Fixed Revenue Auctions: Theory and Behavior

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In this paper we study auctions in which the revenue is fixed but the quantity is determined by the auction mechanism. Specifically, we investigate the theory and behavior of English quantity clock, Dutch quantity clock, last-quantity sealed bid, and penultimate-quantity sealed bid auctions. For theoretically equivalent fixed quantity and fixed revenue auctions, we find that fixed revenue auctions are robust to all of the previously observed empirical regularities in fixed quantity auctions.

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I. Introduction

There are numerous varieties of auction institutions used in practice and studied in the economics literature. Almost exclusively, the focus of that work has been on auctions determining the selling price for a pre-specified lot.\(^1\) However, in some situations a seller may be more concerned about raising a fixed amount of revenue. For example, a business may sell off just enough inventory to gain the needed liquidity to undertake a particular project. A person may pawn just enough items to secure money with which to pay the monthly bills. Alternatively, in a procurement setting a buyer may desire to acquire as much as possible for some set amount of money. For example, a researcher whose grant is expiring may buy as many supplies as possible with the remaining budget or a firm may have a fixed advertising budget with which to buy the most effective campaign. Though not typically thought of in this way, auctions can be used to solve these types of problems as well.\(^2\) We define a fixed revenue auction to be a bidding mechanism in which a pre-specified total payment is exchanged for a variable quantity of a good.\(^3\) Porter and Wessen (1997) developed a fixed revenue auction to cover the $326,000 cost of moving antennae for the Cassini mission to Saturn. The auction allowed competing research teams to place bids in terms of the mass they desired on the craft and the price per unit for the mass.

The four standard mechanisms for selling a fixed quantity as in a single unit or lot are the English, Dutch, first-price sealed bid, and second-price sealed bid auctions. The widely known theoretical results are that the English and second-price auctions are equivalent as are the Dutch and first-price auctions. One of the most insightful theoretical results of private value auctions is that under certain assumptions the expected revenue is constant across the four mechanisms (see Myerson 1981, McAfee and McMillan 1987 and Milgrom 1987). But, behavioral examinations of private value auctions have consistently found that the relationships among the formats are not

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1 There is also a class of market auctions that serve to determine both price and quantity. The double auction and the Walrasian auction are two examples of this type of auction. McCabe, Rassenti and Smith (1990) provide a description of other institutions such as the Double Dutch auction.

2 Transactions costs can explain why a buyer or seller might want to hold a single auction for a set of items even though it might not achieve as much revenue as auctioning items off separately. For example, auctions for surplus equipment are often structured such that a bidder has to purchase an entire pallet of used items rather than a single item. Similarly, transaction costs could explain why someone would prefer to hold a fixed revenue auction thus guaranteeing a single transaction. Further as the examples demonstrate, it is not necessarily the case that the party holding the auction is attempting to maximize accounting profit with respect to the auction itself, even if it is attempting to maximize its economic profit globally.

3 Dastidar (2006) also considers such auctions.
so straightforward. English clock auctions generate truthful revelation as predicted; however second-price auctions, which should also generate truthful revelation, do not in a laboratory setting (Harstad 2000 and Kagel, Harstad and Levine 1987). Further, revenue equivalence does not hold between first-price and second-price auctions (Copinger, Titus, and Smith 1980). In part, this is due to the fact that many bidders in first-price auctions act as if they are risk averse. Furthermore, Dutch auctions and first-price sealed bid auctions are not behaviorally isomorphic; observed prices are significantly lower in the Dutch clock auctions than in first-price auctions (Cox et al. 1982).

The next section presents a theoretical treatment of each mechanism in a fixed revenue context. Separate sections discuss the design and results of laboratory experiments investigating behavior in these auctions. A final section contains concluding remarks. As a prelude to our results, we find that under a generalization of the typical assumption regarding values the theoretical and behavioral properties of the four standard auctions translate to a fixed quantity dimension in a consistent and intuitive way.

II. Theoretical Model

We begin by considering the standard fixed quantity auction format and then identify where and how fixed revenue auctions differ from the familiar model. In the single (fixed) unit independent private value auction there are \( n \) bidders who value the lot up for auction. In the English auction, the price starts low and increases until only one bidder remains willing to purchase. The sole remaining bidder buys the item at the final price. The Dutch auction begins with a high price that falls until a bidder agrees to purchase at that price. In contrast, first- and second-price sealed bid auctions are both static in that potential buyers submit sealed bids. For the first-price sealed bid auction, the party submitting the highest bid wins the auction and pays a price equal to his winning bid, whereas in the second-price sealed bid auction the party submitting the highest bid wins but pays a price equal to the second highest bid.

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5 There are two different formats of English auctions, an outcry version in which bids come from the floor and jump bidding is possible and a clock version in which the bid price is controlled by the auctioneer. Our paper focus on the later and the interested reader is referred to Kamecke (1998) for a discussion of the theoretical differences between the two.
Assuming a uniform distribution of values over the interval \([\bar{v}, \tilde{v}]\) and risk neutral bidders, the following results for the Nash equilibrium bid functions are well known:

\[
b(v) = v + \frac{n-1}{n} (v - v') \quad \text{for first-price sealed bid and Dutch clock auctions} \tag{1}
\]

and

\[
b(v) = v \quad \text{for second-price sealed bid and English clock auctions.} \tag{2}
\]

In the standard auction the quantity \(q\) is set by the seller. To consider fixed revenue auctions, we must generalize the notion of value to be a function of quantity, \(v(q)\). Figure 1 shows various possible value functions. Standard fixed quantity auctions are vertical slice of this figure, as in the dashed line. In a fixed revenue auction, \(q\) is the amount of the bid.

Fixed quantity English auctions start with a “low” price that multiple buyers are willing to accept and gradually increase prices thereby becoming less favorable to the bidders. For a fixed revenue auction a favorable starting position for the buyer would be a large quantity. Making the trade less desirable to the buyer involves reducing the quantity. Thus, in both dimensions English auctions approach value curves from below. Dutch auctions for a standard fixed quantity start with at a “high” price which gradually decreases, becoming more favorable to the bidders. The parallel for a fixed revenue auction would be to start with an undesirable low quantity which increases to become more favorable to buyers. Thus, in both dimensions Dutch auctions approach value functions from above.

The fixed revenue counterparts to the first- and second-price sealed bid auctions would be the last- and penultimate-quantity sealed bid auctions, respectively. In both the first- and second-price sealed bid auctions the winner is the agent submitting the bid most favorable to the seller. In the quantity dimension, the most favorable bids are the ones for the smallest quantity. For the last-quantity auction the winner receives a quantity equal to her bid while the winner of the penultimate-quantity auction would receive a quantity equal to the second lowest bid.

Before presenting a theoretical model of a fixed revenue auction, we offer the following two comments. First, we note that a fixed revenue auction is not simply the re-framing of a traditional auction.\(^6\) The fixed revenue auction is a different allocative mechanism in which the

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\(^6\) A framing effect is the observation that people make different decisions for the same available actions over same outcomes when they (presumably) conceive the decision-making problem as being different, such as posing a
bidders face a different decision-problem. In a traditional Dutch auction, the price linearly (vertically) approaches an individual’s demand curve from above (at a fixed quantity). In a Dutch version of the fixed revenue auction, the price per unit also approaches an individual’s demand from above but along a curve as the quantity increases. Second, in what follows we purposively select a set of assumptions that allows us to compare the theory and behavior of fixed revenue auctions to previous work on standard auctions. We consider this to be a prudent first step in understanding the basic properties of fixed revenue auctions. We are not presuming that these assumptions are appropriate for all or even most applications.

To determine equilibrium behavior in fixed revenue auctions, one cannot simply translate the common assumption of uniform values, \( v(q) \sim U[\bar{v}, \bar{v}] \) to \( q \sim U[q, \bar{q}] \) because bidders consider the expected profit from each potential bid. For fixed quantity auctions a bid reduction of $1 results in an additional profit to the bidder of $1, but in a fixed revenue auction bidders need to know the value function to determine how an increase of 1 unit impacts the bidder’s profits. Thus, as a means for comparing fixed revenue and fixed quantity auction we make an additional assumption about the value functions to determine optimal bidding behavior in a fixed revenue auction. A simple functional form which generalizes the uniform distribution assumption is that \( v = \alpha + \beta q \) where \( \alpha \sim U[\bar{\alpha}, \bar{\alpha}] \). While there are a plethora of assumptions one could make on the form of the value functions, this form simultaneously allows the values associated with a specified quantity to be distributed uniformly and the quantities associated with a specified payment to also be distributed uniformly. Under this assumption, bids are a function of \( \alpha \). With these value functions the optimal bids for a standard fixed quantity auction (1) and (2) can be rewritten as

\[
b(\alpha + \beta q) = \alpha + \beta q + \frac{n-1}{n}(\alpha - \alpha) \quad (1')
\]

and

\[
b(\alpha + \beta q) = \alpha + \beta q. \quad (2')
\]

decision-problem as a gain or a loss. The visual electronic interface of an online English auction is a different decision-frame than an oral English auction with a live auctioneer and bidding paddles.

\(^7\) While multiunit variations of standard auctions, such as the Double Dutch (McCabe, Rassenti and Smith 1990), endogenously determine quantity, in those auctions each bidder is deciding if she should trade a fixed unit for the bid price.

\(^8\) See Dastidar (2006) for a more generalized discussion of auctions in which the bids are in terms of quantities.
To determine the optimal bid function in the last-quantity auction with a payment \( p \) for a bidder with \( v = \alpha + \beta q \), define the breakeven quantity\(^9\) as \( \hat{q} = \frac{p-\alpha}{\beta} \). \( \hat{q} \) is thus bounded by

\[
q = \frac{p-\alpha}{\beta} \quad \text{and} \quad \bar{q} = \frac{p-\alpha}{\beta}.
\]

Given the one-to-one mapping between \( \alpha \) and \( \hat{q} \), let \( b(\hat{q}) \) be the bid function and \( \hat{q}(b) \) be the inverse bid function. The probability that the other \( n-1 \) bidders ask for a quantity greater than \( b \) is

\[
\left( \frac{\bar{q}-\hat{q}}{q-q} \right)^{n-1}
\]

and the expected profit from a bid of \( b \) is \((\alpha+\beta b-p)\left( \frac{\bar{q}-\hat{q}}{q-q} \right)^{n-1} \). The first order condition for profit maximization by a bidder yields equation (3):

\[
(n-1)(\alpha + \beta b - p)\left( \frac{\bar{q}-\hat{q}}{q-q} \right)^{n-2} + \beta \left( \frac{\bar{q}-\hat{q}}{q-q} \right)^{n-1} = 0. \tag{3}
\]

Through standard manipulation this yields

\[
b'\beta(\bar{q}-\hat{q})^{n-1} - (n-1)\beta b(\bar{q}-\hat{q})^{n-2} = (n-1)(\alpha - p)(\bar{q}-\hat{q})^{n-2}
\]

which can be simplified to the following bid function

\[
b = \frac{\bar{q} - \frac{n-1}{n}(\bar{q}-\hat{q})}{n}.
\tag{4}
\]

The similarities between (4) and (1) are clear.

Taking into account that \( \bar{q} = \frac{p-\alpha}{\beta} \), (4) can be rewritten as

\[
b = \frac{p-\alpha}{\beta} - \frac{n-1}{n} \left( \frac{\alpha-\alpha}{\beta} \right).
\]

In a first-price fixed quantity auction, a bidder wants to bid below value to create a profit in the event the bidder wins the auction. The parallel in a fixed revenue auction is to ask for a larger quantity. For a fixed quantity auction, bidders under-reveal by \( v - b \), which can be rewritten as \( \frac{\alpha-a}{n} \) given that \( v = \alpha + \beta q \) with \( q \) fixed. For a bidder with this value function in a fixed revenue auction the optimal amount of “over-revelation” is

\[\text{At } q = \hat{q}, v = p. \quad \text{In the standard fixed quantity auction, a bidder’s value is the breakeven price.}\]
\[ b - \hat{q} = \left[ \frac{p - \alpha}{\beta} - \frac{n - 1}{n} \left( \frac{\alpha - \alpha}{\beta} \right) \right] - \frac{p - \alpha}{\beta} = \frac{\alpha - \alpha}{n\beta} \]  

(5)

Equation (9) also yields the optimal stopping rule for the increasing quantity in a Dutch clock fixed revenue auction. The intuition of the isomorphism is the same in the quantity dimension as in the price dimension.

As in the price dimension, truthful revelation is the dominant strategy in the English quantity clock and penultimate-quantity auctions, \( b = \hat{q} = \frac{p - \alpha}{\beta} \). Intuitively, in the penultimate-quantity auction asking for a larger quantity lowers the likelihood of winning but does not change the amount of the payoff conditional on winning. If asking for a smaller quantity causes a bidder to win that would not have won with truthful revelation, then the bidder would be worse off than having not won the auction. If the bidder would have won anyway, then lowering the bid would not change the payoff. This is also true for the English clock auction.

The familiar expected price in a standard first-price fixed quantity auction is

\[ v + \left( \frac{n - 1}{n + 1} \right)(v - v) \]

or replacing \( v \) with \( \alpha + \beta q \) is \( (\alpha + \beta q) + \left( \frac{n - 1}{n + 1} \right)(\bar{\alpha} - \alpha) \). The translated calculation for the last-quantity fixed revenue auction gives an expected quantity of

\[ \bar{q} \left[ \frac{p - \alpha}{\beta} \right] - \frac{n - 1}{n} \left( \frac{\alpha - \alpha}{\beta} \right) \left( \frac{1}{\bar{\alpha} - \alpha} \right) n d\alpha = \left( \frac{p - \alpha}{\beta} \right) - \left( \frac{n - 1}{n + 1} \right) \left( \frac{\alpha - \alpha}{\beta} \right) \]  

(6)

Taking into account that \( \bar{q} = \frac{p - \alpha}{\beta} \), the right hand side of (12) can be rewritten as

\[ \bar{q} - \left( \frac{n - 1}{n + 1} \right)(\bar{q} - q) \]. The translation of revenue equivalence holds as well. That is, given the form of the value function and the uniform distribution of the \( \alpha \)'s, each of the four auction mechanisms generates the same expected quantity conditional on payment. Further, the expected payment in an auction where the quantity is fixed at the level expected in a fixed revenue auction with payment \( p^* \) is \( p^* \). That is \( E(p|q = E(q|p^*)) = p^* \). Similarly, \( E(q|p = E(p|q^*)) = q^* \).
III. Experimental Design and Procedures

Given that observed behavior in laboratory experiments with fixed quantity auctions sometimes differs from the theoretical predictions, we conducted a series of laboratory auctions to explore how people behave in fixed revenue auctions. We designed this experiment to determine what, if any, behavioral differences arise when the dimension of the auction is changed. Because the ordering of observed prices in standard auctions is well established, our experiment seeks to determine if this ordering is maintained when it is the revenue that is pre-specified.

As detailed by Cox et al. (1982) maintaining similar message spaces and expected payoffs across treatments is imperative in an auction experiment. Here this entails not only comparability across institutions, but also across the dimension of the auction, fixed revenue versus fixed quantity dimension. It is straightforward to calculate that the expected profit of a bidder in the fixed quantity auction is \( \frac{\bar{\alpha} - \alpha}{n(n+1)} \) while the expected profit to a bidder in the fixed revenue auction is \( \frac{\beta n(n+1)}{\bar{\alpha} - \alpha} \). To maintain similarity, the slope parameter \( \beta \) is set equal to 1. With this slope for the value functions, \( \bar{\alpha} - \alpha = q - q \) so that the vertical distance between value curves is the same as the horizontal distance.

The other parameters in the experiments were as follows. Each auction had \( n = 5 \) bidders. The random components of the values functions, the \( \alpha \)'s, were distributed \( U[-10, 5] \), which was public information among the bidders. With these parameters the risk neutral expected profit of the winner was $2.50 per auction. This choice of distribution also gives symmetry in the expected price and quantity. In the standard price auctions the quantity is fixed at 13, thus yielding an expected price \( (\alpha + \beta q) + \left( \frac{n-1}{n+1} \right) (\bar{\alpha} - \alpha) = 13 \). Similarly, the price is set at 13 in the fixed revenue auction, which according to equation (6) gives an expected quantity of 13.\(^{10} \) With these parameters, maximum willingness to pay is distributed \( U[3,18] \) and minimum acceptable quantity is distributed \( U[8,23] \).

\(^{10} \) The parameters were selected so that the expected price and quantity were not focal points.
The English and Dutch auctions require additional parameterization in the form of clock increments and starting and stopping amounts. All clock increments were set at 0.1, which was also the discreteness allowed for bids in the sealed auctions, thereby maintaining an identical message space in each treatment. In a fixed quantity auction, the natural starting price for the English auction and natural stopping price for the Dutch auction is zero. However, there does not appear to be a natural starting price for the Dutch auction or stopping price for the English clock. This ambiguity problem does not occur in the quantity dimension. When it is the revenue that is fixed, zero serves as a natural starting quantity for the Dutch auction and a natural stopping quantity for the English auction. The seller’s total inventory is a natural starting quantity for the English clock and stopping quantity for the Dutch clock. To maintain parity between the dimensions of the auction it is important that the starting point be as far from the expected termination point in both cases. That is the Dutch price should start as far above the expected price as the Dutch quantity starts below the expected quantity. Since the natural starting place of 0 for the Dutch quantity auction is 13 units below the expected quantity of 13, the appropriate starting price for the Dutch auction is 13 units above the expected price of 13 which is 26. The natural stopping point for the Dutch price is 0, 13 units below the expected price, and thus the appropriate stopping point for the Dutch quantity is 13 units above the expected quantity; hence the lot size is set at 26. For the English auction, the natural starting price is 0, which is 13 units below the expected price of 13. Therefore, in the English quantity auction the appropriate starting point is 13 units above the expected quantity of 13 which is 26. Similarly, the natural ending point for the English quantity auction is 0 and thus for the English price auction it is 26. See Figure 2 for a graphic representation of this parallelism in the experimental design. These parameters also have the desirable feature that all four clock auctions should on average take the same amount of time to determine a winner as the expected price and quantity are 13. For consistency, sealed bids also had to be between 0 and 26.

11 Note that with \( n = 5 \) bidders the slope of the bid function is \( .8 = \frac{n - 1}{n} \) which can be realized with an increment of 0.1.
12 Stopping price refers to a price at which the auction is ended. In a Dutch price auction the seller’s reserve price might also serve as a stopping price.
13 Not having a stopping quantity in a Dutch quantity auction exposes the seller (experimenter) to the possibility of an infinite loss. The same would be true in a Dutch price auction if the price were allowed to become negative and fall indefinitely.
We conducted experimental sessions for each of the four mechanisms in a fixed revenue setting. For calibration, we also conducted auctions with a fixed quantity. But given the large literature on sealed bid, single unit (lot) auctions, we investigated only the English and Dutch price clock auctions. The total number of laboratory sessions was 24: four replications of each treatment in the \(2 \times 2\) design of \{Fixed Revenue, Fixed Quantity\} \(\times\) \{Dutch, English\} and four replications of each of the two sealed bid institutions.

In each treatment subjects were shown their random \(\alpha\). In the fixed quantity auctions, a subject’s screen indicated that her value equaled her random component plus 13. A subject’s screen also displayed the current clock price and the profit that the subject would receive if she bought at the current clock price. Subjects in the fixed revenue auctions were shown that the price was always 13. In the fixed revenue clock auctions, the subjects were shown the component of their value that came from the clock and what their total value would be if they were to buy at the current clock quantity. In the sealed bid auctions subjects were told they could type a quantity component bid. After a subject entered such a bid, his value and profit conditional on winning were updated on the screen. As explained to the subjects, these numbers were a lower bound on profit and value in the penultimate-quantity auction. Unlike in the clock auctions, subject confirmed their bids in the sealed auctions. Subjects received feedback after each period in terms of the market price or quantity. This information along with their private information and bids was displayed in a table on the subject’s screen.

In each session subjects first read written instructions and then participated in eight unpaid practice periods.\(^{14}\) After the practice rounds the experiments continued for an additional 15 periods.\(^{15}\) Hence the data set includes 120 subjects and 360 auctions. Subjects were randomly recruited from classes at the University of Arkansas and only participated in one auction mechanism with either the fixed revenue or fixed quantity dimension. The laboratory sessions lasted less than one hour and subjects were paid $5.00 for showing up on time plus their salient earnings which averaged approximately $5.01 across all treatments.\(^{16}\)

\(^{14}\) A copy of the instructions is available from the authors upon request.

\(^{15}\) The sealed bid auctions ran much more quickly than the clock auctions, so as many as 15 additional auctions were also conducted. The results do not differ in any meaningful way when including these auctions, so for the sake of parsimony, the analysis focuses only on the first 15 auctions in each session.

\(^{16}\) Recall that the expected profit to the winner was $2.50 each round. The observed average payoff is the result of aggressive, risk averse bidding behavior which is detailed in the next section. Risk averse behavior implies saliency in the rewards, i.e., subjects are earnestly engaged in the bidding task.
IV. Results

In what follows we report our results as a series of 6 findings. We begin by comparing the transactions in the fixed revenue and fixed quantity versions of the Dutch and English clock auctions. By design, we can translate the observed transaction quantity in a fixed revenue auction into a corresponding transaction price in a fixed quantity auction as a means to compare the behavior across the two dimensions. We define the variable \( \text{Price}_{ij} \) as the transaction price paid by subject \( s \) in session \( i \) and auction \( j \) as the observed transaction price if the session is a fixed quantity auction. If the session is a fixed revenue auction, then \( \text{Price}_{ij} = 26 - \text{Quantity}_{ij} \), where \( \text{Quantity}_{ij} \) is the observed transaction quantity for a fixed revenue of 13.\(^{17}\)

We employ a linear mixed effects model as the basis for the quantitative support for this and our other findings. The treatment effects (Dutch vs. English auctions, and FixedRevenue vs. FixedQuantity) and an interaction effect from the 2 \( \times \) 2 design are modeled as (zero-one) fixed effects, while the 16 independent sessions and winning bidders within the sessions are modeled as random effects, \( e_i \) and \( \zeta_j \), respectively. As a control for the across-auction variation of the realizations of the alphas, we include deviations of the relevant \( k \) highest realization from their theoretical expected values, denoted by \( a_k \).\(^{18}\) We do this because the predicted prices in each round are conditioned on the observed \( \alpha \) realizations; so the location of the second highest \( \alpha \) should not matter in a first price or last quantity auction but should identify the transaction amount in a second price or penultimate quantity auction. For \( \alpha \sim U[-10,5] \), the expected values of the highest and second highest realization of five draws are 2.5 and 0, respectively. Specifically, the model that we estimate via maximum likelihood is:

\(^{17}\) As can be seen from Figure 1, a bid for a large quantity in a fixed revenue auction is equivalent to a low price bid in a fixed quantity auction. For example, a price of 17 which is 4 units above the expected price of 13 is the same deviation as a quantity of 9 which is 4 units below the expected quantity of 13. Formally, we take translated price = expected price + (expected quantity – observed quantity), which is 26 – observed quantity. In the example, 26 - 9 = 17. This is related to the “over-revelation” of equation (5).

\(^{18}\) A priori we expect that the price in the Dutch auction is dependent upon the highest realization of \( \alpha \) while it is dependent upon the second highest realization in the English auction.
\[
\text{Price}_{ijs} = \mu + e_i + \zeta_{is} + \beta_1 \text{Dutch}_i + \beta_2 \text{Fixed Revenue}_i + \beta_3 \text{Dutch}_i \times \text{Fixed Revenue}_i \\
+ \phi_1 a_{1,ij} + \phi_2 a_{2,ij} + \gamma_1 a_{1,ij} \times \text{Dutch}_i + \gamma_2 a_{2,ij} \times \text{Dutch}_i \\
+ \delta_1 a_{1,ij} \times \text{Fixed Revenue}_i + \delta_2 a_{2,ij} \times \text{Fixed Revenue}_i \\
+ \eta a_{1,ij} \times \text{Dutch}_i \times \text{Fixed Revenue}_i + \eta a_{2,ij} \times \text{Dutch}_i \times \text{Fixed Revenue}_i + \epsilon_{ij},
\]
where \( e_i \sim N(0,\sigma^2_i), \zeta_{is} \sim N(0,\sigma^2_s), \) and \( \epsilon_{ij} \sim N(0,\sigma^2_j). \)

**Finding 1:** Consistent with previous work, Dutch clock auction prices are greater than English clock auction prices with fixed revenue and fixed quantity mechanisms. There is no difference in transaction prices between fixed revenue and fixed quantity settings.

Table 1 reports the estimates for the above model. The benchmark for the treatment effects is the fixed quantity English auction. The point estimate for the average price in this treatment, \( \hat{\mu} = 13.07, \) is nearly identical to expected theoretical price of 13. From this we can infer that the bidders are following their dominant strategy to bid until the price exceeds their value. The Dutch clock institution has significantly higher prices, increasing the price paid by \( \hat{\beta}_1 = 0.74 \) \( (p\text{-value} = 0.0130). \) This result is consistent with risk averse bidding and with previous work. Cox et al. (1982) find that Dutch clock prices are greater than second-price sealed bid auction prices. However, none of the terms involving \text{FixedRevenue} \ are statistically significant, individually or jointly \( (\text{LR statistic} = 2.46, \ p\text{-value} = 0.8729). \) Hence, we conclude that transaction amounts in fixed revenue auctions are equivalent to fixed quantity auctions when the settings are directly comparable.

**Finding 2:** The dimension of the auction, fixed revenue or fixed quantity, does not affect efficiency in the Dutch clock auction, but does (marginally) affect efficiency in the English auction.

All four clock auctions were highly efficient. Average efficiency in the Dutch quantity clock and Dutch price clock auctions were 99.1% and 97.5%, respectively. Average efficiency in the English quantity clock and English price clock auctions were 97.2% and 99.5%, respectively. Figure 3 plots the average efficiency over the 15 periods for each session (by treatment). Efficiency is defined as the winning bidder’s surplus divided by the maximum possible surplus. Using the average efficiency in a session as the unit of observation, we cannot
reject the null hypothesis that the Dutch quantity clock and Dutch price clock auctions are equally efficient based upon the Wilcoxon rank sum test ($U_{4,4} = 8, p\text{-value} = 1.0000$). There is marginal evidence to reject the null hypothesis that the English quantity clock and English price clock auctions are equally efficient ($U_{4,4} = 15, p\text{-value} = 0.0571$). The magnitude of this difference is relatively small as the “poorer” performing English quantity clock auction was 97.2% efficient.

**Finding 3:** Consistent with previous work, Dutch clock fixed revenue auctions are not behaviorally isomorphic to last-quantity sealed bid auctions.

Cox et al. (1982) report the same result for fixed, single-unit auctions. Table 2 reports the estimates of a linear mixed effects model that tests the theoretical isomorphism between Dutch clock and last-quantity sealed bid auctions. This data set includes 4 sessions of Dutch clock auctions and 4 sessions of last-quantity sealed bid auctions. The dependent variable is the transaction quantity and the treatment effect of interest is the institution. Since we expect ex ante that the bids are a function of the highest $\alpha_i$, we also include the $a_1$ variable as a control for variation of the $\alpha$ draws. The average quantity in the Dutch clock fixed revenue auctions is $\hat{\mu} = 12.17$ which is less than risk neutral prediction of 13 and consistent with risk averse bidding. (Recall that the Dutch quantity starts at zero and increases until the first bidder accepts the quantity on the clock.) Last-quantity sealed bid auctions have even more risk averse outcomes lowering transaction quantities by $\hat{\beta}_1 = -0.47$ ($p\text{-value} = 0.0460$). In the Dutch auctions, the estimated slope of the quantity bid function is $\hat{\phi}_1 = -0.87$, which is very close to the slope of the bid risk neutral function of $-\frac{n-1}{n} = -0.80$. There is no evidence that last-quantity bid functions are steeper $\hat{\gamma}_1 = 0.02$ ($p\text{-value} = 0.6981$). Figure 4 plots the winning quantity bids against the winning bidder’s value along with the risk neutral prediction. Cox et al. (1983) conclude that this difference is the result of bidders improperly updating their priors as opposed to the “excitement” of watching the clock to continuing tick.

**Finding 4:** Dutch clock and last-quantity sealed bid auctions are equally and highly efficient.
There are only 11 auctions out of 120 that are less than 100% efficient: 5 Dutch clock and 6 last-quantity sealed bid. The average efficiency is 99% over the 60 auctions for each institution, see Figure 3. Using a Wilcoxon rank sum test, we cannot reject the null hypothesis that the two institutions are equally efficient ($U_{4,4} = 8.5$, $p$-value = 0.8857).

**Finding 5**: Consistent with previous work, English clock fixed revenue auctions are not behaviorally isomorphic to penultimate-quantity sealed bid auctions.

Kagel and Levin (1993) find that in single unit, second-price sealed bid auctions bidders consistently bid higher than the dominant strategy prediction, even with experience in the auction mechanism. They speculate that bidders fall to the illusion that bidding higher is a low cost means of increasing the probability of winning. We also find that bidders in the penultimate-quantity sealed bid auction similarly over-reveal (by submitting quantities less than their dominant strategy prediction). Because English auctions are conducted in real time, they provide immediate and overt feedback as to what a bidder should and should not bid and so bidders adopt the strategy very quickly. Sealed bid auctions do not offer such feedback.

Table 3 reports the estimates of a linear mixed effects model that tests the theoretical isomorphism between English clock and penultimate-quantity sealed bid auctions. This data set includes 4 sessions of English clock auctions and 4 sessions of penultimate-quantity sealed bid auctions. The model includes the $a_2$ variable as a control on the variation of the second highest $a$. The average quantity in the English fixed revenue auction is $\hat{\mu} = 13.23$, which compares quite favorably to the theoretical prediction of 13. The penultimate-quantity sealed bid auctions have lower transaction quantities by $\hat{\beta}_2 = -0.58$ ($p$-value = 0.0344). As predicted, the relationship between the second highest $a$ and the transaction quantities is almost exactly -1 ($\hat{\phi}_2 = -0.97$, $p$-value < 0.0001). Figure 5 plots bids against the second lowest $a$ along with the dominant strategy prediction. In panel (a), only the quantity-setting bids are plotted against that bidder’s $a$. This panel clearly displays the Kagel and Levin observation of over-revelation in the penultimate-quantity sealed bid auctions. Just as Cox et al. (1982) report, subjects also “throw away” bids in the English auctions when they receive a very low $a$ and do not expect to win the auction. Hence, they exit nearly immediately.
**Finding 6:** We cannot reject the null hypothesis that penultimate-quantity sealed bid auctions are as efficient as English clock auctions.

As Figure 3 indicates, three of the penultimate-quantity sealed bid auctions are rather inefficient; a full 10 percentage points below the minimum efficiency observed in any of the other conditions. The fourth session, however, is highly efficient. As a result, we cannot reject the null hypothesis that the two institutions are equally efficient ($U_{4,4} = 13, p$-value = 0.2000).

V. Conclusions

The Dutch price, English price, first-price sealed bid, and second-price sealed bid auctions are all commonly used institutions that have been studied extensively both theoretically and empirically. This paper establishes the theoretical and behavioral properties of these standard auction mechanisms employed to raise a fixed amount of revenue for the seller. While this represents a shift in how auctions can be used, under one generalization of the standard assumptions regarding values, the predictions are similar to standard theory. Not surprisingly, with this assumption a bidder in the English quantity or penultimate-quantity sealed bid auction should truthfully reveal her value, while a bidder in the Dutch quantity or the last-quantity auction does not. However, if values are not linear in quantity, the complexity of the auction is dramatically increased. This is an area deserving further study, but beyond the scope this paper.

The results of our experiment indicate that auction outcomes are not affected by the dimension of the auction. Bidders truthfully reveal in the English auction but not in the penultimate-quantity sealed bid auction. Bidders attempting to game this sealed bid institution nominally lower efficiency relative to the English auction. As in the price dimension, the last-quantity auction and the Dutch clock auction are not behaviorally isomorphic. The sealed bid institution leads to lower quantities (analogous to higher prices in a fixed quantity auction). However, the two institutions are equally and highly efficient. Quantity equivalence does not hold across institutions, just as revenue equivalence has regularly been found not to hold in the standard setting. In fact, the dimension of the auction does not change the magnitude or ordering of the differences between auction institutions. These findings suggest that auction behavior is extremely robust and thus lends additional credence to previous work.
References


**Table 1. Estimates of the Linear Mixed-Effects Model of Prices for Fixed Revenue vs. Fixed Quantity Auctions**

\[
\text{Price}_{ij} = \mu + e_i + \xi_{ij} + \beta_1 \text{Dutch}_i + \beta_2 \text{Fixed Revenue}_i + \beta_3 \text{Dutch}_i \times \text{Fixed Revenue}_i + \\
\phi_1 a_{1,ij} + \phi_2 a_{2,ij} + \gamma_1 a_{1,ij} \times \text{Dutch}_i + \gamma_2 a_{2,ij} \times \text{Dutch}_i + \\
\delta_1 a_{1,ij} \times \text{Fixed Revenue}_i + \delta_2 a_{2,ij} \times \text{Fixed Revenue}_i + \\
\eta_1 a_{1,ij} \times \text{Dutch}_i \times \text{Fixed Revenue}_i + \eta_2 a_{2,ij} \times \text{Dutch}_i \times \text{Fixed Revenue}_i + \epsilon_{ij}
\]

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate</th>
<th>Std. Error</th>
<th>Degrees of Freedom*</th>
<th>t-statistic</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\mu)</td>
<td>13.07</td>
<td>0.18</td>
<td>151</td>
<td>74.18</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>(\text{Dutch})</td>
<td>0.74</td>
<td>0.25</td>
<td>12</td>
<td>2.91</td>
<td>0.0130</td>
</tr>
<tr>
<td>(\text{Fixed Revenue})</td>
<td>-0.26</td>
<td>0.25</td>
<td>12</td>
<td>-1.05</td>
<td>0.3153</td>
</tr>
<tr>
<td>(\text{Dutch} \times \text{Fixed Revenue})</td>
<td>0.25</td>
<td>0.36</td>
<td>12</td>
<td>0.71</td>
<td>0.4905</td>
</tr>
<tr>
<td>(a_1)</td>
<td>-0.06</td>
<td>0.08</td>
<td>151</td>
<td>-0.66</td>
<td>0.5093</td>
</tr>
<tr>
<td>(a_2)</td>
<td>0.98</td>
<td>0.07</td>
<td>151</td>
<td>14.77</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>(a_1 \times \text{Dutch})</td>
<td>0.85</td>
<td>0.12</td>
<td>151</td>
<td>7.13</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>(a_2 \times \text{Dutch})</td>
<td>-0.93</td>
<td>0.09</td>
<td>151</td>
<td>-10.13</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>(a_1 \times \text{Fixed Revenue})</td>
<td>0.12</td>
<td>0.13</td>
<td>151</td>
<td>0.96</td>
<td>0.3401</td>
</tr>
<tr>
<td>(a_2 \times \text{Fixed Revenue})</td>
<td>-0.09</td>
<td>0.10</td>
<td>151</td>
<td>-0.90</td>
<td>0.3706</td>
</tr>
<tr>
<td>(a_1 \times \text{Dutch} \times \text{Fixed Revenue})</td>
<td>-0.16</td>
<td>0.17</td>
<td>151</td>
<td>-0.94</td>
<td>0.3487</td>
</tr>
<tr>
<td>(a_2 \times \text{Dutch} \times \text{Fixed Revenue})</td>
<td>0.07</td>
<td>0.13</td>
<td>151</td>
<td>0.58</td>
<td>0.5659</td>
</tr>
<tr>
<td>LR: (\beta_2 = \beta_3 = \delta_1 = \eta_1 = \eta_2 = 0)</td>
<td>2.46</td>
<td>0.8729</td>
<td>238 Obs.*</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

N.B. The linear mixed effects model for repeated measures treats each session as one degree of freedom with respect to the treatments in the $2 \times 2$ design: Dutch, Fixed Revenue, and Dutch $\times$ Fixed Revenue variables. Hence, the degrees of freedom for the estimates of these fixed effects are $12 = 16$ sessions $- 4$ parameters. The linear mixed-effects model is fit by maximum likelihood with 16 groups. For brevity, the session random effects are not included in the table.

* In two Dutch clock price auctions, a subject inadvertently clicked on the “Buy” button nearly immediately after the auction started. Omitting any one of 238 included data points does not change the above estimates in any discernable way. These two outliers, however, do exert undue influence on the estimates, i.e., bias the estimates, and hence are excluded.
### Table 2. Test of Dutch Clock and Last-Quantity Isomorphism

\[ \text{Quantity}_{ijs} = \mu + e_i + \xi_{is} + \beta_1 \text{Sealed}_i + \phi_1 a_{1,ij} + \gamma_1 a_{1,ij} \times \text{Sealed}_i + \varepsilon_{ijs} \]

<table>
<thead>
<tr>
<th></th>
<th>Estimate</th>
<th>Std. Error</th>
<th>Degrees of Freedom</th>
<th>t-statistic</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\mu)</td>
<td>12.17</td>
<td>0.14</td>
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<td>87.78</td>
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</tr>
<tr>
<td>Sealed</td>
<td>-0.47</td>
<td>0.19</td>
<td>6</td>
<td>-2.51</td>
<td>0.0460</td>
</tr>
<tr>
<td>(a_1)</td>
<td>-0.87</td>
<td>0.04</td>
<td>79</td>
<td>-21.32</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>(a_1 \times \text{Sealed})</td>
<td>0.02</td>
<td>0.05</td>
<td>79</td>
<td>0.39</td>
<td>0.6981</td>
</tr>
</tbody>
</table>

120 Obs.

### Table 3. Test of English Clock and Penultimate-Quantity Isomorphism

\[ \text{Quantity}_{ijs} = \mu + e_i + \xi_{is} + \beta_1 \text{Sealed}_i + \phi_2 a_{2,ij} + \gamma_2 a_{2,ij} \times \text{Sealed}_i + \varepsilon_{ijs} \]

<table>
<thead>
<tr>
<th></th>
<th>Estimate</th>
<th>Std. Error</th>
<th>Degrees of Freedom</th>
<th>t-statistic</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\mu)</td>
<td>13.23</td>
<td>0.11</td>
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<td>124.96</td>
<td>&lt;0.0001</td>
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<tr>
<td>Sealed</td>
<td>-0.58</td>
<td>0.21</td>
<td>6</td>
<td>-2.73</td>
<td>0.0344</td>
</tr>
<tr>
<td>(a_2)</td>
<td>-0.97</td>
<td>0.04</td>
<td>80</td>
<td>-23.00</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>(a_2 \times \text{Sealed})</td>
<td>0.01</td>
<td>0.08</td>
<td>80</td>
<td>0.13</td>
<td>0.8983</td>
</tr>
</tbody>
</table>

120 Obs.
Figure 1. Generalized Value Functions

Figure 2. Message Space for Experimental Design
Figure 3. Average Efficiency by Session and Treatment
Panel (a). Winners’ Bids presented in Auction Space

Panel (b). Winners’ Bids presented in Typical Experiment Space ("value" vs. "bid")

Figure 4. Dutch Clock vs. Last-Quantity Sealed Bid Auctions
Figure 5. English Clock vs. Penultimate-Quantity Sealed Bid Auctions
Subject Instructions

The subject instructions are included for use in the review process and would be available to the general reader upon request.

The order of presentation is English price clock, Dutch price clock, English quantity clock, Dutch quantity clock, last quantity sealed bid, and penultimate quantity sealed bid.
This is an experiment in the economics of decision-making. Various research foundations have provided funds for this research. The instructions are simple, and if you understand them, you may earn a considerable amount of money that will be paid to you in CASH at the end of the experiment. Your earnings will be determined partly by your decisions and partly by the decisions of others. If you have questions at any time while reading the instructions, please raise your hand and a lab monitor will assist you.

This is what your screen will look like in the experiment. In each period of the experiment you will be a potential buyer of a fictitious product and will be matched with four other potential buyers who are in the room. The computer will act as the seller in this experiment. Your “Value” for buying this fictitious product is at the top of your screen. This represents the amount of money that you will be paid if you buy the fictitious product. Your profit in the period equals your value minus your payment if you buy the fictitious product.

You value consists of two components. Each buyer has an equally like chance of receiving a “Random Component” between -10 and 5, inclusive. That is, they are equally likely to receive -10, -9, … , 4, 5.

Furthermore, the chance of a buyer being assigned any particular random component in this range is not changed if that random component was assigned to one buyer or to another. It is therefore possible for one buyer to get the same random component in different periods or for two buyers to have the same random component in the same period. All buyers will each receive their own randomly drawn component each period.
The second part of your value is a “Quantity Component.” This will always be 13 for each bidder and will be added to the “Random Component” to yield the total value for purchasing the product.

How do you buy? Good question. At the beginning of each period, the “Bid” will start at 0 and increase by 0.1 each second. When the “Bid” reaches a level at which you do not wish to buy, click on the “Exit” button. When four bidders have clicked on the “Exit” button, the last or fifth buyer, who has not clicked on the button, will buy the product. That is, when the fourth bidder clicks on the “Exit” button, the remaining bidder buys at the “Bid” listed at that time. All ties are broken randomly. If the “Bid” reaches 26, one of the bidders who has not clicked “Exit” will be randomly selected as the buyer.

Now let’s go through an example of how to read the payoffs which are listed in the table. Each row contains results for a single period. Look at the second row. In this example, the fourth bidder clicked on the “Exit” button at a bid of 7 and you did not click on the “Exit” button, so you bought the item.

The first column records your “Random Component” that period and the second column indicates the “Quantity Component.” The third column indicates your “Value” for that period which is the Random Component + Quantity Component. The fourth column indicates the bid at which you clicked on the “Exit” button. Since you did not Exit in the second round this column is left blank.

If you buy a unit in a period (that is, you don’t click on “Exit” button), the fifth column records your profit, which is the difference between the “Payment” and your value, or:

\[
\text{Value} - \text{Transaction Payment} = \text{Profit}.
\]

Only one bidder can buy each period. The last column records the “Payment” that was made by the bidder who won the auction. Notice that in this example you did not buy in the first period because you clicked on the “Exit” button at 8 and the forth bidder clicked “Exit” at 11. You did not buy in the third period because you exited at 5 which was the transaction payment which means you were the fourth bidder to exit.

At the end of the period you will have 8 seconds to review the results. At the end of that time, the next period will begin.

Any questions? If so, please raise your hand. If not, please wait quietly until you are given further directions.
This is an experiment in the economics of decision-making. Various research foundations have provided funds for this research. The instructions are simple, and if you understand them, you may earn a considerable amount of money that will be paid to you in CASH at the end of the experiment. Your earnings will be determined partly by your decisions and partly by the decisions of others. If you have questions at any time while reading the instructions, please raise your hand and a lab monitor will assist you.

This is what your screen will look like in the experiment. In each period of the experiment you will be a potential buyer of a fictitious product and will be matched with four other potential buyers who are in the room. The computer will act as the seller in this experiment. Your “Value” for buying this fictitious product is at the top of your screen. This represents the amount of money that you will be paid if you buy the fictitious product. Your profit in the period equals your value minus your payment if you buy the fictitious product.

You value consists of two components. Each buyer has an equally like chance of receiving a “Random Component” between -10 and 5, inclusive. That is, they are equally likely to receive -10, -9, … , 4, 5.

Furthermore, the chance of a buyer being assigned any particular random component in this range is not changed if that random component was assigned to one buyer or to another. It is therefore possible for one buyer to get the same random component in different periods or for two buyers to have the same random component in the same period. All buyers will each receive their own randomly drawn component each period.
The second part of your value is a “Quantity Component.” This will always be 13 for each bidder and will be added to the “Random Component” to yield the total value for purchasing the product.

How do you buy? Good question. At the beginning of each period, the “Bid” will start at 26 and decrease by 0.1 each second. The first buyer to click on the “Buy” button will buy the product at the “Bid” when the button is clicked. All ties are broken randomly. If the “Bid” reaches 0, the auction will end and no one will be the buyer that period.

Now let’s go through an example of how to read the payoffs which are listed in the table. Each row contains results for a single period. Look at the second row. In this example, you clicked on the “Buy” button at a quantity component of 10, so you bought the item.

The first column records your “Random Component” that period and the second column indicates the “Quantity Component” which will always be 13. The third column indicates your “Value” for that period which is the Random Component + Quantity Component. The fourth column indicates the bid at which you clicked on the “Buy” button.

If you buy a unit in a period (that is, you click on the “Buy” button), the fifth column records your profit, which is the difference between the “Payment” and your value, or:

\[ \text{Value} - \text{Transaction Payment} = \text{Profit}. \]

Only one bidder can buy each period. The last column records the “Payment” that was made by the bidder who won the auction. Notice that in this example you did not buy in the first period because someone else clicked on the “Buy” button at 16.

At the end of the period you will have 8 seconds to review the results. At the end of that time, the next period will begin.

Any questions? If so, please raise your hand. If not, please wait quietly until you are given further directions.
This is an experiment in the economics of decision-making. Various research foundations have provided funds for this research. The instructions are simple, and if you understand them, you may earn a considerable amount of money that will be paid to you in CASH at the end of the experiment. Your earnings will be determined partly by your decisions and partly by the decisions of others. If you have questions at any time while reading the instructions, please raise your hand and a lab monitor will assist you.

This is what your screen will look like in the experiment. In each period of the experiment you will be a potential buyer of a fictitious product and will be matched with four other potential buyers who are in the room. The computer will act as the seller in this experiment. Your “Value” for buying this fictitious product is at the top of your screen. This represents the amount of money that you will be paid if you buy the fictitious product. Your profit in the period equals your value minus your payment if you buy the fictitious product.

You value consists of two components. Each buyer has an equally like chance of receiving a “Random Component” between -10 and 5, inclusive. That is, they are equally likely to receive -10, -9, … , 4, 5.

Furthermore, the chance of a buyer being assigned any particular random component in this range is not changed if that random component was assigned to one buyer or to another. It is therefore possible for one buyer to get the same random component in different periods or for two buyers to have the same random component in the same period. All buyers will each receive their own randomly drawn component each period.
The second part of your value is a “Quantity Component.” This portion of your value will determined by the auction and will be added to the “Random Component” to yield the total value for purchasing the product.

How do you buy? Good question. At the beginning of each period, the “Quantity Component” will start at 26 and decrease by 0.1 each second. When the “Bid for Quantity Component” reaches a level at which you do not wish to buy, click on the “Exit” button. When four bidders have clicked on the “Exit” button, the last or fifth buyer, who has not clicked on the button, will buy the product. That is, when the fourth bidder clicks on the “Exit” button, the remaining bidder buys at the “Quantity Component” listed at that time. All ties are broken randomly. If the quantity component reaches 0, one of the bidders who has not clicked “Exit” will be randomly selected as the buyer.

Now let’s go through an example of how to read the payoffs which are listed in the table. Each row contains results for a single period. Look at the second row. In this example, the fourth bidder clicked on the “Exit” button at a quantity component of 12 and you did not click on the “Exit” button, so you bought the item.

The first column records your “Random Component” that period. The second column indicates the “Bid for the Quantity Component” at which you clicked on the “Exit” button. Since you did not Exit in the second round this column is left blank. The third column indicates your “Value” for that period when you clicked on the “Exit” button, or if won the auction, your value with the transaction quantity when you won the auction.

The fourth column indicates how much you paid, which will always be 13 for each bidder each period. If you buy a unit in a period (that is, you don’t click on “Exit” button), the fifth column records your profit, which is the difference between the “Payment” and your value, or:

\[ \text{Random Component} + \text{Transaction Quantity} - \text{Payment} = \text{Profit}. \]

Only one bidder can buy each period. The last column records the “Quantity Component” that was received by the bidder who won the auction. Notice that in this example you did not buy in the first period because you clicked on the “Exit” button at 17 and the forth bidder clicked “Exit” at 14. You did not buy in the third period because you exited at 18 which was the transaction quantity which means you were the fourth bidder to exit.

At the end of the period you will have 8 seconds to review the results. At the end of that time, the next period will begin.

Any questions? If so, please raise your hand. If not, please wait quietly until you are given further directions.
This is an experiment in the economics of decision-making. Various research foundations have provided funds for this research. The instructions are simple, and if you understand them, you may earn a considerable amount of money that will be paid to you in CASH at the end of the experiment. Your earnings will be determined partly by your decisions and partly by the decisions of others. If you have questions at any time while reading the instructions, please raise your hand and a lab monitor will assist you.

This is what your screen will look like in the experiment. In each period of the experiment you will be a potential buyer of a fictitious product and will be matched with four other potential buyers who are in the room. The computer will act as the seller in this experiment. Your “Value” for buying this fictitious product is at the top of your screen. This represents the amount of money that you will be paid if you buy the fictitious product. Your profit in the period equals your value minus your payment if you buy the fictitious product.

Value = 2
- Payment = -8 + 10
Profit = -11

<table>
<thead>
<tr>
<th>Random Component</th>
<th>Bid for Quantity</th>
<th>Value</th>
<th>Payment</th>
<th>Profit</th>
<th>Transactions Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>-4</td>
<td>13</td>
<td>13</td>
<td>17</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>-3</td>
<td>17</td>
<td>13</td>
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<tr>
<td>-2</td>
<td>13</td>
<td>13</td>
<td>17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-8</td>
<td>13</td>
<td>13</td>
<td>17</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

My Cumulative Profit: 1

You value consists of two components. Each buyer has an equally like chance of receiving a “Random Component” between -10 and 5, inclusive. That is, they are equally likely to receive -10, -9, … , 4, 5.

Furthermore, the chance of a buyer being assigned any particular random component in this range is not changed if that random component was assigned to one buyer or to another. It is therefore possible for one buyer to get the same random component in different periods or for two buyers to have the same random component in the same period. All buyers will each receive their own randomly drawn component each period.
The second part of your value is a “Quantity Component.” This portion of your value will determined by the auction and will be added to the “Random Component” to yield the total value for purchasing the product.

How do you buy? Good question. At the beginning of each period, the “Quantity Component” will start at 0 and increase by 0.1 each second. The first buyer to click on the “Buy” button will buy the product at the “Quantity Component” when the button is clicked. All ties are broken randomly. If the “Quantity Component” reaches 26, the auction will end and no one will be the buyer that period.

Now let’s go through an example of how to read the payoffs which are listed in the table. Each row contains results for a single period. Look at the second row. In this example, you clicked on the “Buy” button at a quantity component of 17, so you bought the item.

The first column records your “Random Component” that period. The second column indicates the “Bid for the Quantity Component” if you clicked on the “Buy” button. The third column indicates your “Value” for that period if you won the auction (that is if you clicked on the “Buy” button).

The fourth column indicates how much you paid, which will always be 13 for each bidder each period. If you buy a unit in a period (that is, you click on the “Buy” button), the fifth column records your profit, which is the difference between the “Payment” and your value, or:

\[ \text{Random Component} + \text{Transaction Quantity} - \text{Payment} = \text{Profit}. \]

Only one bidder can buy each period. The last column records the “Quantity Component” that was received by the bidder who won the auction. Notice that in this example you did not buy in the first period because someone else clicked on the “Buy” button at 17.

At the end of the period you will have 8 seconds to review the results. At the end of that time, the next period will begin.

Any questions? If so, please raise your hand. If not, please wait quietly until you are given further directions.
Experiment Instructions

This is an experiment in the economics of decision-making. Various research foundations have provided funds for this research. The instructions are simple, and if you understand them, you may earn a considerable amount of money that will be paid to you in CASH at the end of the experiment. Your earnings will be determined partly by your decisions and partly by the decisions of others. If you have questions at any time while reading the instructions, please raise your hand and a lab monitor will assist you.

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You value consists of two components. Each buyer has an equally likely chance of receiving a “Random Component” between -10 and 5, inclusive. That is, they are equally likely to receive -10, -9, … , 4, 5.

Furthermore, the chance of a buyer being assigned any particular random component in this range is not changed if that random component was assigned to one buyer or to another. It is therefore possible for one buyer to get the same random component in different periods or for two buyers to have the same random component in the same period. All buyers will each receive their own randomly drawn component each period.
The second part of your value is a “Quantity Component.” This portion of your value will be determined by the auction and will be added to the “Random Component” to yield the total value for purchasing the product.

How do you buy? Good question. Each period each bidder will submit a “Bid for the Quantity Component.” The bidder who submits the lowest quantity component will buy the product for the “Quantity Component” he or she submitted. Bids must be between 0 and 26 and ties are broken randomly.

To submit your bid, type it in the box and click on the “Update” button. This will calculate what your profit will be \textbf{if you win the auction}. In the example above, you typed in a bid of 23. If you are satisfied with this bid, then you would click on the “Bid” button that will appear after you press “Update.” If you would like to change your bid, simply type a new number in the box.

Now let’s go through an example of how to read the payoffs which are listed in the table. Each row contains results for a single period. Look at the second row. In this example, you submitted a quantity component bid for 22, which was the lowest submitted bid, so you bought the item.

The first column records your “Random Component” that period. The second column indicates your “Bid for the Quantity Component.” The third column indicates your “Value” given your bid for that period.

The fourth column indicates how much you paid, which will always be 13 for the winning bidder each period. If you buy a unit in a period, the fifth column records your profit, which is the difference between the “Payment” and your value, or:

\[
\text{Random Component} + \text{Transaction Quantity} - \text{Payment} = \text{Profit}.
\]

Only one bidder can buy each period. The last column records the “Transaction Quantity” that was received by the bidder who won the auction. Notice that in this example you did not buy in the first period because someone else submitted a bid of 12 which was lower than your bid of 16.

At the end of the period you will have 8 seconds to review the results. At the end of that time, the next period will begin.

Any questions? If so, please raise your hand. If not, please wait quietly until you are given further directions.
This is an experiment in the economics of decision-making. Various research foundations have provided funds for this research. The instructions are simple, and if you understand them, you may earn a considerable amount of money that will be paid to you in CASH at the end of the experiment. Your earnings will be determined partly by your decisions and partly by the decisions of others. If you have questions at any time while reading the instructions, please raise your hand and a lab monitor will assist you.

This is what your screen will look like in the experiment. In each period of the experiment you will be a potential buyer of a fictitious product and will be matched with four other potential buyers who are in the room. The computer will act as the seller in this experiment. Your “Value” for buying this fictitious product is at the top of your screen. This represents the amount of money that you will be paid if you buy the fictitious product. Your profit in the period equals your value minus your payment if you buy the fictitious product.

You value consists of two components. Each buyer has an equally like chance of receiving a “Random Component” between -10 and 5, inclusive. That is, they are equally likely to receive -10, -9, …, 4, 5.

Furthermore, the chance of a buyer being assigned any particular random component in this range is not changed if that random component was assigned to one buyer or to another. It is therefore possible for one buyer to get the same random component in different periods or for two buyers to have the same random component in the same period. All buyers will each receive their own randomly drawn component each period.
Experiment Instructions

The second part of your value is a “Quantity Component.” This portion of your value will be determined by the auction and will be added to the “Random Component” to yield the total value for purchasing the product.

How do you buy? Good question. Each period each bidder will submit a “Bid for the Quantity Component.” The bidder who submits the lowest bid for the quantity component will buy the product, but they will receive as part of their value the second lowest bid for the “Quantity Component.” Bids must be between 0 and 26 and ties are broken randomly.

To submit your bid, type it in the box and click on the “Update” button. While there is no way to know what your quantity component and your profit would be if you won, you know that the quantity component would be equal to or more than your bid. In the example above, you typed in a bid of 17. If you are satisfied with this bid, then you would click on the “Bid” button that will appear after you press “Update.” If you would like to change your bid simply type a new number in the box.

Now let’s go through an example of how to read the payoffs which are listed in the table. Each row contains results for a single period. Look at the second row. In this example, you submitted a quantity component bid for 21, which was the lowest submitted bid, so you bought the item.

The first column records your “Random Component” that period. The second column indicates your “Bid for the Quantity Component.” The third column indicates your minimum potential “Value” for that period.

The fourth column indicates how much you paid, which will always be 13 for the winning bidder each period. If you buy a unit in a period, the fifth column records your profit, which is the difference between the “Payment” and your value, or:

$$\text{Random Component} + \text{Transaction Quantity} - \text{Payment} = \text{Profit}.$$  

Only one bidder can buy each period. The last column records the “Transaction Quantity” that was received by the bidder who won the auction. Notice that in this example you did not buy in the first period because someone else submitted a bid less than or equal to 18 which was lower than your bid of 22. Also note in the third period that you submitted a bid of 20, which was the transaction quantity. This means that you submitted the second lowest quantity, so you did not win the auction.

At the end of the period you will have 8 seconds to review the results. At the end of that time, the next period will begin.

Any questions? If so, please raise your hand. If not, please wait quietly until you are given further directions.