conditional on winning the auction, bidders in the NBC earn more than both SBC and MBC. Between the bid cap variants, winners tend to earn more in the MBC case. The number of subjects who lost their endowment in NBC sessions was 8, 12 in SBC sessions and 10 in MBC sessions. These subjects were removed from their sessions and replaced by alternate participants. Our second result summarises the findings on auction prices and seller surplus.

Table 3: Summary of Participant Surplus

Treatment	Session	Avg Surplus		
		All	1st Half	2nd Half
NBC	3	46.69	1.21	53.05
	8	24.04	10.71	14.55
	10	34.50	34.36	0.17
	All	34.58	12.94	24.56
SBC	2	-8.80	-4.07	-7.10
	4	-8.16	-5.26	-3.67
	5	-2.38	-3.13	0.80
	All	-6.50	-4.22	-2.85
MBC	1	-1.60	-2.90	1.73
	7	-4.08	-4.79	0.85
	9	-3.19	-1.81	-1.45
	All	-3.03	-3.25	0.25

Note: Figures are inclusive of participation fee.

Table 4: Summary of Winner Surplus

Treatment	Session	Avg Surplus		
		All	1st Half	2nd Half
NBC	3	86.03	14.34	95.58
	8	52.20	35.93	29.71
	10	81.33	101.17	15.63
	All	70.05	37.17	48.03
SBC	2	2.89	6.20	-0.71
	4	5.59	3.33	5.00
	5	13.20	4.50	16.00
	All	7.03	4.28	6.08
MBC	1	14.38	6.91	15.40
	7	10.20	2.64	10.33
	9	13.13	7.67	8.75
	All	12.61	5.79	11.26

Note: Figures are inclusive of participation fee.

RESULT 2. On average, prices are lower with SBC and MBC than in NBC auctions. Seller surplus is lower for both bid cap cases with those with the SBC losing more than those with the MBC.

We provide statistical support for this result in Table 5, which contains regressions on auction price for each round. The variables in these regressions include dummy variables indicating whether the bid cap is SBC or MBC, the lowest and second lowest cost among participating bidders in a group, and a dummy variable indicating whether the round is in the second half of the experiment. Round 1 regression, column (1), confirms that, indeed, prices across treatments are not statistically different, as shown by the coefficients of the SBC and MBC indicator variables. In the regressions for rounds 2 and 3, specifically columns (2) and (4), we see that prices in the SBC and MBC are different from NBC. In round 2, prices in both bid caps institutions are similarly lower by 11 than NBC. In round 3, surprisingly, prices in SBC are even lower than those in MBC. Despite the endogenous feature of the mechanism, bidders in SBC auctions are competing more aggressively than in MBC auctions. These statements are true even after controlling for the number of bidders in the auction, seen in columns (3) and (5). Because bidding behaviour becomes increasingly less competitive in NBC auctions over time, auction prices increase. This is consistent with the analysis on bidding behaviour. Similarly, because bidding behaviour in the SBC and MBC auctions grows more competitive in subsequent rounds because of the bid caps, auction prices fall. The summary statistics in Table 1, clearly show that immediately after round 1, bidder attrition is more severe in both the SBC and MBC auctions. Without any bid caps, this level of competition would have resulted in bids from remaining sellers being much higher, as standard theory predicts.

However, there is a monotone, inverse relation between the average auction price and the number of bidders, which can be problematic for both sellers and auctioneer. Sellers who stay could take advantage of the low level of competition and charge a high price. If in the limit entry is so severely impacted that all bidders stay out of the market, the auctioneer is faced with a failed auction and is not able to acquire the object. We discuss this in the following sections.

Table 5: Regressions on Auction Price

	Auction price				
	Round 1	Round 2		Round 3	
	(1)	(2)	(3)	(4)	(5)
SBC	1.266	-11.264^{***}	-20.129^{***}	-28.029^{***}	-53.643^{***}
	(1.903)	(4.127)	(4.551)	(7.730)	(7.401)
MBC	2.235	-11.024^{***}	-19.549^{***}	-21.932^{***}	-48.251^{***}
	(1.778)	(3.820)	(4.251)	(7.678)	(7.407)
Lowest Cost (LC1)	0.875^{***}	0.805^{***}	0.796^{***}	0.656^{**}	0.750^{***}
	(0.066)	(0.151)	(0.145)	(0.252)	(0.214)
2nd Lowest Cost (LC2)	0.040	0.101	0.038	0.331^{*}	0.131
	(0.057)	(0.119)	(0.116)	(0.194)	(0.166)
H2	4.989^{***}	8.648^{***}	7.337^{**}	2.839	8.646^{*}
	(1.510)	(3.265)	(3.161)	(5.839)	(5.013)
No. of Bidders			-6.933^{***}		-22.962^{***}
			(1.734)		(3.079)
Constant	8.563	16.410	46.149^{***}	26.119	90.025^{***}
	(6.153)	(13.465)	(14.948)	(25.214)	(23.038)
Observations	250	197	197	146	146

Note: *p<0.1; **p<0.05; ***p<0.01

5.3 Entry

In Figure 3, we see a visualisation of the average prices and bidder counts presented in Table 1. The difference between NBC and the other treatments is clearly seen in rounds 2 and 3 for both prices and bidder counts. Lower prices resulting from the bid caps forced more sellers out of the markets. In the NBC auctions, bidder attrition is as expected with high cost bidders exiting in subsequent rounds. When bid caps are imposed endogenously, the winning bid in the previous period, which is likely from a bidder with a low cost draw, priced out all bidders that have higher cost draws in subsequent rounds. Imposing price caps somewhat reverses the standard prediction. Even with fewer bidders competing, bids stay low. This outcome is misleading because the auctioneer should also consider the rate at which the auctions fail. In some procurement settings, failed auctions are dealt with a re-run of the failed auction with the reserve price adjusted upward.

RESULT 3. The auctioneer's problem of high prices is addressed, but bidders are more likely to exit markets with the SBC and MBC than in NBC auctions.

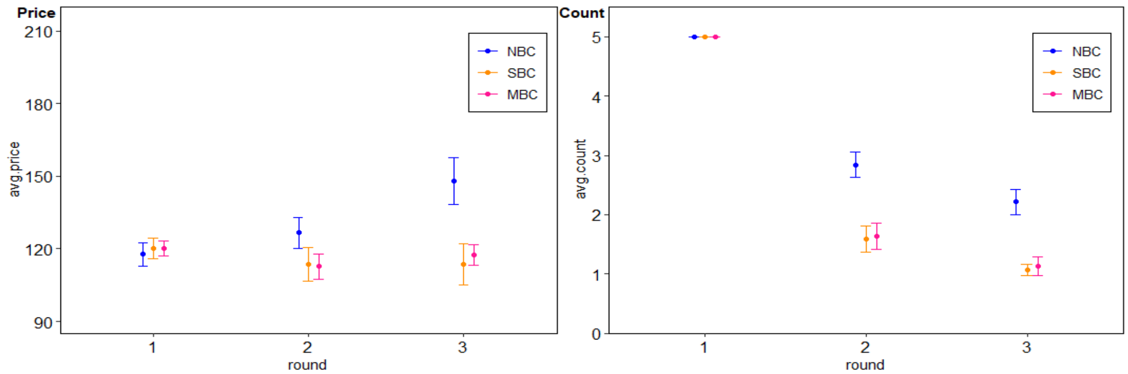

Figure 3: Price and Bidder Count Outcomes by Treatment, Round

Table 6 provide statistical support for this result. Here, we present a series of probit regressions in columns (1)-(4), with the dependent variable being whether or not the bidder decided to join the auction, as well as a set of marginal effects in columns (5)-(8), which were calculated from standard probit regressions with the same specifications. We find that the probability of entry is significantly reduced by the SBC and MBC dummies. Looking at the magnitudes of the marginal effects, we see that the probability of entry is lower for MBC than for SBC relative to the NBC case.

Table 6: Regressions on Likelihood of Entry

	Binary for Entry†							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Cost	−0.021***	−0.021***	−0.027***	−0.028***	−0.006***	−0.006***	−0.007***	−0.007***
	(0.001)	(0.001)	(0.002)	(0.002)	(0.000)	(0.000)	(0.000)	(0.000)
Bid Cap			0.027***	0.028***			0.007***	0.007***
			(0.004)	(0.004)			(0.001)	(0.001)
SBC	−1.197***	−1.198***	0.117	0.111	−0.387***	−0.388***	0.031	0.030
	(0.094)	(0.094)	(0.100)	(0.101)	(0.024)	(0.024)	(0.027)	(0.027)
MBC	−1.272***	−1.272***			−0.425***	−0.425***		
	(0.087)	(0.087)			(0.024)	(0.024)		
Round 2 (R2)	−0.291***	−0.291***	−0.211*	−0.215*	−0.113***	−0.113***	−0.060	−0.060
	(0.082)	(0.082)	(0.125)	(0.126)	(0.032)	(0.032)	(0.038)	(0.038)
H2		−0.028		−0.261***		−0.011		−0.069***
		(0.071)		(0.100)		(0.027)		(0.026)
Constant	3.671***	3.688***	−0.045	0.056	1.035***	1.040***	−0.011	0.014
	(0.208)	(0.212)	(0.407)	(0.410)	(0.060)	(0.061)	(0.101)	(0.100)
Observations	1,648	1,648	953	953	1,648	1,648	953	953

Note: Columns (1)-(4) are panel probit regressions. Columns (5)-(8) are marginal effects from standard probit regressions. † Only rounds 2 and 3 are considered.
*p<0.1; **p<0.05; ***p<0.01

In Figure 4, we check whether subjects make the decision to leave if the current cost exceeds the current bid cap. Similarly, subjects should make the decision to enter the auction when there is a positive surplus to be had by staying in. In round 2 we find that some subjects are deciding to enter even though the surplus expected by staying is negative. We take this as evidence of some subjects expecting to have a lower cost draw in round 3 and therefore staying in. The figures show that the mass of subjects leaving are found on the left of zero and those that stay on the other side. This suggests that subjects are leaving or entering the auctions when they should.

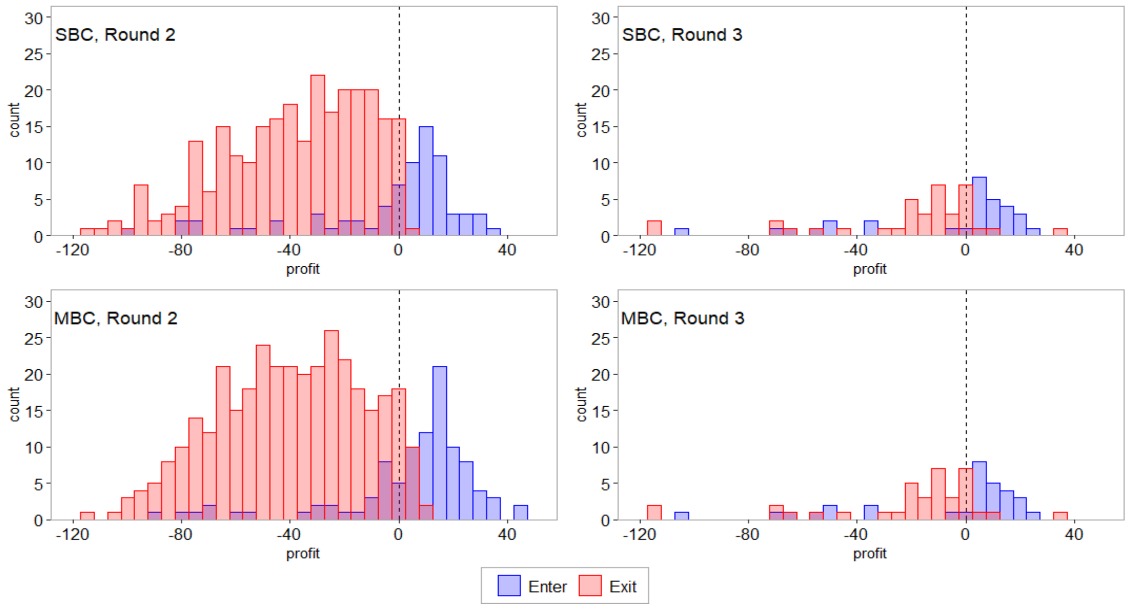

Figure 4: Seller Entry Decision by Surplus

5.4 Failed Auctions

Dynamic bid caps put such strong downward pressure on prices that failure becomes widespread. Even sellers with low cost draws end up exiting markets over time. The competition to win drives down the bid cap such that subjects end up staying out of the market.

RESULT 4. Auction markets are more likely to fail with SBC and MBC auctions.

Table 7 provide statistical support for this result. Here, we present a series of probit regressions in columns (1)-(4), with the dependent variable being whether or not the auction failed, as well as a set of marginal effects in columns (5)-(8), which were calculated from standard probit regressions with the same specifications. We find that the probability of failure is significantly affected by the SBC and MBC dummies. On average, both bid cap institutions make failure 56% more likely than without a bid cap, seen in columns (5) and (6). Including a variable for bid cap, coefficients are now with reference to the MBC auctions. In columns (7) and (8), after controlling for round 2 and second half auctions, for every unit higher of the bid cap, auctions are 0.9% less likely to fail.

We find that this is a key result since auction prices could be deceptively low, despite a lower number of participating bidders in the auctions that are observed to have succeeded. A closer examination of auction outcomes reveals that these low prices come at the expense of

Table 7: Regressions on Likelihood of Failure

	Binary for Failed Auction†							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
SBC	1.911***	1.912***	−0.155	−0.150	0.559***	0.559***	−0.058	−0.056
	(0.296)	(0.296)	(0.165)	(0.166)	(0.072)	(0.072)	(0.061)	(0.061)
MBC	2.051***	2.050***			0.557***	0.557***		
	(0.290)	(0.290)			(0.060)	(0.060)		
Bid Cap			−0.025***	−0.025***			−0.009***	−0.009***
			(0.006)	(0.006)			(0.002)	(0.002)
R2	−0.271*	−0.271*	−0.198	−0.192	−0.058*	−0.058*	−0.074	−0.072
	(0.155)	(0.155)	(0.167)	(0.168)	(0.034)	(0.034)	(0.063)	(0.063)
H2		0.032		0.146		0.007		0.055
		(0.152)		(0.165)		(0.032)		(0.061)
Constant	−2.163***	−2.180***	2.741***	2.745***	−0.506***	−0.510***	0.950***	0.949***
	(0.274)	(0.285)	(0.660)	(0.661)	(0.033)	(0.038)	(0.232)	(0.231)
Observations	442	442	263	263	442	442	263	263

Note: Columns (1)-(4) are panel probit regressions. Columns (5)-(8) are marginal effects from standard probit regressions. † Only rounds 2 and 3 are considered.
*p<0.1; **p<0.05; ***p<0.01

destroying markets. In the context of real-world auctions, this means that hospitals cannot acquire essential drugs. If these auctions can be re-run after relaxing the bid cap, then the situation could be similar to NBC auctions where prices rise over time. This then places the auctioneer in its original predicament with the added cost of multiple auctions.

In Table 8, conditional on auctions failing, we look at the frequency of subjects making the decision to leave even when there is a positive surplus from winning in the current auction. We find that for both bid cap variants, this is quite rare. Subjects in the auctions that eventually failed are largely deciding to leave when the surplus from staying in and winning the current auction is negative.

Table 8: Exit Decisions in Failed Auctions

Treatment	Round 2	Round 3	All
SBC	0.89%	1.54%	0.98%
	(1/112)	*(3/195)*	*(3/307)*
MBC	2.76%	2.68%	2.70%
	(4/145)	*(8/299)*	*(12/444)*
All	1.91%	2.18%	2.09%
	(5/262)	*(11/504)*	*(16/766)*

Note: In parenthesis, the numerator is the count of exit when a subject could have earned a positive surplus by staying in and the denominator is the count of exit in auctions that failed.

5.5 Efficiency

We look at the efficiency properties of the bid cap institutions by computing two measures that we present in Table 9 and Table 10. First, we look at efficiency in the sense that the lowest cost bidder wins in the auction. This notion of efficiency reflects how often an auction awards the object to the most cost efficient bidder. SBC auctions are on average more efficient at 84.25% than MBC auctions at 80. 00%, and NBC auctions are the least efficient at 77.53%. These figures suggest that in multi-round auctions, a dynamic bid cap, particularly the SBC, offers an improvement from the NBC.

Table 9: Efficiency of Auctions

Treatment	Session	Efficient Seller Wins		
		All	1st Half	2nd Half
NBC	3	79.55	75.56	83.72
	8	78.33	78.33	78.33
	10	72.29	75.86	70.00
	All	77.53	76.87	78.20
SBC	2	82.61	78.26	86.96
	4	84.93	80.00	88.46
	5	86.36	83.33	90.00
	All	84.25	80.52	88.41
MBC	1	70.91	73.08	68.97
	7	80.60	75.00	85.71
	9	87.93	89.29	86.67
	All	80.00	79.07	80.85

Table 10: Ratio of Winning Cost to Optimal Cost

Treatment	Session	Winner Cost / Lowest Cost			
		All	1st Half	2nd Half	$M^{\dagger}$
NBC	3	1.04	1.04	1.03	1.26
	8	1.04	1.05	1.02	1.30
	10	1.04	1.03	1.05	1.28
	All	1.04	1.05	1.03	1.28
SBC	2	1.06	1.11	1.02	1.23
	4	1.07	1.09	1.05	1.32
	5	1.05	1.03	1.07	1.29
	All	1.06	1.08	1.04	1.28
MBC	1	1.07	1.11	1.04	1.32
	7	1.03	1.05	1.01	1.26
	9	1.02	1.02	1.03	1.28
	All	1.04	1.06	1.03	1.29

In Table 10 we measure a notion of efficiency that looks at the deviation of the winning bidder's cost to the lowest possible cost among participating bidders in an auction. Figures in the table suggest that the lowest cost subjects tend to win at these auctions and the deviation of the winning bidder's cost is not very large. Our hypothetical benchmark M is calculated as the expected cost of bidders participating in the round divided by the lowest cost in that round for that group. This indicates that institutions are improvements over the case where the winners are simply selected at random.

6 Concluding Remarks

Auctions are common modalities for public procurement because they use the competitive nature of auctions to keep government costs low. If we introduce the issue of a weakened state of competition in these markets over time, the auctioneer faces the problem of rising auction prices. Regulating the reserve price can be an option to resolve this issue, but regulators need to be careful in designing a reserve price mechanism to try and minimise unintended consequences, some of which could be harder to correct than the original problem. In multi-round auctions, the issue of rising prices can conceivably be controlled by imposing a dynamic bid cap that prevents price increases even when there are only a few bidders participating. An example of this is studied by Bokhari et al. (2023) and their results indicate some degree of success in reducing prices. Although a mechanism that endogenizes the reserve price in subsequent periods may appear to be ill-suited from a theoretical perspective, competition to win in earlier auctions can overwhelm the ability to manipulate the policy resulting in price outcomes favourable to the auctioneer. When the collusive equilibrium is not sustained, the bidders end up competing with each other the rest of the time. Even with dampened competition, the bid caps put a strong downward pressure on prices, and the level of shading predicted by standard theory does not happen.

The unintentional consequence of this reserve price mechanism is that in subsequent auctions, bidder entry is adversely affected. Although bidder attrition is also expected even in there are no bid caps, it is on average 39-43% more likely that bidders leave the markets with a dynamic bid cap. We find that bidders exit markets so much that auctions are almost 60% on average more likely to fail with bid caps. Compared to NBC auctions, with an average failure rate of up to 2% in round 3, for SBC and MBC, about 1 in 3 auctions fail in round 2 and up to 2 in 3 auctions fail in round 3. When the policy for failed auctions is to allow a re-run of the auction with an inflated reserve price, the governments can find themselves faced with prices that are increasing rather than decreasing because of the bid cap. The resulting trade-off between price and entry is that by controlling prices, bidders are pushed out, markets are left without any bidders participating, resulting in a widespread failure of these auctions. Although the choice of reserve price is important, it is better to attract an additional bidder than to run the perfect auction. The auctioneer gains more by increasing competition than by holding the "perfect" auction Bulow & Klemperer (1996).

The results of our experiment show that an endogeneous dynamic reserve price can be effective in addressing high prices in our benchmark case. Bidders were unable to use this mechanism as a focal point to tacitly collude and keep prices high. Due to the strong downward pressure on prices, bidders leave and a large number of auctions fail. There are likely other reserve price mechanisms that prevent these failed auctions while keeping prices low. The way forward for research is to determine the solution to the auctioneer's problem, as well as the seller's problem of being priced out of markets.

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Appendix A. Experiment Instructions, Treatment 1

General information

Thank you for participating in today's experiment. I will read you a script to explain the nature of today's experiment and how to navigate the computer interface with which you will be working. I will be using this script to ensure that all sessions of this experiment receive the same information. This is an experiment in decision-making. In addition to a 200 Philippine Peso (PhP) fee for showing up on time, you will have the opportunity to earn more money through your decisions and the decisions of others, which we will explain soon. You will be paid in PhP at the end of the experiment after adding earnings from all rounds to your balance. All monetary amounts you will see in this experiment will be denominated in ECUs or Experimental Currency Units. They will translate into PhP at the rate of 1 ECU = 10 PhP therefore 15 ECU = 150 PhP. You will start with a balance of 50 ECUs. In each round of the experiment, you will have the opportunity to make additional earnings which will increase this balance but it will be possible to make losses as well. Your total earnings will increase with profits and decrease with losses. Should you lose so much money that your total earnings become negative, you will be declared bankrupt and asked to leave the experiment receiving only your show-up fee. At that time, one of the participants in the role of alternate will replace you. The alternate will begin participating with a balance of 50 ECUs and will have the same opportunities to gain or lose money in the experiment. If you have any questions during the experiment, raise your hand and wait for an experimenter to come to you. Do not talk, exclaim, or try to communicate with other participants during the experiment. Participants intentionally violating the rules may be asked to leave the experiment with only your show-up payment.

Outline of the Experiment

Before we go through the computer interface for the experiment, we will explain the structure of the decisions you will be making. You will be participating in a series of multiple round procurement auctions in which you will be attempting to sell a product to a buyer. There will be 10 sequences in today's experiment with each sequence giving you the opportunity to participate in up to 3 auction rounds.

In each sequence you will have some fundamental cost for providing the product to the buyer, let us call this F. In each auction round, your actual cost will be equal to this fundamental cost F plus a random draw D. So your actual cost C in a round will be C = F + D. F will be redrawn for each sequence from a uniform distribution in the range [100, 200], meaning that each value is equally likely. Then in each auction round, D will be redrawn from a uniform distribution on the range [-15, 15]. What you will be told in a round is your actual value of C=F+D. This means that from one round to another in the same sequence, your fundamental cost, F, will not change, but your realized cost, C,will as D will change from round to round. Your fundamental cost F, will change between sequences. We will take you through some examples later to make it clear how this works.

In the first round of each sequence, you will be told your realized cost for that round and everyone will participate. In each subsequent round, you will be told your realized cost for that round and will be allowed to choose whether or not to participate in the auction for that round. If you choose to participate, you will pay a cost of 2 ECUs to do so, whether you win

or not. If you choose not to participate in a round, you will not be able to participate for the remaining rounds in that sequence, but you will be able to rejoin in the subsequent sequence. If you choose not to participate, there will be an alternative uncompensated activity for you to engage in while you wait for the experiment to continue. If you join an auction, then you will compete to sell the product to a hypothetical buyer with the other participants in your group who also elect to participate. You will begin a sequence in a group of five bidders, you and four others, meaning the largest possible auction will consist of five total bidders.

In the actual auction, you will know the number of competitors who are participating. Each competitor will have received a realized cost using the same method with all draws being independent. This means that all bidders will have different costs with a possible range between [85, 215]. Each bidder will submit a bid indicating the price they would be willing to sell the item at. The seller who submitted the lowest price will win the auction and receive earnings equal to the difference between the price they submitted, P and their realized cost for that auction, C, less the 2 ECU participation cost. Therefore, the earnings from the auction will be $P - C - 2$, if you win. If you entered and lost the auction, your earnings are -2 ECU while if you do not enter the auction your earnings are 0.

Examples

We will now go through several examples to show you how all this works. Please go to your computer now and follow along. Let us examine potential auction rounds inside of a sequence. What you can see now are the realized costs for all five bidders in the first auction round of a sequence. In an actual auction, you would see only your own cost, but for this example, we will show you what is happening with all five competitors. These competitors have realized costs of 187, 125, 136, 178 and 152.

	Bidder 1	Bidder 2	Bidder 3	Bidder 4	Bidder 5
Realized Cost	187	125	136	178	152
Participate ?	Yes	Yes	Yes	Yes	Yes
Bid	225	150	145	204	190
Earnings	-2	-2	7	-2	-2

In the first auction round, everyone participates. The next line in the table shows you what bids each chose to submit. Note that these bid values were chosen randomly and are not meant to indicate suggested bids.

In this case, bidder 3 would win since they submitted the lowest price. You can then see the earnings for each bidder. The bidders who did not win all receive a -2 earnings for the auction as they paid the entry fee. Bidder 3 won the auction and therefore receives the earnings of 145-136 = 9 less the entry fee of 2 ECU, which produces a net pay-off of 7 ECU. After this auction round ends, the bidders see the results and the second round of the sequence begins.

All bidders would see their new realized costs. Each bidder must then choose whether to participate and pay the 2 ECU fee. Note that each bidder has a new realized cost. Given your cost in the first auction round, your new cost could potentially be anything in the range of 30 ECU above or 30 ECU below that previous cost realization. You should keep this in mind as it means that your cost can shift substantially from one auction to the next.

Let us assume that after seeing their new realized costs, bidders 4 and 5 decide that they no longer wish to participate, but the three others do. Bidders 1, 2, and 3 then submit

	Bidder 1	Bidder 2	Bidder 3	Bidder 4	Bidder 5
Realized Cost	168	120	140	195	160
Participate ?	Yes	Yes	Yes	No	No
Bid	145	138	143	–	–
Earnings	-2	16	-2	0	0

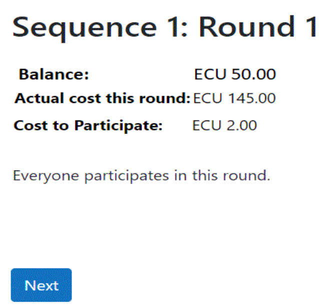
the bids, meaning that bidder 2 now wins with a bid of 138 ECU. Given that their cost realization for this auction was 120 ECU, they earn an auction profit of 18 ECU less the 2 ECU participation fee, leading to total earnings of 16 ECU. The other two participants make an earnings of -2 ECU each while those staying out earn 0 for the round.

After the second round has concluded, the bidders would see the results, and there will now be one additional round in this sequence, where bidders 1, 2, 3 could participate. See the next table for their new cost draws. Assume now that bidder 1 no longer wishes to participate but bidders 2 and 3 remain in. Bidder 2 bids 138 ECU while bidder 3 bids at 135 ECU and wins. This yields a net profit to bidder 3 of 3 ECU and to bidder 2 of -2 ECU.

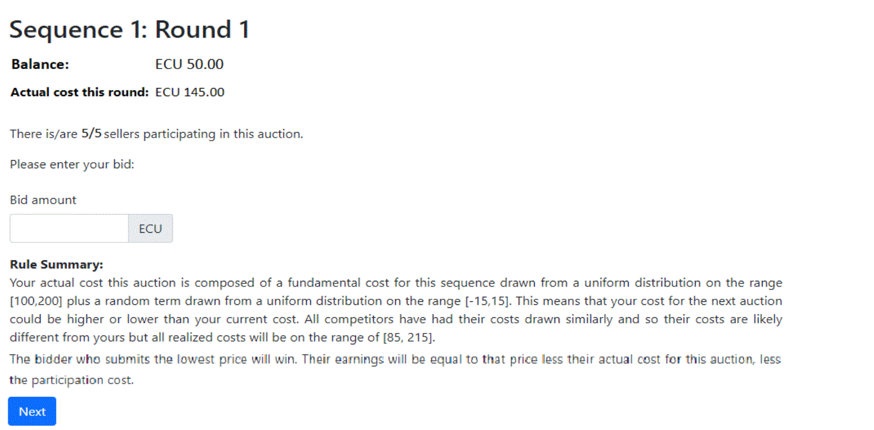
	Bidder 1	Bidder 2	Bidder 3	Bidder 4	Bidder 5
Realized Cost	175	137	130	–	–
Participate ?	No	Yes	Yes	–	–
Bid	–	138	135	–	–
Earnings	0	-2	3	0	0

We went through this extended example to make it clear to you how the cost realizations for each participant might change across auctions and the number of competitors might also shift. Of course, in an actual round, you will see only your own cost realization and not that of the other bidders. It is important to remember that your realized cost in a sequence will shift between rounds and can go up or down. When a new sequence begins, you will have a new fundamental cost draw that will be unrelated to the one from the prior sequence. We will now take you through the actual bidding interface to show you how a sequence of auctions would unfold from the perspective of an actual bidder.

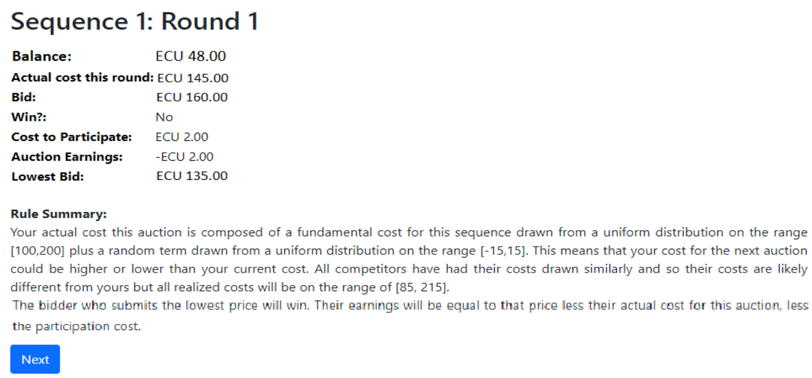
In this first screen, you are told that this is the first auction round in a sequence. You are told your realized cost for this auction round. For this example, it has been set to 145. You are also told that the cost to participate is 2 ECU. In round 1 everyone participates. You then click 'Next' to go to the next screen.



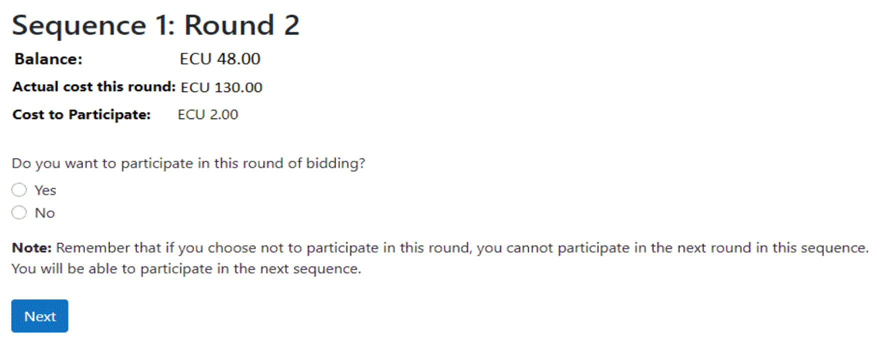
After all players in the group clicks 'Next' you will again see your cost which is 145. You are reminded how many sellers are participating in this auction. You are then asked to enter your bid. The bidder who submits the lowest bid will win the auction and will receive as earnings the difference between their bid and their realized cost less the participation fee. All other participants will receive -2 ECU earnings from the auction. A rule summary is given at the bottom of the screen. Suppose you enter 160 and then click 'Next'.



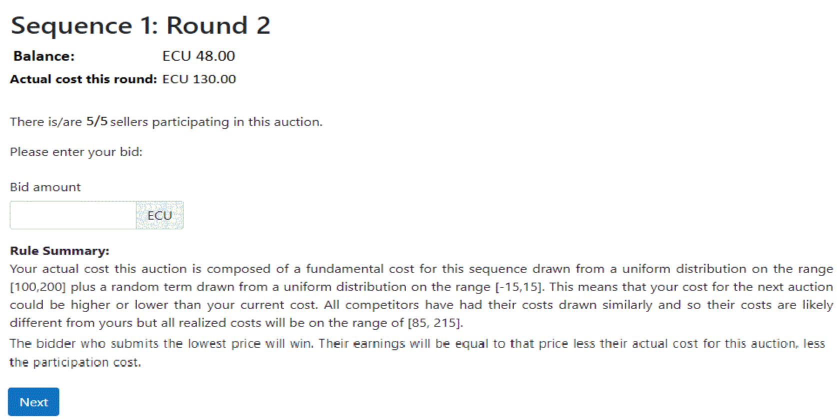
After all bidders enter their bids and click 'Next', you will see the results screen for an auction round. In this case, we presume that a bid of 160 was entered. You see that you did not win this auction and so your earnings for this round are -2 ECU due to paying the participation cost. The lowest bid was 135 submitted by some other bidder. A rule summary is again given at the bottom of the screen.



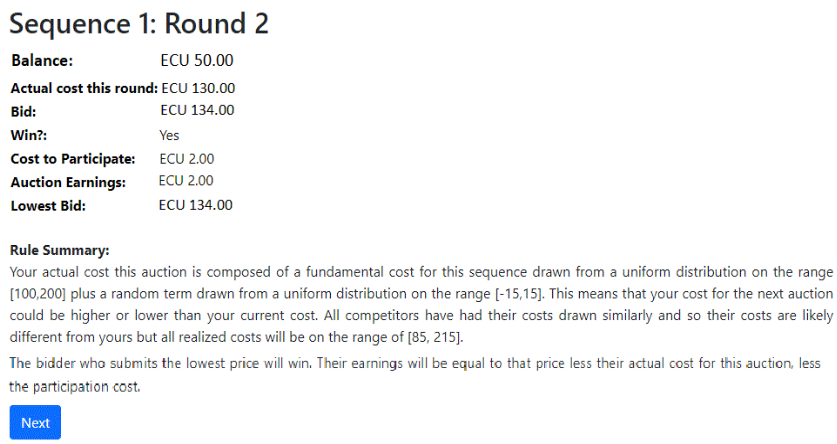
When you click 'Next' you will see what might be a second round for this sequence. You are told your new realized cost which is now 130 for this example. It was 145 in the previous round but as we explained, this value will shift up or down between rounds in a sequence. In this case, it has shifted down to 130. Seeing this information, you would be able to choose to participate and pay the 2 ECU fee or not. If you choose 'Yes', then you will be able to participate in this auction round and have the option to participate in the subsequent round in this sequence. If you choose 'No', then you will participate in no more auctions this sequence, but you will be able to participate in a future sequence. Suppose you choose 'Yes'.



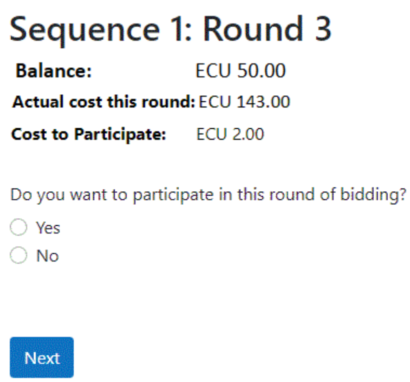
You then see a screen identical to the previous bidding screen except note that the auction round is now 2 as this is the second of this sequence. As noted on the last screen, your realized cost is now 130. Suppose you enter a bid of 134 and click 'Next'.



This takes you to the results screen for this auction. Here we represented this results screen with you winning with your bid of 134. Given that your realized cost is 130, you have auction earnings of 4 less the 2 ECU participation cost. Yielding net earnings of 2 ECUs. Clicking 'Next' will take you to the last auction round in this sequence.



You see a screen asking you if you wish to participate in the last auction for this sequence. You see that your realized cost is now 143. In the real auctions, you would make a choice and then compete in the auction or not as you choose. We skip this last round for this example.



There will be 10 sequences of these three round auctions. Remember that in each sequence, you will get a new fundamental cost draw on the range [100, 200]. This fundamental cost will then be shifted by an amount in the range [-15, 15] in each auction round for that sequence. For each auction you enter and earn a profit, your total earnings will rise. If you enter and make a loss your total earnings will fall. Remember that you will all begin with an initial balance of 50 ECUs. If you lose enough such that your total earnings reach 0, then you will be declared bankrupt and be asked to leave receiving only your show-up fee. The experiment will continue for the other participants with an alternate subject taking your place in future auctions.

If you have questions about how this experiment works, kindly raise your hand. If there are none, we will begin the first auction sequence.

Appendix B. Experiment Instructions, Treatment 2

General information

Thank you for participating in today's experiment. I will read you a script to explain the nature of today's experiment and how to navigate the computer interface with which you will be working. I will be using this script to ensure that all sessions of this experiment receive the same information. This is an experiment in decision-making. In addition to a 200 Philippine Peso (PhP) fee for showing up on time, you will have the opportunity to earn more money through your decisions and the decisions of others, which we will explain soon. You will be paid in PhP at the end of the experiment after adding earnings from all rounds to your balance. All monetary amounts you will see in this experiment will be denominated in ECUs or Experimental Currency Units. They will translate into PhP at the rate of 1 ECU = 10 PhP therefore 15 ECU = 150 PhP. You will start with a balance of 50 ECUs. In each round of the experiment, you will have the opportunity to make additional earnings which will increase this balance but it will be possible to make losses as well. Your total earnings will increase with profits and decrease with losses. Should you lose so much money that your total earnings become negative, you will be declared bankrupt and asked to leave the experiment receiving only your show-up fee. At that time, one of the participants in the role of alternate will replace you. The alternate will begin participating with a balance of 50 ECUs and will have the same opportunities to gain or lose money in the experiment. If you have any questions during the experiment, raise your hand and wait for an experimenter to come to you. Do not talk, exclaim, or try to communicate with other participants during the experiment. Participants intentionally violating the rules may be asked to leave the experiment with only your show-up payment.

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Before we go through the computer interface for the experiment, we will explain the structure of the decisions you will be making. You will be participating in a series of multiple round procurement auctions in which you will be attempting to sell a product to a buyer. There will be 10 sequences in today's experiment with each sequence giving you the opportunity to participate in up to 3 auction rounds.

In each sequence you will have some fundamental cost for providing the product to the buyer, let us call this F. In each auction round, your actual cost will be equal to this fundamental cost F plus a random draw D. So your actual cost C in a round will be C = F + D. F will be redrawn for each sequence from a uniform distribution in the range [100, 200], meaning that each value is equally likely. Then in each auction round, D will be redrawn from a uniform distribution on the range [-15, 15]. What you will be told in a round is your actual value of C=F+D. This means that from one round to another in the same sequence, your fundamental cost, F, will not change, but your realized cost, C,will as D will change from round to round. Your fundamental cost F, will change between sequences. We will take you through some examples later to make it clear how this works.

In the first round of each sequence, you will be told your realized cost for that round and everyone will participate. In each subsequent round, you will be told your realized cost for that round and will be allowed to choose whether or not to participate in the auction for that round. If you choose to participate, you will pay a cost of 2 ECUs to do so, whether you win

or not. If you choose not to participate in a round, you will not be able to participate for the remaining rounds in that sequence, but you will be able to rejoin in the subsequent sequence. If you choose not to participate, there will be an alternative uncompensated activity for you to engage in while you wait for the experiment to continue. If you join an auction, then you will compete to sell the product to a hypothetical buyer with the other participants in your group who also elect to participate. You will begin a sequence in a group of five bidders, you and four others, meaning the largest possible auction will consist of five total bidders.

In the actual auction, you will know the number of competitors who are participating. Each competitor will have received a realized cost using the same method with all draws being independent. This means that all bidders will have different costs with a possible range between [85, 215]. Each bidder will submit a bid indicating the price they would be willing to sell the item at. The seller who submitted the lowest price will win the auction and receive earnings equal to the difference between the price they submitted, P and their realized cost for that auction, C, less the 2 ECU participation cost. Therefore, the earnings from the auction will be $P - C - 2$, if you win. If you entered and lost the auction, your earnings are -2 ECU while if you do not enter the auction your earnings are 0.

Price Cap rule

Inside a sequence, there will be a bid cap on possible bids that can be submitted based on the winning bid from the prior round. This means that there will be no cap placed on bids in round 1 of a sequence but there will be in rounds 2 and 3. This bid cap will limit what bids competitors can submit, as bids must be no higher than the cap. This means that the bid cap will be the highest price that a bidder can receive in an auction. This cap will be reset between sequences, so after one sequence ends and a new one begins, in the first auction round of a new sequence, there will be no bid cap.

Examples

We will now go through several examples to show you how all this works. Please go to your computer now and follow along. Let us examine potential auction rounds inside a sequence. What you can see now are the realized costs for all five bidders in the first auction round of a sequence. In an actual auction, you would see only your own cost, but for this example, we will show you what is happening with all five competitors. These competitors have realized costs of 187, 125, 136, 178 and 152.

	Bidder 1	Bidder 2	Bidder 3	Bidder 4	Bidder 5
Realized Cost	187	125	136	178	152
Participate ?	Yes	Yes	Yes	Yes	Yes
Bid	225	150	145	204	190
Earnings	-2	-2	7	-2	-2

In the first auction round, everyone participates. The next line in the table shows you what bids each chose to submit. Note that these bid values were chosen randomly and are not meant to indicate suggested bids.

In this case, bidder 3 would win since they submitted the lowest price. You can then see the earnings for each bidder. The bidders who did not win all receive a -2 earnings for the auction as they paid the entry fee. Bidder 3 won the auction and therefore receives the earnings of 145-136 = 9 less the entry fee of 2 ECU, which produces a net pay-off of 7 ECU. After this auction round ends, the bidders see the results and the second round of the sequence begins.

All bidders would see their new realized costs. Each bidder must then choose whether to participate and pay the 2 ECU fee. Note that each bidder has a new realized cost. Given your cost in the first auction round, your new cost could potentially be anything in the range of 30 ECU above or 30 ECU below that previous cost realization. You should keep this in mind as it means that your cost can shift substantially from one auction to the next.

	Bidder 1	Bidder 2	Bidder 3	Bidder 4	Bidder 5
Realized Cost	168	120	140	195	160
Participate ?	Yes	Yes	Yes	No	No
Bid	145	138	143	–	–
Earnings	-2	16	-2	0	0

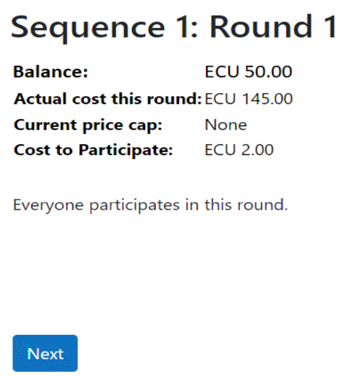
Since bidder 3 won the first auction with a bid of 145, that is the cap in bids allowed in this second auction. Let us assume that after seeing their new realized costs and the bid cap for this auction round, bidders 4 and 5 decide that they no longer wish to participate, but the three others do. Bidders 1, 2, and 3 then submit their bids, meaning that bidder 2 now wins with a bid of 138 ECU. Given that their cost realization for this auction was 120 ECU, they earn an auction profit of 18 ECU less the 2 ECU participation fee, leading to total earnings of 16 ECU. The other two participants make earnings of -2 ECU each while those staying out earn 0 for the round.

After the second round has concluded, the bidders would see the results, and there will now be one additional round in this sequence, where bidders 1, 2, 3 could participate, and the bid cap will now be 138 ECU. See the next table for their new cost draws. Assume now that bidder 1 no longer wishes to participate but bidders 2 and 3 remain in. Bidder 2 bids at the cap of 138 ECU while bidder 3 bids at 135 ECU and wins. This yields a net profit to bidder 3 of 3 ECU and to bidder 2 of -2 ECU.

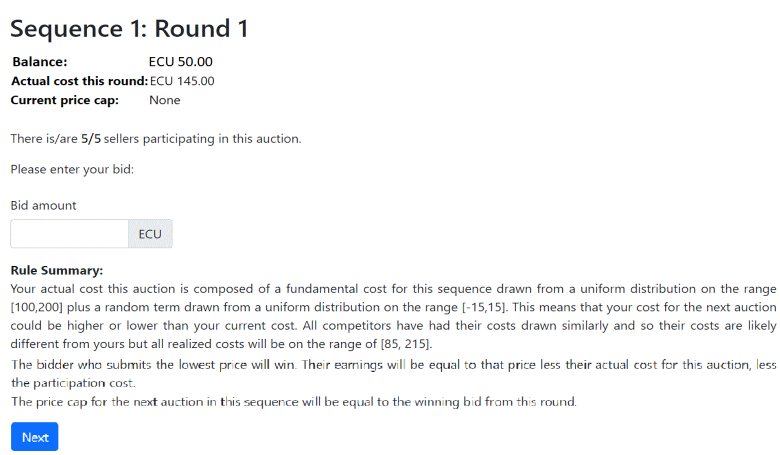
	Bidder 1	Bidder 2	Bidder 3	Bidder 4	Bidder 5
Realized Cost	175	137	130	–	–
Participate ?	No	Yes	Yes	–	–
Bid	–	138	135	–	–
Earnings	0	-2	3	0	0

We went through this extended example to make it clear to you how the cost realizations for each participant might change across auctions and how the bid cap and number of competitors might also shift. Of course, in an actual round, you will see only your own cost realization and not that of the other bidders. It is important to remember that your realized cost in a sequence will shift between rounds and can go up or down. When a new sequence begins, you will have a new fundamental cost draw that will be unrelated to the one from the prior sequence. We will now take you through the actual bidding interface to show you how a sequence of auctions would unfold from the perspective of an actual bidder.

In this first screen, you are told that this is the first auction round in a sequence. You are told your realized cost for this auction round. For this example, it has been set to 145. You are also told about the current price cap. Since this is the first auction in this sequence, there is none. You are told the cost to participate, 2 ECU, and that in round 1 everyone participates. You then click 'Next' to go to the next screen.

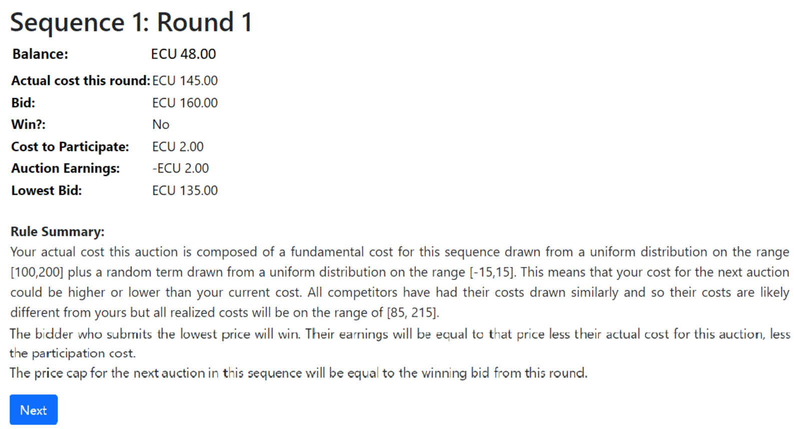


After all players in the group clicks 'Next' you will again see your cost which is 145. You are reminded of the current price cap and told how many sellers are participating in this auction. You are then asked to enter your bid. The bidder who submits the lowest bid will win the auction and will receive as earnings the difference between their bid and their realized cost less the participation fee. All other participants will receive -2 ECU earnings from the auction. A rule summary is given at the bottom of the screen. Suppose you enter 160 and then click 'Next'.

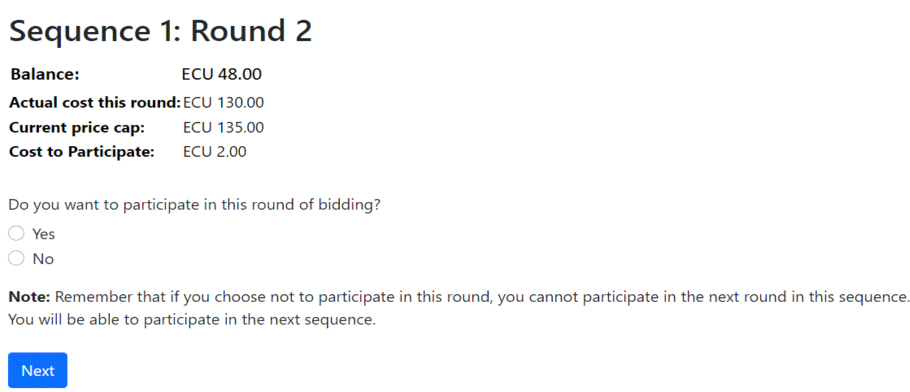


After all bidders enter their bids and click 'Next', you will see the results screen for an auction round. In this case, we presume that a bid of 160 was entered. You see that you did not win this auction and so your earnings for this round are -2 ECU due to paying the participation cost. The lowest bid was 135 submitted by some other bidder. They won this round and the new bid cap will now be 135 in the next auction. A rule summary is again given at the bottom of the screen.

When you click 'Next' you will see what might be a second round for this sequence. You are told your new realized cost which is now 130 for this example. It was 145 in the previous round but as we explained, this value will shift up or down between rounds in a sequence. In this case, it has shifted down to 130. Notice that the bid cap is 135 meaning the highest price you can bid in this round is 135. Seeing this information, you would be able to choose



to participate and pay the 2 ECU fee or not. If you choose 'Yes', then you will be able to participate in this auction round and have the option to participate in the subsequent round in this sequence. If you choose 'No', then you will participate in no more auctions this sequence, but you will be able to participate in a future sequence. Suppose you choose 'Yes'.



You then see a screen identical to the previous bidding screen except note that the auction round is now 2 as this is the second of this sequence. As noted on the last screen, your realized cost is now 130 and the bid cap is 135. Suppose you enter a bid of 134 and click 'Next'.

Sequence 1: Round 2

Balance:	ECU 48.00
Actual cost this round:	ECU 130.00
Current price cap:	ECU 135.00

There is/are **5/5** sellers participating in this auction.

Please enter your bid:

Bid amount

ECU

Rule Summary:
Your actual cost this auction is composed of a fundamental cost for this sequence drawn from a uniform distribution on the range [100,200] plus a random term drawn from a uniform distribution on the range [-15,15]. This means that your cost for the next auction could be higher or lower than your current cost. All competitors have had their costs drawn similarly and so their costs are likely different from yours but all realized costs will be on the range of [85, 215].

The bidder who submits the lowest price will win. Their earnings will be equal to that price less their actual cost for this auction, less the participation cost.

The price cap for the next auction in this sequence will be equal to the winning bid from this round.

Next

This takes you to the results screen for this auction. Here we represented this results screen with you winning with your bid of 134. Given that your realized cost is 130, you have auction earnings of 4 less the 2 ECU participation cost. Yielding net earnings of 2 ECUs. As your bid was the lowest, your bid sets the cap for the third and final auction of this sequence. Clicking 'Next' will take you to that one.

Sequence 1: Round 2

Balance:	ECU 50.00
Actual cost this round:	ECU 130.00
Bid:	ECU 134.00
Win?:	Yes
Cost to Participate:	ECU 2.00
Auction Earnings:	ECU 2.00
Lowest Bid:	ECU 134.00

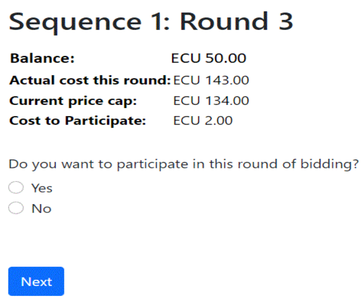
Rule Summary:
Your actual cost this auction is composed of a fundamental cost for this sequence drawn from a uniform distribution on the range [100,200] plus a random term drawn from a uniform distribution on the range [-15,15]. This means that your cost for the next auction could be higher or lower than your current cost. All competitors have had their costs drawn similarly and so their costs are likely different from yours but all realized costs will be on the range of [85, 215].

The bidder who submits the lowest price will win. Their earnings will be equal to that price less their actual cost for this auction, less the participation cost.

The price cap for the next auction in this sequence will be equal to the winning bid from this round.

Next

You see a screen asking you if you wish to participate in the last auction for this sequence. You see that your realized cost is now 143. The bid cap as set by your winning bid in the last round is 134 meaning that you would have to bid at most 134 if you entered the auction. In the real auctions, you would make a choice and then compete in the auction or not as you choose. We skip this last round for this example.



There will be 10 sequences of these three round auctions. Remember that in each sequence, you will get a new fundamental cost draw on the range [100, 200]. This fundamental cost will then be shifted by an amount in the range [-15, 15] in each auction round for that sequence. For each auction you enter and earn a profit, your total earnings will rise. If you enter and make a loss your total earnings will fall. Remember that you will all begin with an initial balance of 50 ECUs. If you lose enough such that your total earnings reach 0, then you will be declared bankrupt and be asked to leave receiving only your show-up fee. The experiment will continue for the other participants with an alternate subject taking your place in future auctions.

If you have questions about how this experiment works, kindly raise your hand. If there are none, we will begin the first auction sequence.

Appendix C. Experiment Instructions, Treatment 3

General information

Thank you for participating in today's experiment. I will read you a script to explain the nature of today's experiment and how to navigate the computer interface with which you will be working. I will be using this script to ensure that all sessions of this experiment receive the same information. This is an experiment in decision-making. In addition to a 200 Philippine Peso (PhP) fee for showing up on time, you will have the opportunity to earn more money through your decisions and the decisions of others, which we will explain soon. You will be paid in PhP at the end of the experiment after adding earnings from all rounds to your balance. All monetary amounts you will see in this experiment will be denominated in ECUs or Experimental Currency Units. They will translate into PhP at the rate of 1 ECU = 10 PhP therefore 15 ECU = 150 PhP. You will start with a balance of 50 ECUs. In each round of the experiment, you will have the opportunity to make additional earnings which will increase this balance but it will be possible to make losses as well. Your total earnings will increase with profits and decrease with losses. Should you lose so much money that your total earnings become negative, you will be declared bankrupt and asked to leave the experiment receiving only your show-up fee. At that time, one of the participants in the role of alternate will replace you. The alternate will begin participating with a balance of 50 ECUs and will have the same opportunities to gain or lose money in the experiment. If you have any questions during the experiment, raise your hand and wait for an experimenter to come to you. Do not talk, exclaim, or try to communicate with other participants during the experiment. Participants intentionally violating the rules may be asked to leave the experiment with only your show-up payment.

Outline of the Experiment

Before we go through the computer interface for the experiment, we will explain the structure of the decisions you will be making. You will be participating in a series of multiple round procurement auctions in which you will be attempting to sell a product to a buyer. There will be 10 sequences in today's experiment with each sequence giving you the opportunity to participate in up to 3 auction rounds.

In each sequence you will have some fundamental cost for providing the product to the buyer, let us call this F. In each auction round, your actual cost will be equal to this fundamental cost F plus a random draw D. So your actual cost C in a round will be C = F + D. F will be redrawn for each sequence from a uniform distribution in the range [100, 200], meaning that each value is equally likely. Then in each auction round, D will be redrawn from a uniform distribution on the range [-15, 15]. What you will be told in a round is your actual value of C=F+D. This means that from one round to another in the same sequence, your fundamental cost, F, will not change, but your realized cost, C,will as D will change from round to round. Your fundamental cost F, will change between sequences. We will take you through some examples later to make it clear how this works.

In the first round of each sequence, you will be told your realized cost for that round and everyone will participate. In each subsequent round, you will be told your realized cost for that round and will be allowed to choose whether or not to participate in the auction for that round. If you choose to participate, you will pay a cost of 2 ECUs to do so, whether you win

or not. If you choose not to participate in a round, you will not be able to participate for the remaining rounds in that sequence, but you will be able to rejoin in the subsequent sequence. If you choose not to participate, there will be an alternative uncompensated activity for you to engage in while you wait for the experiment to continue. If you join an auction, then you will compete to sell the product to a hypothetical buyer with the other participants in your group who also elect to participate. You will begin a sequence in a group of five bidders, you and four others, meaning the largest possible auction will consist of five total bidders.

In the actual auction, you will know the number of competitors who are participating. Each competitor will have received a realized cost using the same method with all draws being independent. This means that all bidders will have different costs with a possible range between [85, 215]. Each bidder will submit a bid indicating the price they would be willing to sell the item at. The seller who submitted the lowest price will win the auction and receive earnings equal to the difference between the price they submitted, P and their realized cost for that auction, C, less the 2 ECU participation cost. Therefore, the earnings from the auction will be $P - C - 2$, if you win. If you entered and lost the auction, your earnings are -2 ECU while if you do not enter the auction your earnings are 0.

Treatment Specific Instructions

Price Cap rule

Each participant will be randomly assigned to a group. Each group will be randomly matched with another. Inside a sequence, there will be a bid cap on possible bids that can be submitted based on the based on winning bid in matched group in the prior round. Note that this means your bids do not effect the bid cap in your group. This means that there will be no cap placed on bids in round 1 of a sequence but there will be in rounds 2 and 3. This bid cap will limit what bids competitors can submit, as bids must be no higher than the cap. This means that the bid cap will be the highest price that a bidder can receive in an auction. This cap will be reset between sequences, so after one sequence ends and a new one begins, in the first auction round of a new sequence, there will be no bid cap.

Examples

We will now go through several examples to show you how all this works. Please go to your computer now and follow along. Let us examine potential auction rounds inside a sequence. What you can see now are the realized costs for all five bidders in the first auction round of a sequence. In an actual auction, you would see only your own cost, but for this example, we will show you what is happening with all five competitors. These competitors have realized costs of 187, 125, 136, 178 and 152.

	Bidder 1	Bidder 2	Bidder 3	Bidder 4	Bidder 5
Realized Cost	187	125	136	178	152
Participate ?	Yes	Yes	Yes	Yes	Yes
Bid	225	150	145	204	190
Earnings	-2	-2	7	-2	-2

In the first auction round, everyone participates. The next line in the table shows you what bids each chose to submit. Note that these bid values were chosen randomly and are not meant to indicate suggested bids.

In this case, bidder 3 would win since they submitted the lowest price. You can then see the earnings for each bidder. The bidders who did not win all receive a -2 earnings for the auction as they paid the entry fee. Bidder 3 won the auction and therefore receives the earnings of 145-136 = 9 less the entry fee of 2 ECU, which produces a net pay-off of 7 ECU. After this auction round ends, the bidders see the results and the second round of the sequence begins.

All bidders would see their new realized costs. Each bidder must then choose whether to participate and pay the 2 ECU fee. Note that each bidder has a new realized cost. Given your cost in the first auction round, your new cost could potentially be anything in the range of 30 ECU above or 30 ECU below that previous cost realization. You should keep this in mind as it means that your cost can shift substantially from one auction to the next.

	Bidder 1	Bidder 2	Bidder 3	Bidder 4	Bidder 5
Realized Cost	168	120	140	195	160
Participate ?	Yes	Yes	Yes	No	No
Bid	145	138	143	–	–
Earnings	-2	16	-2	0	0

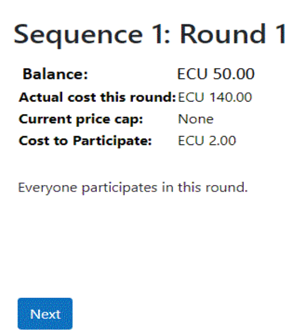
The winning bid in the matched group from round 1 is 165. That is the cap in bids allowed in this second auction. Let us assume that after seeing their new realized costs and the bid cap for this auction round, bidders 4 and 5 decide that they no longer wish to participate, but the three others do. Bidders 1, 2, and 3 then submit their bids, meaning that bidder 2 now wins with a bid of 138 ECU. Given that their cost realization for this auction was 120 ECU, they earn an auction profit of 18 ECU less the 2 ECU participation fee, leading to total earnings of 16 ECU. The other two participants make earnings of -2 ECU each while those staying out earn 0 for the round.

After the second round has concluded, the bidders would see the results, and there will now be one additional round in this sequence, where bidders 1, 2, 3 could participate. The winning bid in the matched group in round 2 is 153 so that will be the bid cap in this last round. See the next table for their new cost draws. Assume now that bidder 1 no longer wishes to participate but bidders 2 and 3 remain in. Bidder 2 bids 138 ECU while bidder 3 bids at 135 ECU and wins. This yields a net profit to bidder 3 of 3 ECU and to bidder 2 of -2 ECU.

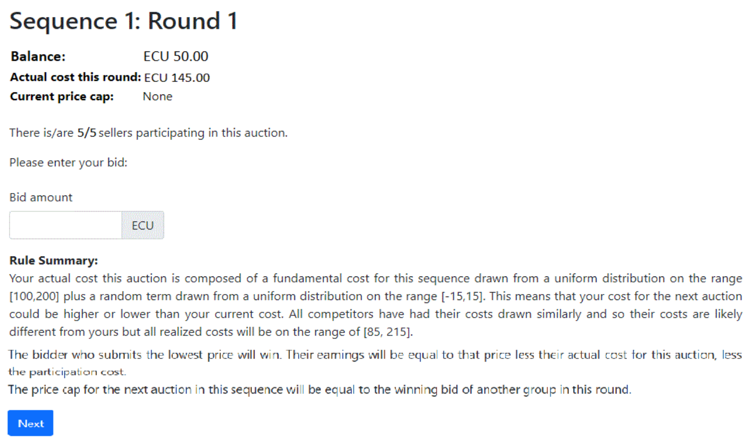
	Bidder 1	Bidder 2	Bidder 3	Bidder 4	Bidder 5
Realized Cost	175	137	130	–	–
Participate ?	No	Yes	Yes	–	–
Bid	–	138	135	–	–
Earnings	0	-2	3	0	0

We went through this extended example to make it clear to you how the cost realizations for each participant might change across auctions and how the bid cap and number of competitors might also shift. Of course, in an actual round, you will see only your own cost realization and not that of the other bidders. It is important to remember that your realized cost in a sequence will shift between rounds and can go up or down. When a new sequence begins, you will have a new fundamental cost draw that will be unrelated to the one from the prior sequence. We will now take you through the actual bidding interface to show you how a sequence of auctions would unfold from the perspective of an actual bidder.

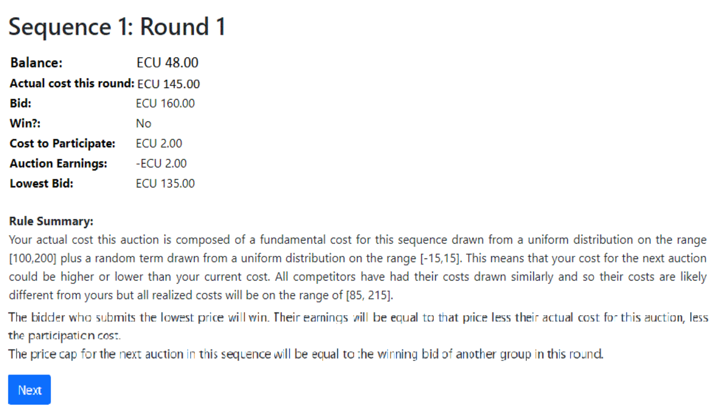
In this first screen, you are told that this is the first auction round in a sequence. You are told your realized cost for this auction round. For this example, it has been set to 145. You are also told about the current price cap. Since this is the first auction in this sequence, there is none. You are told the cost to participate, 2 ECU, and that in round 1 everyone participates. You then click 'Next' to go to the next screen.



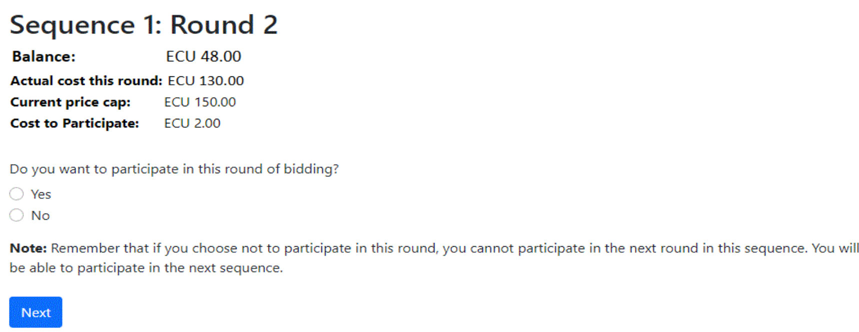
After all players in the group clicks 'Next' you will again see your cost which is 140. You are reminded of the current price cap and told how many sellers are participating in this auction. You are then asked to enter your bid. The bidder who submits the lowest bid will win the auction and will receive as earnings the difference between their bid and their realized cost less the participation fee. All other participants will receive -2 ECU earnings from the auction. A rule summary is given at the bottom of the screen. Suppose you enter 160 and then click 'Next'.



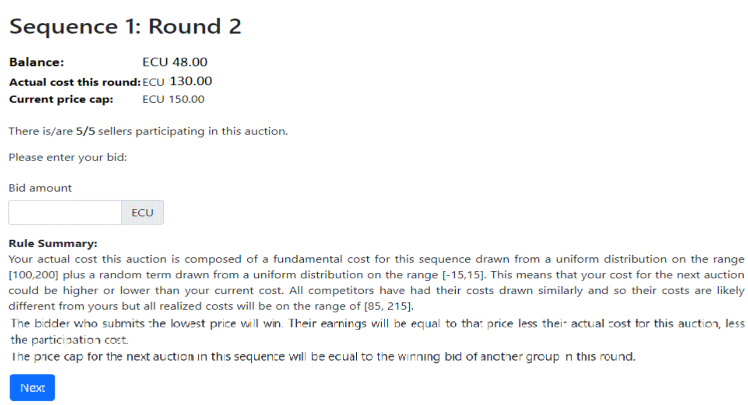
After all bidders enter their bids and click 'Next', you will see the results screen for an auction round. In this case, we presume that a bid of 160 was entered. You see that you did not win this auction and so your earnings for this round are -2 ECU due to paying the participation cost. The lowest bid was 135 submitted by some other bidder in your group. Suppose the lowest bid in another group was 150. The new bid cap in your group in the next round will be 150. A rule summary is again given at the bottom of the screen.



When you click 'Next' you will see what might be a second round for this sequence. You are told your new realized cost which is now 126 for this example. It was 145 and as we explained in each round your cost will shift up or down. In this case, it has shifted down to 130. Notice that the bid cap is 150 meaning the highest price you can bid in this round is 150. Seeing this information, you would be able to choose to participate and pay the 2 ECU fee or not. If you choose 'Yes', then you will be able to participate in this auction round and have the option to participate in the subsequent round in this sequence. If you choose 'No', then you will participate in no more auctions this sequence, but you will be able to participate in a future sequence. Suppose you choose 'Yes'.



You then see a screen identical to the previous bidding screen except note that the auction round is now 2 as this is the second of this sequence. As noted on the last screen, your realized cost is now 130 and the bid cap is 150. Suppose you enter a bid of 134 and click 'Next'.



This takes you to the results screen for this auction. Here we represented this results screen with you winning with your bid of 134. Given that your realized cost is 130, you have auction earnings of 4 less the 2 ECU participation cost. Yielding net earnings of 2 ECUs. Suppose that the lowest bid in the other group in this round is 120. The bid cap for your group in the third and final auction of this sequence will be 120. Clicking 'Next' will take you to that one.

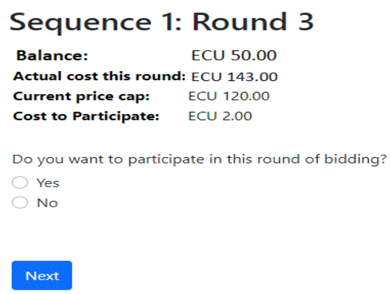
Sequence 1: Round 2

Balance:	ECU 50.00
Actual cost this round:	ECU 130.00
Bid:	ECU 134.00
Win?:	Yes
Cost to Participate:	ECU 2.00
Auction Earnings:	ECU 2.00
Lowest Bid:	ECU 134.00

Rule Summary:
Your actual cost this auction is composed of a fundamental cost for this sequence drawn from a uniform distribution on the range [100,200] plus a random term drawn from a uniform distribution on the range [-15,15]. This means that your cost for the next auction could be higher or lower than your current cost. All competitors have had their costs drawn similarly and so their costs are likely different from yours but all realized costs will be on the range of [85, 215].
The bidder who submits the lowest price will win. Their earnings will be equal to that price less their actual cost for this auction, less the participation cost.
The price cap for the next auction in this sequence will be equal to the winning bid of another group in this round.

Next

You see a screen asking you if you wish to participate in the last auction for this sequence. You see that your realized cost is now 143. The bid cap as set by the winning bid in another group last round is 120 meaning that you would have to bid at most 120 if you entered the auction. In the real auctions, you would make a choice and then compete in the auction or not as you choose. We skip this last round for this example.



There will be 10 sequences of these three round auctions. Remember that in each sequence, you will get a new fundamental cost draw on the range [100, 200]. This fundamental cost will then be shifted by an amount in the range [-15, 15] in each auction round for that sequence. For each auction you enter and earn a profit, your total earnings will rise. If you enter and make a loss your total earnings will fall. Remember that you will all begin with an initial balance of 50 ECUs. If you lose enough such that your total earnings reach 0, then you will be declared bankrupt and be asked to leave receiving only your show-up fee. The experiment will continue for the other participants with an alternate subject taking your place in future auctions.

If you have questions about how this experiment works, kindly raise your hand. If there are none, we will begin the first auction sequence.

Appendix D. Standard Bid Function

From Equation 3, multiply both sides by $(1-F(s))^{n-2}$,

$$\begin{aligned}\big(1-F(s)\big)^{n-1}b'(s)-b(s)(n-1)\big(1-F(s)\big)^{n-2}f(s)&=-s(n-1)f(s)\big(1-F(s)\big)^{n-2}\\ \frac{d}{ds}\Big[\big(1-F(s)\big)^{n-1}b(s)\Big]&=-s(n-1)f(s)\big(1-F(s)\big)^{n-2}\end{aligned}$$

Let $s=\tilde{s}$, rewrite and integrate both sides from s to $\overline{s}$,

$$\int_s^{\overline{s}}\frac{d}{d\tilde{s}}\Big[\Big(1-F(\tilde{s})\Big)^{n-1}b(\tilde{s})\Big]=\int_s^{\overline{s}}-\tilde{s}(n-1)f(\tilde{s})\big(1-F(\tilde{s})\big)^{n-2}$$

Since F is continuous, and integrating the right hand side by parts, this reduces to,

$$b(\tilde{s})-\big(1-F(s)\big)^{n-1}b(s)=\tilde{s}-s\big(1-F(s)\big)^{n-1}-\int_s^{\overline{s}}\big(1-F(s)\big)^{n-1}d\tilde{s}$$

Using the boundary condition $b(\overline{s})=\overline{s}$ and re-arranging terms, we get Equation 4 in section 4.

Appendix E. Standard Bid Function Examples

From Equation 4, symmetric equilibrium with $c = s$, F is uniform, continuous on $[100, 200]$

$$b(s) = s + \frac{\int_s^{\overline{s}} \big(1 - F(\tilde{s})\big)^{n-1}\, d\tilde{s}}{\big(1 - F(s)\big)^{n-1}}$$

Example 1.1.1 Suppose $c = 110$ and $n = 5$

$$\begin{aligned} b(s) &= 110 + \frac{\int_{110}^{200} \big(1 - F(\tilde{s})\big)^{4}\, d\tilde{s}}{\big(1 - F(110)\big)^{4}} \\ &= 110 + \frac{11.8090}{0.6561} \\ &= 128 \end{aligned}$$

Example 1.1.2 Given same $c = 110$ but with less competitors, $n = 4$

$$\begin{aligned} b(s) &= 110 + \frac{\int_{110}^{200} \big(1 - F(\tilde{s})\big)^{3}\, d\tilde{s}}{\big(1 - F(110)\big)^{3}} \\ &= 110 + \frac{16.4025}{0.729} \\ &= 132.5 \end{aligned}$$

Appendix F. Bid Function with Trapezoidal Distribution

From Figure 1, define line segments between a, c, d, b as $l_1 = (c - a)$, $l_2 = (d - c)$, and $l_3 = (d - b)$, where $w \equiv l_1 + l_2 + l_3 = (b - a)$. The expression for the area of the trapezoid is $h(c - a)/2 + h(d - c) + h(b - d)/2$. Equating this expression to one, to represent a pdf, we can solve for the height, $h = 2/(l_1 + 2l_2 + l_3)$. The pdf $f(x)$ is then given by,

$$f(r) = \begin{cases} \dfrac{(r-a)}{(c-a)}h & \text{if} \quad a \leq r \leq c, \\ h & \text{if} \quad c \leq r \leq d, \\ \dfrac{(b-r)}{(b-d)}h & \text{if} \quad d \leq r \leq b. \end{cases} \tag{6}$$

The cdf is obtained by integrating the pdf within the limits $-\infty$ to r. We can therefore express the cdf of the trapezoid distribution as,

$$F(r) = \begin{cases} \dfrac{h(r-a)^2}{2(c-a)} & \text{if} \quad a \leq r \leq c, \\ \dfrac{h}{2}(c-a) + h(r-c) & \text{if} \quad c \leq r \leq d, \\ 1 - \dfrac{h(b-r)^2}{2(b-d)} & \text{if} \quad d \leq r \leq b. \end{cases} \tag{7}$$

Substituting the cdf in the standard equilibrium bid function we arrive at Equation 5.

Appendix G. Trapezoid Distribution Bid Function Examples

From Equation 5, symmetric equilibrium with $c + \delta = s = r$, F is trapezoid, continuous on $[85, 100, 200, 215]$

For cost realizations, $a \le r \le c$

$$b(r) = r + \frac{\displaystyle\int_r^c \left(1 - \frac{(\tilde{r} - a)^2}{l_1(w + l_2)}\right)^{n-1} d\tilde{r}}{\left(1 - \dfrac{(r - a)^2}{l_1(w + l_2)}\right)^{n-1}}$$

Example 2.1.1 Suppose $c = 90, \delta = 5$ and $n = 5$

$$\begin{aligned} b(r) &= 95 + \frac{\displaystyle\int_{95}^{100} \left(1 - \frac{(\tilde{r} - 90)^2}{10(120 + 10)}\right)^{4} d\tilde{r}}{\left(1 - \dfrac{(95 - 90)^2}{10(120 + 10)}\right)^{4}} \\ &= 95 + 4.5055 \\ &= 99.5055 \end{aligned}$$

Example 2.1.2 Suppose $c = 90, \delta = 5$ and $n = 4$

$$\begin{aligned} b(r) &= 95 + \frac{\displaystyle\int_{95}^{100} \left(1 - \frac{(\tilde{r} - 90)^2}{10(120 + 10)}\right)^{3} d\tilde{r}}{\left(1 - \dfrac{(95 - 90)^2}{10(120 + 10)}\right)^{3}} \\ &= 95 + 4.6222 \\ &= 99.6222 \end{aligned}$$

For cost realizations, $c \le r \le d$

$$b(r) = r + \frac{\displaystyle\int_r^d \left(1 - \frac{l_1 + 2(\tilde{r} - c)}{w + l_2}\right)^{n-1} d\tilde{r}}{\left(1 - \dfrac{l_1 + 2(r - c)}{w + l_2}\right)^{n-1}}$$

Example 2.2.1 Suppose $c = 150, \delta = 5$ and $n = 5$

$$
\begin{aligned}
b(r) &= 155 + \frac{\displaystyle\int_{155}^{200} \left(1 - \frac{10 + 2(\tilde{r} - 100)}{120 + 100}\right)^4 d\tilde{r}}{\left(1 - \dfrac{10 + 2(155 - 100)}{120 + 100}\right)^4} \\
&= 155 + 9.9999 \\
&= 164.9999
\end{aligned}
$$

Example 2.2.2 Suppose $c = 90, \delta = 5$ and $n = 4$

$$
\begin{aligned}
b(r) &= 155 + \frac{\displaystyle\int_{155}^{200} \left(1 - \frac{10 + 2(\tilde{r} - 100)}{120 + 100}\right)^3 d\tilde{r}}{\left(1 - \dfrac{10 + 2(155 - 100)}{120 + 100}\right)^3} \\
&= 155 + 12.4988 \\
&= 167.499
\end{aligned}
$$

For cost realizations, $d \leq r \leq b$

$$b(r) = r + \frac{\int_r^b \left(\frac{(b-\tilde{r})^2}{l_3 \big(w + l_2 \big)} \right)^{n-1} d\tilde{r}}{\left(\frac{(b-r)^2}{l_3 \big(w + l_2 \big)} \right)^{n-1}}$$

Example 2.2.1 Suppose $c = 200, \delta = 5$ and $n = 5$

$$\begin{aligned} b(r) &= 205 + \frac{\int_{205}^{210} \left(\frac{(210-\tilde{r})^2}{10 \big(120 + 100 \big)} \right)^4 d\tilde{r}}{\left(\frac{(210-205)^2}{10 \big(120 + 100 \big)} \right)^4} \\ &= 205 + 1 \\ &= 206 \end{aligned}$$

Example 2.2.2 Suppose $c = 90, \delta = 5$ and $n = 4$

$$\begin{aligned} b(r) &= 205 + \frac{\int_{205}^{210} \left(\frac{(210-\tilde{r})^2}{10 \big(120 + 100 \big)} \right)^3 d\tilde{r}}{\left(\frac{(210-205)^2}{10 \big(120 + 100 \big)} \right)^3} \\ &= 205 + 1.25 \\ &= 206.25 \end{aligned}$$

Appendix H. Dynamics by First and Second Half

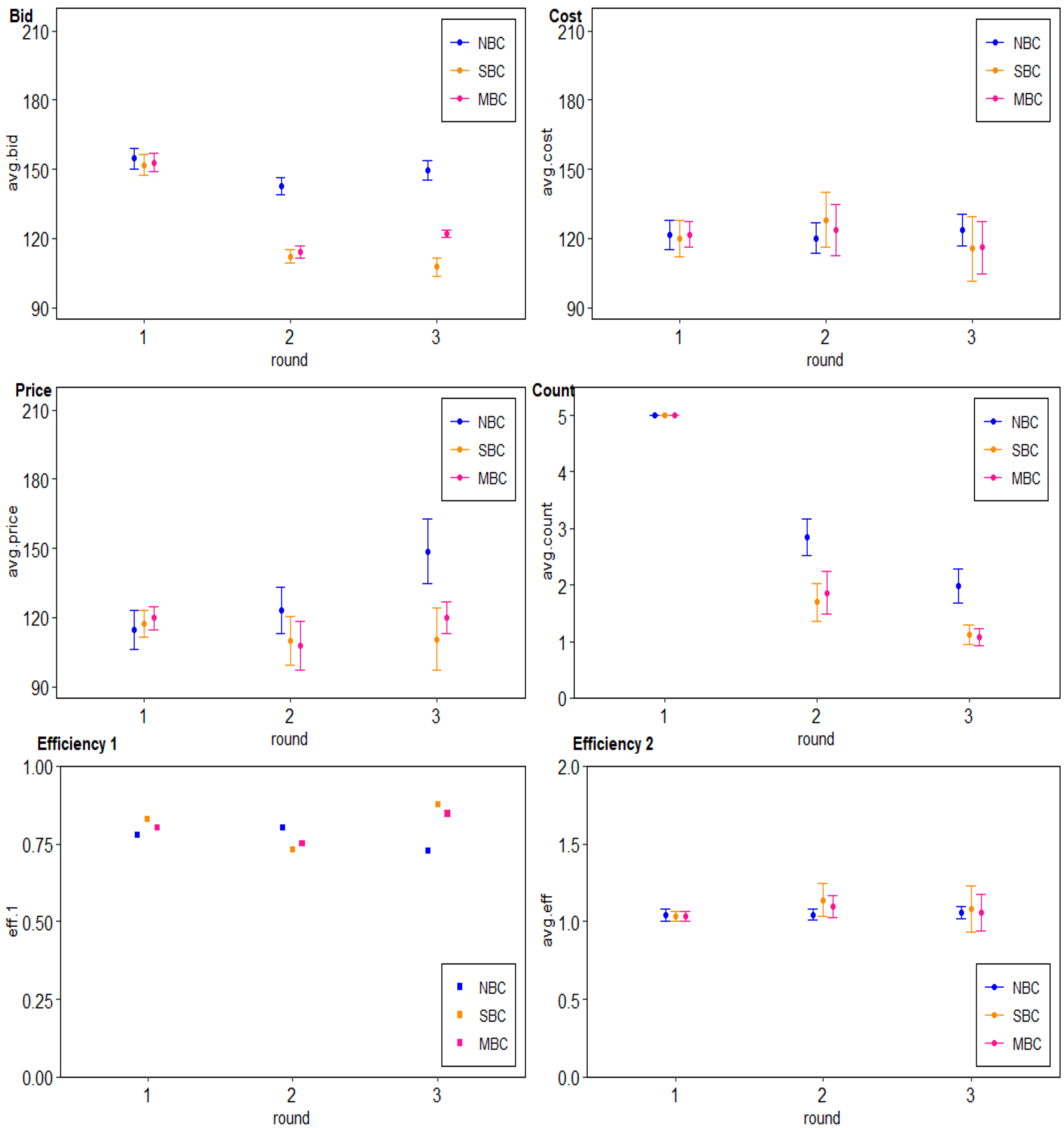


Figure 5: Experiment Dynamics (First Half) by Treatment and Round

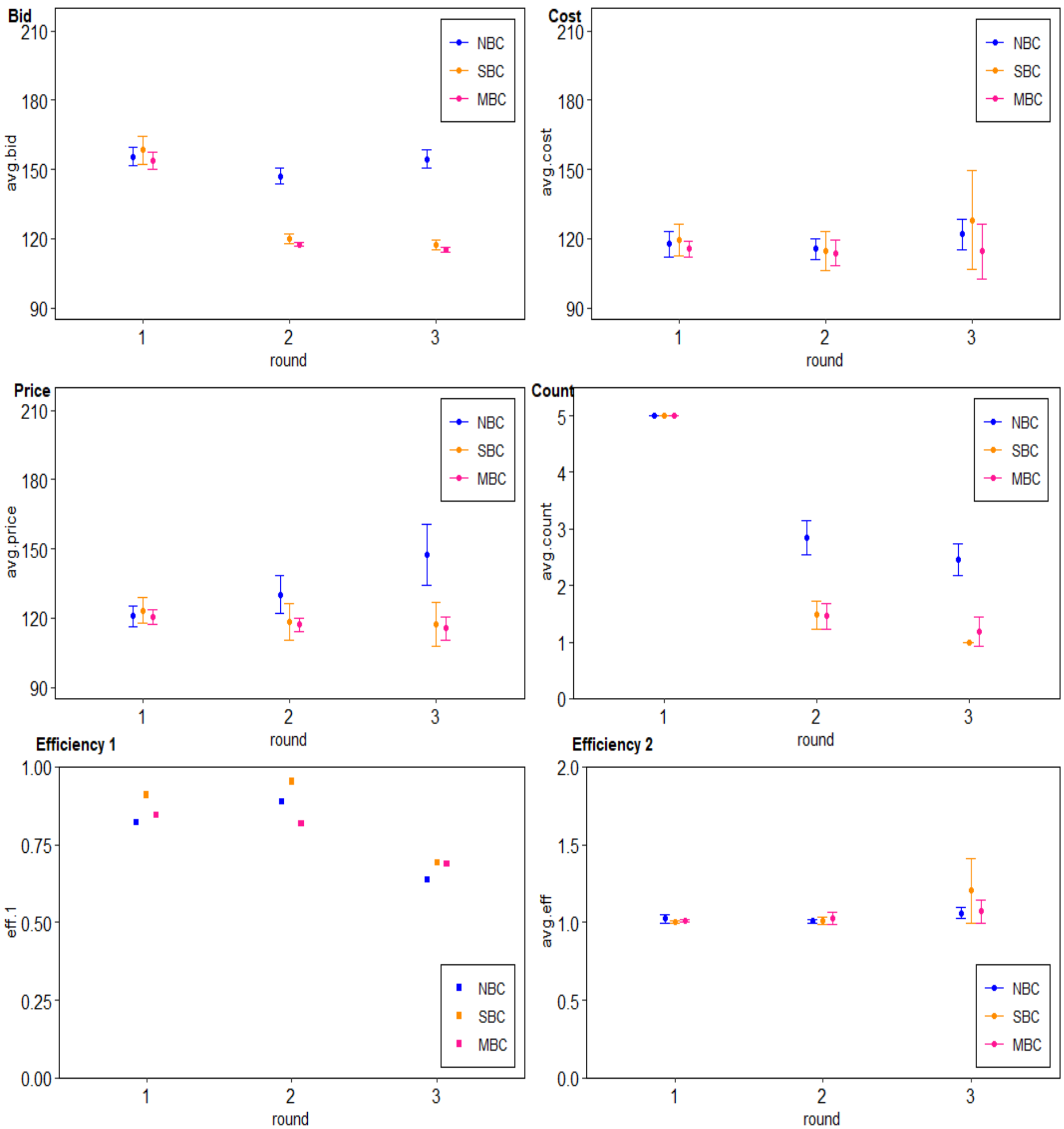


Figure 6: Experiment Dynamics (Second Half) by Treatment and Round