Reservation Values in Laboratory Auctions:  
Context and Bidding Behavior

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Abstract

We show that bidding behavior in laboratory first-price private-values auctions is sensitive to the way the outcomes of the auction are presented. We embed the auction in a context in which each subject purchases an object each period. A bidder’s idiosyncratic reservation value is the price at which he will purchase a close substitute outside the auction market in the event he does not win the auction. A subject’s earnings for a period are computed as his total consumer surplus. This modification makes salient the price-probability tradeoff bidders face, which plays a central role in both theoretical and empirical work. Using this design, we find seller revenue to be significantly lower than has been consistently reported in the literature, even though the risk-neutral Bayes-Nash equilibrium remains unchanged.

Keywords: first-price auctions, framing effects, methodology of experiments.

1 Introduction

Laboratory experiments in economics intermediate between pure theory and empirical observations in the field. In the lab, experimenters observe the decisions of real, human agents, while being able to control at least some environmental variables. Whether implic-
itly or explicitly, experimenters deal in two kinds of mappings: the mapping between a theoretical model and the laboratory environment, and the mapping between a field environment and its laboratory counterpart. The usefulness of laboratory results in improving theoretical models and in understanding field behavior depends on the validity of these mappings. In the terminology of Schram’s [9] recent survey, these can be thought of as the “internal validity” and the “external validity,” respectively, of a design. The interplay among theory, lab, and field is particularly evident in auction markets. Results of laboratory auctions have been used to refine auction models and theories of bidding (Cox et al [3]), and have informed the design of mechanisms in the world at large (for example, Roth [8]).

The strategic consideration faced by any bidder in a private-values first-price auction, irrespective of his attitude towards monetary risk, is a price-probability tradeoff. A higher bid increases the probability of winning the auction, but decreases the surplus the bidder gains when he wins, because he pays a higher price. Theoretical models assume agents reason about this price-probability tradeoff. In the field, it is taken as a given that they do. The validity of a private-values, first-price auction experiment depends on the salience of this tradeoff to the subjects.

In the lab, a robust finding is that subjects bid significantly more aggressively than predicted by the risk-neutral Bayes-Nash equilibrium. (See the survey of Kagel [6] for cites and discussion.) We argue that this finding is an artifact of the standard method for inducing incentives in these experiments. Using an alternate presentation of the incentives, in which subjects are paid according to the total consumer surplus they generate, we find that bidding is significantly less aggressive, even though the risk-neutral Nash equilibrium prediction is unchanged.

In evaluating an institution’s performance, an objective of the experimental method is to separate regularities which are inherent to the institution from observations which are artifacts of experimental design. In the language of Smith [10], interpreting laboratory
results assumes that a set of auxiliary hypotheses relating to the implementation of the experiment hold. The validity of these auxiliary hypotheses cannot be directly observed, but their plausibility can be assessed in part by considering modifications to an experimental protocol.

In the context of understanding individual preferences and choice behavior, PLOTT AND ZEILER [7] investigate the “willingness to pay/willingness to accept gap,” the claim that there is a systematic difference between the amount a subject is willing to pay for an object and the amount for which he is willing to sell the same object. They show that the gap can be turned on and off by the choice of experimental procedure. They note that “this variation in experimental results undermines the claim that the gap is a fundamental feature of human preferences.” Our result is analogous in showing that the levels of seller revenue generated by the bidding behavior reported in the literature is not a fundamental institutional feature of the first-price private-values auction in the laboratory.

The paper is organized as follows. Section 2 motivates the design choices leading to our presentation of the auction environment and derives corresponding theoretical predictions. Section 3 describes the experimental protocols, and Section 4 reports the results. Section 5 concludes with a discussion.

2 Presenting auction environments in the laboratory

The first-price auction with a single, indivisible object for sale is generally modeled as a Bayesian game, in the tradition of VICKREY [13]. In the independent private values version, each bidder has a private, idiosyncratic reservation value for the object. These values are independently distributed over some interval, and the distribution is common knowl-
edge. The bidders submit bids simultaneously (in a first-price sealed-bid auction) or using a clock mechanism (in the Dutch auction), and the highest bidder purchases the object. If bidders are risk-neutral, the payoff to the winning bidder is the difference between his reservation value and the price he pays. The utility of the outcome for bidders who do not purchase is normalized to zero.

This environment, with the private values drawn from a uniform distribution, has been studied extensively in the laboratory. In this literature, reservation values are presented using the methods and terminology developed in Coppinger, Smith, and Titus [1], Cox, Roberson, and Smith [2], and Cox, Smith, and Walker [3]. The instructions describe the reservation value as a cash “resale value.” The bidder who purchases the fictitious object being auctioned sells it back to the experimenter for this amount, and earns the difference between the resale value and the price he pays in the auction. Bidders who do not purchase the object receive monetary earnings of zero.

This resale value (RV) protocol uses a direct translation of the utility function from the standard auction model, where the reservation value is motivated by the artifice of the subject selling the object back to the experimenter. This translation is straightforward and clear to anyone familiar with the standard auction model, but may not communicate the nature of the experimental task to a nonspecialist in the same way. In the context of their decision task, Plott and Zeiler comment that “[d]ecision theorists might find the language used to describe procedures to be very clear because they are trained to give an operational meaning to technical language.” Therefore, we consider a different way to make the concept of a reservation value operational to our nonspecialist subjects.

In the field, a reservation value may be determined by the existence of opportunities to purchase a close substitute outside the auction market. Consider a consumer who wishes to purchase an iPod. iPods are frequently sold on Internet auction sites such as eBay. iPods are also widely available at electronics stores. Suppose the consumer has already
made the decision to purchase an iPod, but is willing to try an online auction to get a better deal than is available locally. If the consumer fails to win the eBay auction, he then purchases locally. The implied reservation value generated by the possibility of store purchase varies across consumers. Posted prices at stores may depend on geographic location. In addition, consumers differ in the cost of traveling to a store, due to physical distance or opportunity cost of personal time. Thus, consumers have idiosyncratic private reservation values.

Regardless of where he purchases, though, the consumer engages in an economic activity that is essentially the same. In either case, he purchases an iPod at a price lower than his maximum willingness to pay, and he earns positive consumer surplus. The only distinction between winning and not winning the eBay auction is the price he actually pays in the end. Thus, there is a parallel structure between the two outcomes. More generally, if a consumer does not purchase an object in an auction, he will instead participate in some other gainful exchange with the unspent money.

The RV method does not maintain this parallel structure. Instructions for experiments using RV necessarily distinguish between how earnings are calculated in the case in which the subject wins the auction, versus when the subject does not. When the earnings for not winning are set to zero, there is a textual difference in the presentation of the earnings calculation. Specifically, when a subject wins, earnings are computed according to a formula like “resale value minus purchase price.” When a subject does not win, no formula is needed; his earnings are zero.

Thus, under RV, earnings are positive if and only if the subject is successful in increasing consumer surplus. This further emphasizes the dichotomous presentation by segregating the outcomes into those with positive earnings versus those with zero earnings. There is one, and only one, way to earn positive earnings in the experiment: win. Discussions we have led following classroom auction experiments suggest that subjects do
take note of the dichotomy and use it as an input in their decision-making process. Despite using neutral terminology, such as “market” instead of “auction” and “purchase” instead of “win,” students frequently indicate they chose their bids to “try to win” the auction, or to avoid “getting no payoff.” This distraction undermines the salience of the tradeoff between the probability of purchasing the object and the consumer surplus from that purchase.

We place the auction market in a context motivated by the iPod story. All bidders have an identical maximum willingness to pay for one unit of a commodity. Each bidder receives an idiosyncratic outside price, representing an opportunity to purchase a unit outside the auction market. This outside price serves as the reservation value from the theoretical model. The winning bidder purchases the unit for sale in the auction, paying the amount he bid. The other bidders purchase their units elsewhere at their respective outside prices.

This outside price (OP) method presents the outcomes in a way which is textually and conceptually parallel. In each period, every subject purchases a unit. Earnings are always computed using the formula “maximum willingness to pay minus the price paid,” that is, the consumer surplus. The only difference between the outcomes is how the price paid is determined. All subjects earn a positive amount each period, so the two outcomes – win or lose – are no longer distinguishable based on whether earnings are positive or zero.

The symmetric Bayes-Nash equilibrium bidding function is identical under RV and OP when bidders are risk-neutral. When bidders are risk-averse, there are qualitative differences in the shape of the symmetric equilibrium bidding functions between the two treatments. Let there be \( N \geq 2 \) bidders with identical \( C^2 \) utility function \( u(\cdot) \), where, following Cox et al. [3], we treat subjects as being expected utility maximizers over income within an auction period. Letting \( x \) be a bidder's reservation value, which is assumed to be independently drawn across bidders from the uniform distribution on \([0, 1]\), the symmetric
Bayes-Nash equilibrium bidding function with risk-neutral bidders under RV is

\[ b(x) = \frac{N - 1}{N} x. \]  

(1)

Furthermore, if all bidders have constant relative risk aversion (CRRA) utility functions with parameter \( r \), \( u(x) = x^r \), then the equilibrium bidding function under RV is

\[ b(x) = \frac{N - 1}{N - 1 + r} x, \]  

(2)

which is linear in the reservation value with slope greater than the risk-neutral equilibrium. As a further extension, Van Boening et al. [12] numerically compute equilibrium bid functions under the assumption of CRRA utility functions with different but commonly-known parameters. In that case, the equilibrium involves all bidders following (2) until reaching the point at which the least risk-averse bidder “drops out,” i.e., the bid that bidder submits when he has the largest possible reservation value. The upper tails of the bid functions of the bidders remaining active then become concave in the reservation value.

Now consider the problem faced by a bidder under OP. Let \( v \geq 1 \) be the maximum willingness to pay for the object, which is the same across bidders. A bidder with outside price \( x \), again distributed i.i.d. uniformly on \([0, 1]\), faces the maximization problem

\[
\max_b P(b)u(v - b) + (1 - P(b))u(v - x),
\]

where \( P(b) \) is the probability that a bid \( b \) wins the auction. The first-order condition for the optimal choice of \( b \) is

\[
P'(b)[u(v - b) - u(v - x)] - P(b)u'(v - b) = 0.
\]

We work in terms of the inverse bid function \( x(b) \). Since we are looking for a symmetric equilibrium, the probability of winning can be written

\[ P(b) = x(b)^{N-1}. \]
with derivative

\[ P'(b) = (N - 1)x(b)^{N-2}x'(b). \]

Therefore, the first-order condition implies that a symmetric equilibrium (inverse) bidding function must satisfy the differential equation

\[ (N - 1)x'(b)[u(v - b) - u(v - x(b))] - x(b)u'(v - b) = 0. \]

This can be rearranged to

\[ x'(b) = \frac{x(b)u'(v - b)}{(N - 1)[u(v - b) - u(v - x(b))]}, \tag{3} \]

Clearly, \( x(0) = 0 \) must be a boundary condition. However, at \( x, b = 0 \), the right hand side of (3) is \( 0/0 \). To determine the slope, we apply L'Hôpital’s Rule:

\[
\begin{align*}
\lim_{b \to 0} x'(b) &= \lim_{b \to 0} \frac{x'(b)u'(v - b) - x(b)u''(v - b)}{(N - 1)[u'(v - x(b))x'(b) - u'(v - b)]} \\
&= \lim_{b \to 0} \frac{x'(b)u'(v - b)}{(N - 1)[u'(v - x(b))x'(b) - u'(v - b)]} - \lim_{b \to 0} \frac{x(b)u''(v - b)}{(N - 1)[u'(v - x(b))x'(b) - u'(v - b)]} \\
x'(0) &= \frac{x'(0)}{(N - 1)(x'(0) - 1)} \tag{4}
\end{align*}
\]

which implies that \( x'(0) = \frac{N}{N - 1} \). That is to say, the slope of the bidding function at the lowest reservation value is independent of the shape of the utility function. To illustrate, Figure 1 plots the bid functions for two CRRA utility functions, \( u(x) = \sqrt{x} \) and \( u(x) = \ln x \), for \( N = 3 \), the market size used in the experiments. The bid function remains quantitatively close to the risk-neutral slope of \( \frac{2}{3} \) through much of the range of reservation values, and the bid function is convex in the reservation value.

Thus, under OP, with the assumption of expected utility over this-period earnings:

1. Bidders with low reservation values should bid close to the risk-neutral bid, irrespective of risk preferences;
2. CRRA bidders should exhibit bidding behavior which is convex in their reservation value.

Note that the result (4) does not hold for CRRA in the RV frame. In deriving (4), when taking limits, $u'$ and $u''$ are evaluated at $v > 0$. Replicating the same exercise in the RV frame, $u'$ and $u''$ would be evaluated at 0; $u'(0)$ and $u''(0)$ are not well-defined for CRRA utility functions.

Finally, when the bidders are risk neutral, observe that (3) reduces to

$$x'(b) = \frac{x(b)}{(N-1)[x(b)-b]}$$

which is solved by $x(b) = \frac{N}{N-1} b$; thus the Bayes-Nash equilibrium is the same with RV and OP when bidders are risk-neutral.

3 Design

The design extends the protocol of Turocy, Watson, and Battalio [11] (TWB). Each cohort consisted of nine subjects, indexed $i \in \mathcal{I} = \{1, \ldots, 9\}$. Each session lasted 60 periods, indexed $t \in \mathcal{T} = \{1, \ldots, 60\}$. In each period, the bidders $\mathcal{I}$ were divided into three markets, with three bidders each, according to a function $M: \mathcal{I} \times \mathcal{T} \rightarrow \{1, 2, 3\}$. Each bidder received a reservation value each period according to a function $R: \mathcal{I} \times \mathcal{T} \rightarrow \{0.15, 0.30, \ldots, 5.85, 6.00\}$. The functions $M$ and $R$ were determined in advance, such that subject assignments to markets were independent across periods, and reservation values were uniformly distributed and independent across periods and subjects. The same functions $M$ and $R$ were used for all sessions. The instructions described the process used to generate $M$ and $R$, and stated that the session would last for 60 periods.
We report results on a total of 12 experimental sessions, with three sessions in each of four cells of a $2 \times 2$ design. We consider two implementations of the first-price auction. In the sealed-bid treatment, subjects, after observing their reservation value, simultaneously choose a bid from the set \{0.10, 0.20, ..., 6.10, 6.20\}; the bidder submitting the highest bid purchased the object in the auction at a price equal to his bid. In the Dutch, or descending-clock, implementation, a price clock was set to 6.20 at the start of each period, and decreased by 0.10 per second until a bidder in the market clicked a button labeled “Purchase.” The first bidder to do so in a market purchased the object in the auction at the price on the clock at the time he clicked. Ties in both implementations were resolved by choosing one of the tied bidders at random.

The second dimension of the design manipulates the presentation of the reservation value. In sessions using the standard “resale value” (RV) method, the relevant part of the instructions read

- **Your Earnings for a period will depend on whether you purchase the commodity in your market, and on the Market Price.**
- **If you purchase a unit of the commodity, your earnings for that period will be calculated according to the equation**

\[
\text{Your Earnings} = \text{Resale Value} - \text{Market Price}
\]

- **If you do not purchase a unit of the commodity, then your earnings for that period will be zero.**

In sessions using the “outside price” (OP) method, this was replaced with\(^1\)

- **You will purchase exactly one unit of the commodity each period. If you purchase the unit of the commodity in the market, your earnings for that period will be calculated as**

\[
\text{Your Earnings} = $6.20 - \text{Market Price}
\]

\(^1\) Appendix A contains the text of the instructions for sessions using OP. Screenshots of the instructions as seen by the subjects for all treatments are available online at http://econweb.tamu.edu/turocy/papers/revframe.html.
If you do not purchase the unit of the commodity in the market, then you will purchase a unit outside the market at your Outside Price. Your Earnings for the period are then computed as

\[
\text{Your Earnings} = $6.20 - \text{Outside Price}
\]

The remainder of the instructions was identical, except for these changes in terminology. With the choices for reservation values and bids, it is a symmetric Bayes-Nash equilibrium for risk-neutral bidders to bid $\frac{2}{3}$ of their value whether RV or OP was used.

Also identical, up to changes in terminology, was the graphical computer interface the subjects used to receive information and make their decisions. In addition to the display of the current auction period, the screen contained a record sheet reporting the results of the last 25 periods, with scroll buttons available to view earlier periods once filled. In the RV sessions, subjects were paid their total earnings from all 60 periods, plus a $5.00 initial balance; the record sheet kept a running total of earnings, with the $5.00 balance already included at the start of the session. In the OP sessions, to maintain the same level of expected earnings over the session assuming the same bidding behavior, subjects were paid their earnings from 7 of the 60 periods, with no initial balance. This was announced in the instructions for the session, and the periods which were paid were selected after all 60 periods were completed, by physically drawing numbered chips from a cup in front of all subjects.

Each cohort consisted of 9 subjects recruited from the undergraduate student body at Texas A&M University. No subject participated in more than one session, and no subjects had previously participated in any auction experiment. All interaction among the subjects was mediated via computer in the Economic Research Laboratory at Texas A&M. All matching and bidding was done anonymously; no ID numbers or other identifying information was made known to the subjects. At the end of each period, subjects only found
out the highest bid in their market; no information about other bids was revealed.

4 Results

Result 1. (Institutional Performance) The seller extracts a significantly lower proportion of the surplus under OP. This holds for both the sealed-bid and Dutch implementations.

<table>
<thead>
<tr>
<th>Type</th>
<th>Cohort</th>
<th>Revenue (All Periods)</th>
<th>% of surplus extracted</th>
<th>1-10</th>
<th>6-15</th>
<th>51-60</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sealed</td>
<td>RV-1</td>
<td>377.2</td>
<td>86.0</td>
<td>86.0</td>
<td>85.9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>RV-2</td>
<td>378.6</td>
<td>87.9</td>
<td>87.5</td>
<td>81.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>RV-3</td>
<td>376.1</td>
<td>85.8</td>
<td>84.4</td>
<td>83.1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>377.3</td>
<td>86.6</td>
<td>86.0</td>
<td>83.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>OP-1</td>
<td>344.7</td>
<td>74.3</td>
<td>79.3</td>
<td>76.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>OP-2</td>
<td>339.4</td>
<td>74.6</td>
<td>79.0</td>
<td>77.9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>OP-3</td>
<td>335.6</td>
<td>81.7</td>
<td>79.2</td>
<td>72.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>339.9</td>
<td>76.9</td>
<td>79.2</td>
<td>75.6</td>
<td></td>
</tr>
<tr>
<td>Dutch</td>
<td>RV-1</td>
<td>360.5</td>
<td>78.2</td>
<td>77.2</td>
<td>78.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>RV-2</td>
<td>336.1</td>
<td>75.5</td>
<td>77.6</td>
<td>74.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>RV-3</td>
<td>333.2</td>
<td>80.6</td>
<td>74.8</td>
<td>69.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>343.3</td>
<td>78.1</td>
<td>76.5</td>
<td>74.1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>OP-1</td>
<td>300.8</td>
<td>67.0</td>
<td>68.5</td>
<td>71.9</td>
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<tr>
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<td>320.6</td>
<td>56.0</td>
<td>63.2</td>
<td>72.2</td>
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<tr>
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<td>69.9</td>
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<tr>
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<td>Mean</td>
<td>310.2</td>
<td>64.6</td>
<td>67.2</td>
<td>70.5</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Statistics on market performance for all cohorts. Cohorts labeled RV used the resale value frame; those labeled OP used the outside price frame.

Table 1 reports summary data on seller revenues for the twelve cohorts. The six cohorts using RV are those reported as cohorts a in Turocy, Watson, and Battalio [11]. The first data column of Table 1 lists the average seller revenue for each cohort, taken over all periods. In both the sealed-bid and Dutch institutions, these revenues are
significantly lower in the sessions using OP. We adopt the convention of treating cohort-level results as the unit of independent observation. We test the null hypothesis that the average revenue per cohort under OP equals that under RV against the two-sided alternative. This null hypothesis is rejected for both the sealed-bid ($p$-value .003) and Dutch ($p$-value .041).

The difference in revenues is evident across all periods. Figure 2 plots ten-period moving averages of the percentage of the gains from trade extracted by the seller. We use percentage of gains from trade rather than revenue to control for the different realizations of the reservation values across periods.\(^2\) In the sealed-bid, the treatment effect is visually significant. The time series for all cohorts using OP lie everywhere below those using RV. In the Dutch, the effect is most evident early in the sessions. In contrast to the other three treatments, the time trend in the Dutch under OP is upwards.

The last three columns of Table 1 report the percentage of gains extracted by the seller across three ten-period intervals: periods 1-10, periods 6-15, and periods 51-60. In all cases, the point estimates for this percentage are lower under OP than RV, holding fixed the institution. We test the null of equal percentages of extraction under RV and OP against the two-sided alternative. For the sealed-bid cohorts, we reject this null hypothesis for each interval ($p$-values .048 for periods 1-10, .016 for periods 6-15, and .025 for periods 51-60). For the Dutch, we reject the null hypothesis for periods 1-10 ($p$-value .081) and 6-15 ($p$-value .030), but cannot reject the null of equality late in the sessions ($p$-value .330 for periods 51-60).

We conjecture that the upward price trend in the Dutch sessions arises because experimentation is relatively inexpensive under OP. There is only a 7 in 60 chance a period will be selected to count towards earnings. Even if it is selected, the bidder still receives positive earnings for that period, irrespective of whether he wins the auction. A savvy first-period strategy is to submit the minimum bid of $0.10 independent of the reservation

\(^2\) Recall, though, that the realizations of reservation values were identical across cohorts.
value the bidder receives. This strategy provides the most information about others’ behavior. Because only the winning bid is reported, winning the auction is informationally costly. If the bidder does not win the auction, he learns the maximum of the other two bids submitted in his market; if he does win the auction, he learns only that the maximum of the other two bids was less than his bid. The usefulness of this experimentation might be more transparent in the Dutch implementation, as the clock-based presentation might suggest the idea of playing a waiting game, or game of chicken, in the first few periods.

<table>
<thead>
<tr>
<th>Cohort</th>
<th>Bidder</th>
<th>$\beta_{ls}^L$</th>
<th>$\beta_{ls}^H$</th>
<th>$\beta_{ls}$</th>
<th>$F$</th>
<th>$b(600)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>RV-1</td>
<td>5</td>
<td>0.78</td>
<td>0.77</td>
<td>0.77</td>
<td>0.00</td>
<td>464</td>
</tr>
<tr>
<td>RV-3</td>
<td>1</td>
<td>0.92</td>
<td>0.93</td>
<td>0.93</td>
<td>0.01</td>
<td>541</td>
</tr>
<tr>
<td>RV-1</td>
<td>7</td>
<td>0.67</td>
<td>0.71</td>
<td>0.70</td>
<td>0.07</td>
<td>431</td>
</tr>
<tr>
<td>RV-3</td>
<td>8</td>
<td>0.83</td>
<td>0.86</td>
<td>0.85</td>
<td>0.10</td>
<td>501</td>
</tr>
<tr>
<td>RV-1</td>
<td>1</td>
<td>0.92</td>
<td>0.89</td>
<td>0.91</td>
<td>0.31</td>
<td>531</td>
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<td>RV-3</td>
<td>4</td>
<td>0.75</td>
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<td>465</td>
</tr>
<tr>
<td>RV-3</td>
<td>7</td>
<td>0.86</td>
<td>0.83</td>
<td>0.84</td>
<td>0.48</td>
<td>501</td>
</tr>
<tr>
<td>RV-2</td>
<td>5</td>
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<td>0.77</td>
<td>0.73</td>
<td>464</td>
</tr>
<tr>
<td>RV-2</td>
<td>1</td>
<td>0.92</td>
<td>0.81</td>
<td>0.87</td>
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<td>509</td>
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<td>2</td>
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<td>570</td>
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<td>RV-1</td>
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<td>0.86</td>
<td>0.80</td>
<td>1.71</td>
<td>495</td>
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<td>0.75</td>
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<tr>
<td>RV-2</td>
<td>2</td>
<td>0.86</td>
<td>0.76</td>
<td>0.81</td>
<td>3.22</td>
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</tr>
<tr>
<td>RV-1</td>
<td>3</td>
<td>0.95</td>
<td>0.88</td>
<td>0.92</td>
<td>3.47</td>
<td>525</td>
</tr>
<tr>
<td>RV-2</td>
<td>8</td>
<td>0.87</td>
<td>0.63</td>
<td>0.75</td>
<td>3.61</td>
<td>458</td>
</tr>
<tr>
<td>RV-3</td>
<td>0</td>
<td>0.83</td>
<td>0.98</td>
<td>0.92</td>
<td>5.64</td>
<td>526</td>
</tr>
<tr>
<td>RV-3</td>
<td>5</td>
<td>0.92</td>
<td>0.74</td>
<td>0.84</td>
<td>6.24</td>
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</tr>
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<td>RV-1</td>
<td>8</td>
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<td>0.45</td>
<td>0.67</td>
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<td>0.74</td>
<td>0.83</td>
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</tr>
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<td>0.75</td>
<td>16.58</td>
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<tr>
<td>RV-2</td>
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<td>0.82</td>
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<td>RV-2</td>
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<td>0.93</td>
<td>0.76</td>
<td>0.85</td>
<td>28.77</td>
<td>509</td>
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<td>1.00</td>
<td>0.66</td>
<td>0.82</td>
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<td>0.56</td>
<td>0.79</td>
<td>67.96</td>
<td>500</td>
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Table 2. Estimated bid function parameters, RV frame. For bidders above the horizontal line, the null hypothesis of constant-slope bidding cannot be rejected.
### Table 3. Estimated bid function parameters, OP frame. For bidders above the horizontal line, the null hypothesis of constant-slope bidding cannot be rejected.

**Result 2. (Individual Behavior)** In sealed-bid auctions under both RV and OP, bidders adopt constant-slope or concave bidding functions. Bidders under OP using concave bidding functions qualitatively match features of the best-response function.

To get a qualitative sense of the individual bidding behavior underlying the revenue results, we estimate a simple piecewise-linear model of bidding. For each bidder $i$ in each cohort $s$ in each period $t$, let

$$x_{ist}^L = \begin{cases} x_{ist} & \text{if } x_{ist} \leq 300 \\ 300 & \text{if } x_{ist} > 300 \end{cases}$$
and

\[ x_{ist}^H = \begin{cases} 
0 & \text{if } x_{ist} \leq 300 \\
 x_{ist} - 300 & \text{if } x_{ist} > 300 
\end{cases} \]

and write

\[ \text{bid}_{ist} = \alpha_{is} + \beta_{is}^L \times x_{ist}^L + \beta_{is}^H \times x_{ist}^H + \varepsilon_{ist}. \]  

Placing the knot at $3.00 is arbitrary, and the results do not qualitatively change if it is moved. With a reservation value of $3.00, a bidder has a one-in-four chance of being the bidder with the highest reservation value in his market. This point roughly divides the interval of reservation values into regions where the chance of winning the auction is and is not salient. In specification (5), bidders with \( \beta_{is}^H > \beta_{is}^L \) exhibit bidding behavior which is “convex” in their reservation value, and those with \( \beta_{is}^H < \beta_{is}^L \) exhibit “concave” bidding behavior. We additionally consider the restriction of (5) with \( \beta_{is}^L = \beta_{is}^H \equiv \beta_{is} \),

\[ \text{bid}_{ist} = \alpha_{is} + \beta_{is} \times x_{ist} + \varepsilon_{ist}. \]  

Table 2 presents the estimated values of the parameters \( \beta^L, \beta^H \), and \( \beta \) for bidders in the RV frame, and Table 3 the same for the OP frame. The columns labeled \( F \) give the \( F \)-statistics for the hypothesis test of the restriction \( \beta_{is}^L = \beta_{is}^H \equiv \beta_{is} \). Bidders are sorted by the value of the \( F \)-statistic. Since there are 60 observations in each regression, 3 parameters in the unrestricted regression, and 1 restriction, the null hypothesis \( \beta_{is}^L = \beta_{is}^H \equiv \beta_{is} \) can be rejected at the 5% level if the \( F \) statistic exceeds a critical value of about 4.01. Thus, bidders towards the top of the tables are bidders for whom we cannot reject the hypothesis of constant-slope bidding functions. In these tables, we omit the intercept estimates. Similar to previous studies, we find these are small, though they are sometimes statistically different than zero.

We focus on the slope estimates, as they tell us how bidders react to changes in their reservation value. During a session, a subject has at best a fuzzy assessment of the proba-
bility-of-winning function $P(b)$. Furthermore, missing the level of the optimal bid by a small amount has small expected payoff consequences. A subject therefore is unlikely to determine the level of the best-response bid with pinpoint accuracy. However, the situation a bidder faces with a reservation value, for example, of $5.55$ is similar to the situation he faces with reservation value $5.40$ or $5.70$. Slope estimates inform us whether the bidder is reacting qualitatively in a way that is consistent with how his payoff function depends on his realized reservation value.

For 15 bidders under RV and 14 bidders under OP, we cannot reject the null hypothesis of constant-slope bidding behavior; we will refer to these as “type H” bidders. Among bidders for whom we reject the constant-slope restriction, we estimate that $\beta_{is}^H < \beta_{is}^L$ for all except one bidder in RV; that is, those bidders exhibited bidding behavior concave in the reservation value. These will be called “type S” bidders. Since equilibrium with risk-averse bidders predicts bid functions convex in the reservation value under OP, we can reject equilibrium with risk aversion over current period income as an explanation for lower bid function slopes when reservation values are higher.

While the proportion of type S bidders is about the same in RV and OP, the type S bidders in OP typically have much smaller $\beta_{is}^H$ estimates. The 11 type S bidders in RV have a median $\beta_{is}^H$ estimate of 0.68, while the median $\beta_{is}^H$ of the 13 type S bidders in OP is 0.42. Some typical bidding patterns are shown in Figure 3 for RV and Figure 4 for OP.

The difference in the $\beta_{is}^H$ estimates is consistent with differences in the structure of the best response. We construct an estimate of the probability-of-winning function $P(b)$ for both frames by simulating draws of pairs of bids from the data.\(^3\) We then compute the bid for each reservation value that maximizes expected earnings, given $P(b)$. These best-response bid functions are plotted in Figure 5. Under OP, the best-response function is

\(^3\) Each draw is done from the entire set of observed bids in all cohorts in all periods. The results are qualitatively unchanged if this is done cohort-by-cohort, restricting attention to earlier or later periods, etc.
very flat in the top third of the interval of values; from $4.00 to $6.00, the best-response bid increases only from $3.20 to $3.60. The shape of the payoff function for those reservation values does not change much as the reservation value is increased. Under RV, the best-response function has an approximately constant slope of about $\frac{2}{3}$.

These observations suggest a levels-of-reasoning model of bidder behavior. Crawford and Iriberri [4] have analyzed auctions, including first-price auctions with private values, using “level-$k$” reasoning. They consider two specifications for the lowest, “non-strategic” level of bidder, one in which those bidders bid randomly, and one in which they bid their value. We propose to operationalize the concept of a nonstrategic bidder in our auction environment as one who bids a constant fraction of the reservation value, as this is a simple, straightforward, and reasonable heuristic, though not necessarily a best response. Among bidders classified as type $H$, the median $\beta$ estimate is 0.81 in RV and 0.79 in OP. As a group, these bidders submit similar bids in RV and OP, and are not reacting differentially to the presentation of the auction environment.

The second-level bidders, then, are the type $S$ bidders. These bidders are sophisticated insofar as they are approximately best-responding to the empirical distribution of bids, at least in the qualitative sense of the values of $\beta_{iS}^H$. This is not true of the estimates of $\beta_{iS}^L$, the median of which in RV is 0.95 and in OP is 0.89. Under OP, the theoretical analysis indicates a strong argument for bidding approximately $\frac{2}{3}$ the reservation value for low reservation values, irrespective of risk attitude. However, in that regime, a bidder has a small chance of winning the auction, and a prospect of only a small amount of additional earnings in the event he does win. Thus, we interpret the observed $\beta_{iS}^L$ estimates under OP as an indication that experimental control simply fails in this regime.

As a final indication of the quantitative differences in bidding in the two treatments, Tables 2 and 3 present $b(600)$, the estimated bid submitted when the bidder has the maximum reservation value of $6.00$. Under RV, the median of the estimates of $b(600)$ is 493
for type $H$ bidders, and 484 for type $S$ bidders. Under OP, these are 463 for type $H$ and 388 for type $S$. Lower revenues under OP result primarily from type $S$ bidders choosing bids which are much closer to the expected value-maximizing best response.

5 Conclusion

We show that bidding behavior in private-values, first-price laboratory auctions is sensitive to the presentation of the reservation values and outcomes. With a frame in which the payoff computation for outcomes is presented in parallel, seller revenues are significantly lower in both sealed-bid and Dutch implementations. The lower seller revenues arise because a segment of the population of bidders adopts bidding behavior which is noticeably concave in reservation values; this behavior is qualitatively consistent with the shape of the best-response function. Thus, there is evidence that subjects perceive the environments differently, even though a theorist would consider the payoff transformation created by the difference in framing irrelevant for a risk-neutral bidder.

In a study of field auctions for antique collectible United States coins, Harrison, List, and Towe [5] write

We hypothesize that there is a danger that the imposition of an exogenous laboratory control might make it harder, in some settings, to make reliable inferences about field behavior. The reason is that the experimenter might not understand something about the factor being controlled, and might impose it in a way that is inconsistent with the way it arises naturally in the field... (p. 433)

The reservation value in a private values auction may be such a factor. While specialists are comfortable with the idea that every agent has a reservation value, in practice,
such a reservation value is latent, insofar as an agent does not stop and formally assess a particular number unless called upon to do so. In imposing controls to establish the private values setting, the concept of the reservation value must be presented in a way that communicates the concept in terms familiar to the subject.

The ultimate goal of absolutely establishing the internal and external validity of any design for an auction experiment is, by definition, unreachable. Our results represent progress in understanding how to map theory and field to the lab by proposing an alternative means of establishing the private value setting. Two translations of the private values environment elicit different behavioral patterns, leading to significantly different assessments of seller revenue. Which method – if either – adequately establishes the control that maintains the validity of those mappings is a topic for future consideration and research.

Acknowledgements

Funding for the reported experimental sessions was provided by the Department of Economics at Texas A&M. We thank the Economic Research Laboratory at Texas A&M University for use of facilities and logistical support in running these sessions. We also thank Glenn Harrison, as well as participants at Economic Science Association meetings in Tucson in September 2006 and Rome in June 2007, for helpful comments.

Bibliography

[1] Vicki M. Coppinger, Vernon L. Smith, and Jon A. Titus. Incentives and Behavior in English,


Figure 1. Symmetric equilibrium bid functions under constant relative risk aversion. The lower dotted line represents the risk-neutral equilibrium; the higher dotted line is the 45-degree line.
Figure 2. Ten-period moving averages of the percentage of surplus extracted by the seller, by cohort. Solid lines represent cohorts using the resale value frame, dotted lines the use of the one-outside price frame.

Bibliography
Figure 3. Bids of three “typical” subjects in RV: a linear bidder (left); linear with a concave top (center); and “banded” at focal bids in increments of 50 cents (right).
Figure 4. Bids of three “typical” subjects in OP: a linear bidder (left); linear with a slightly concave top (center); and linear with an almost-flat top (right).
**Best response against empirical bid distribution**

![Graph showing best response bid functions against the empirical distribution of bids for both frames.]

**Figure 5.** Best response bid functions against the empirical distribution of bids for both frames.

## Appendix A Instructions

We present the complete text of the instructions for the OP sessions.

### A.1 Instructions for sealed-bid sessions

**INSTRUCTIONS**

This is an experiment in the economics of market decision making. Various agencies have provided funds for this research. If you follow the instructions and make appropriate decisions, you can earn an appreciable amount of money. At the end of today’s session you will be paid in private and in cash.

It is important that you remain silent and do not look at other people’s work. If you have any questions, or need assistance of any kind, please raise your hand and an experimenter will come to you. If you talk, laugh, exclaim out loud, etc., you will be asked to leave and you will not be paid. We expect and appreciate your cooperation.

We will now describe the session in more detail. Please follow along with these instructions on your computer screen as they are read aloud. When each screen has been read aloud, you will be instructed to press the button labeled **Click to proceed**, which will appear below the instructions on each screen.
Each of you has been assigned a participant number. Your participant number is written on the outside of the envelope on your desk. Your participant number will not change during the session. Your participant number will determine the order in which you will be called to be paid at the end of the session.

GROUPS AND MARKETS

In today's session there are nine (9) participants. Today's session will last for a total of sixty (60) periods. In every period, the participants will be divided into three (3) markets, each with three (3) participants. At the beginning of each period, you will be randomly assigned to one of the three markets.

The assignment of participants to markets will be done in such a way that your chance of being in a given market in a given period does not depend upon the market assignments you received in previous periods or those you will receive in subsequent periods. Also, you will be assigned to markets in such a way that your chances of being in a market with another given participant in your group are the same regardless of whether you were assigned to the same market as that participant in a previous period.

THE MARKET

Each period the experimenter will have one unit of commodity to sell in each market. The value of the commodity to you is $6.20. Prior to the start of the period, you will receive information about an opportunity to purchase a unit of the commodity outside the market. The price at which the commodity is available to you outside the market will be referred to as your Outside Price. Each market period, each participant will receive an Outside Price. Your Outside Price in each period is your private information, and will not be revealed to other participants, nor will the Outside Prices of other participants be revealed to you.

You will purchase exactly one unit of the commodity each period. If you purchase the unit of the commodity in the market, your earnings for that period will be calculated as

\[ \text{Your Earnings} = 6.20 - \text{Market Price} \]

where the Market Price for a given period is determined by the choices of the participants in that market in that period. The Market Price for a given market in a given period is independent of the Market Prices of other markets in the same period and of Market Prices for the same market in other periods.

If you do not purchase the unit of the commodity in the market, then you will purchase a unit outside the market at your Outside Price. Your Earnings for the period are then computed as

\[ \text{Your Earnings} = 6.20 - \text{Outside Price} \]

Your earnings for the session will be computed as follows. At the end of the session, seven (7) of the 60 periods will be selected at random by drawing numbered chips out of a cup. Each period is equally likely to be selected in this drawing. Your total earnings for the session will be determined by adding up your earnings for each of the seven periods selected in the drawing.

EARNINGS EXAMPLES

Example 1. Suppose you receive an Outside Price of $5.00, and you purchase the unit of the commodity in the market at a Market Price of $4.00. Your earnings for the period will be calculated as:

\[ \text{Your Earnings} = 6.20 - \text{Market Price} \]

\[ \text{Your Earnings} = 6.20 - 4.00 = 2.20 \]

Thus, your earnings for that period are $2.20.
Example 2. Suppose you receive an Outside Price of $3.00, the Market Price in your market is $4.50, and you do not purchase the unit of the commodity in the market. In this case, since you did not purchase a unit of the commodity in the market, you purchase a unit outside the market at your Outside Price. Your earnings for the period will be calculated as

\[ \text{Your Earnings} = 6.20 - \text{Outside Price} \]
\[ \text{Your Earnings} = 6.20 - 3.00 = 3.20 \]

Thus, your earnings for that period are $3.20.

PARTICIPATING IN THE MARKET

On the screen to the left of these instructions is a display similar to the one you will use to participate in the market. The rectangle will be referred to as a clock. On the clock are marked amounts in dollars and cents.

In each period, the clock will display your private Outside Price for that period. You will use the clock to indicate a price at which you would be willing to purchase the unit of commodity the experimenter has to sell.

After you have selected a price, you confirm your decision by clicking the button labeled Confirm bid, located beneath the clock. The price which you select and confirm will be referred to as Your Bid. Until the time you click the Confirm bid button, you will have the ability to change the price you have selected. Once the Confirm bid button has been clicked, you will not be able to change your selected price for that period.

The participant in each market who selects the highest price will be the one to purchase the unit of commodity, and the price that participant selected will be the Market Price for that market for that period.

In the event that this highest price was selected by two or more participants in the same market (i.e. a tie), one of those participants will be chosen at random to purchase the unit at the Market Price.

INTERACTING WITH THE CLOCK

You will now have an opportunity to practice selecting prices on the clock.

There will be a total of three practice periods. In each period, you will be given a target price. Use the mouse pointer to point at the target price. As you move the mouse over the clock area, the price to which the mouse points will appear in light blue. Click in the clock area at the desired price to set the bid. If you make a mistake, you can click again at a different location in the clock to re-set the bid to a new price. Once you have set the price to the target price, click Confirm bid to complete the selection of the price.

You will be given different target prices for the three periods.

On the next screen we will begin the first practice period. For this first period, the target price will be $4.50.

RECORD SHEET

On your screen during the session will be a record sheet similar to the one on the right of this screen.

Each period your record sheet will show your Outside Price for that period. It will also display information from previous periods. After the markets have completed each period, your record sheet will be updated with information on the Market Price for your market in that period, your bid, whether you purchased the object inside or outside the market, and your earnings for that period.

While the session will consist of 60 periods, the record sheet only has space to display 25 periods at a time. After the first 25 periods the arrow buttons, located on the bottom right of the record sheet, will become active. When these are active, you may use these to scroll the record sheet and view all information from all previous periods.

EXAMPLE PERIOD 1

Suppose you receive an Outside Price of $5.00 and you submit a bid of $3.50 for the unit. Also suppose that $3.50 is the highest bid submitted in your market, and that you were the only participant in your market to submit that bid.
You would therefore purchase the unit in the market, and the Market Price would be $3.50. Your earnings would be calculated as

\[
\text{Your Earnings} = 6.20 - \text{Market Price}
\]

\[
\text{Your Earnings} = 6.20 - 3.50 = 2.70
\]

On the left is an example of how the clock would appear at the end of the period given the above situation. Notice that your Outside Price, the Market Price, Your Bid, and your earnings are all labeled on the clock.

**EXAMPLE PERIOD 1**

Given the scenario described on the previous page, your record sheet would look exactly like the one on the right half of the screen. The record sheet summarizes the results of the period. Proceeding from left to right, the columns display:

- The period number (period 1);
- Your Outside Price ($5.00);
- Your Bid ($3.50);
- The Market Price ($3.50);
- Whether you purchased the unit in the market (Market since you did);
- Your Earnings for the period ($2.70, computed as $6.20 - Market Price).

**EXAMPLE PERIOD 2**

Suppose you receive an Outside Price of $3.00 and you submit a bid of $3.80 for the unit. Also suppose that $3.80 is the highest bid submitted in your market, and that you were the only participant in your market to submit that bid.

You would therefore purchase the unit in the market and the Market Price would be $3.80. Your earnings would be calculated as

\[
\text{Your Earnings} = 6.20 - \text{Market Price}
\]

\[
\text{Your Earnings} = 6.20 - 3.80 = 2.40
\]

On the left is an example of how the clock would appear at the end of the period given the above situation. Notice that your Resale Value, the Market Price, Your Bid, and your earnings are all labeled on the clock.

**EXAMPLE PERIOD 2**

Given the scenario described on the previous page, your record sheet would look exactly like the one on the right half of the screen. For this example period 2, the record sheet displays

- The period number (period 2);
- Your Outside Price ($3.00);
- Your Bid ($3.80);
- The Market Price ($3.80);
- Whether you purchased the unit in the market (Market since you did);
- Your Earnings for the period ($2.40, computed as $6.20 - Market Price).

**EXAMPLE PERIOD 3**

Suppose you receive an Outside Price of $2.00 and you submit a bid of $1.80. The highest bid submitted in your market however was $4.00.

Since your bid was not the highest bid submitted in your market, you did not purchase the unit in the market. Therefore, you purchase a unit outside the market at your Outside Price. Your earnings would be calculated as

\[
\text{Your Earnings} = 6.20 - \text{Outside Price}
\]

\[
\text{Your Earnings} = 6.20 - 2.00 = 4.20
\]
In this situation the clock will appear as it does on the left side of the screen. Notice that your Outside Price, the Market Price, Your Bid, and your earnings are all labeled on the clock.

**EXAMPLE PERIOD 3**

Given the scenario described on the previous page, your record sheet would look exactly like the one on the right half of the screen. For this example period 3, the record sheet displays

- The period number (period 3);
- Your Outside Price (\$2.00);
- Your Bid (\$1.80);
- The Market Price (\$4.00);
- Whether you purchased the unit in the market (Outside since you did not);
- Your Earnings for the period (\$4.20, computed as \$6.20 - Outside Price).

**EXAMPLE PERIOD 4**

Suppose you receive an Outside Price of \$4.50 and that you submit a bid of \$3.90. In addition, suppose that another participant in your market also submits a bid of \$3.90, and that the third participant in your market submits a bid of \$2.00.

In the case of a tie such as this, one of the participants who submitted a bid of \$3.90 will be selected at random to purchase the unit in the market. Suppose the other participant is selected to purchase the unit in the market. Then, you would purchase a unit at your Outside Price. Your earnings would be calculated as

\[
\text{Your Earnings} = \$6.20 - \text{Outside Price} \\
\text{Your Earnings} = \$6.20 - \$4.50 = \$1.70
\]

In this situation the clock will appear as it does on the left side of the screen. Notice that your Outside Price, the Market Price, and Your Bid, and your earnings are all labeled on the clock.

**EXAMPLE PERIOD 4**

Given the scenario described on the previous page, your record sheet would look exactly like the one on the right half of the screen. For this example period 4, the record sheet displays

- The period number (period 4);
- Your Outside Price (\$4.50);
- Your Bid (\$3.90);
- The Market Price (\$3.90);
- Whether you purchased the unit in the market (Outside (tie) since there was a tie and you were not the participant selected to purchase in the market);
- The earnings for the period (\$1.70, computed as \$6.20 - Outside Price).

**DETERMINING OUTSIDE PRICES**

Recall that during today’s session you will each receive an Outside Price each period.

These Outside Prices will be randomly selected from the 40 values \$0.15, \$0.30, \$0.45, ... \$5.70, \$5.85, \$6.00. Each of these values is equally likely to be chosen for each participant in each period.

The likelihood that another participant receives any of these values is not affected by the value assigned to any other participant in that period, or in any previous or future periods.

This means that it is possible for you to receive the same Outside Price two or more periods in a row, and it is possible for two or more participants, even participants in the same market, to receive the same Outside Price in the same period.
OPERATION OF THE MARKET

Each period will begin with a five second countdown. During this time you will be able to view your Outside Price for
the upcoming period and your record sheet with information from the previously completed periods.

After the countdown concludes, you will be able to select your bid for the period. Bids may be selected from the 62
values $0.10, $0.20, $0.30, ..., $6.00, $6.10, $6.20. That is, bids may be selected from the values between $0.10 and
$6.20, in increments of $0.10.

Remember that once you have selected your bid for a period, you must click the button labeled Confirm bid to send the
bid to the market.

SUMMARY

During today’s session, you will be randomly placed into one of three markets each period, with each market having a
total of three participants.

Each period you will receive an Outside Price randomly drawn from the 40 values $0.15, $0.30, ..., $5.85, $6.00 for a
unit of commodity that can be purchased outside of the market.

If you purchase the unit in the market, then your earnings are calculated as Your Earnings = $6.20 - Market Price.
If you do not purchase the unit in the market, then your earnings are calculated as Your Earnings = $6.20 - Outside
Price.

For each market, the Market Price is determined by the highest bid selected by a participant in that market.

If the highest bid in a market is selected by two or more participants, one of them will be chosen at random to purchase
the unit in the market.

Your record sheet is updated each period with the information from that period. Your final earnings for the session will
be determined by randomly drawing seven of the 60 periods, and adding up your earnings from those seven selected periods.

QUESTIONNAIRE

An experimenter will now come around the room to distribute a questionnaire which reviews the instructions we have
just completed.

Please answer the questions on the questionnaire. When you have completed the questions, please raise your hand, and
an experimenter will come around to check your answers.

Once all participants have answered the questions on the questionnaire correctly, we will review the answers aloud. Once
this is done, there will be an opportunity for any further questions to be asked and answered. When all questions have been
answered, the experimenter will start the session, and Period 1 will begin.

A.2 Instructions for Dutch sessions

INSTRUCTIONS

This is an experiment in the economics of market decision making. Various agencies have provided funds for this research.
If you follow the instructions and make appropriate decisions, you can earn an appreciable amount of money. At the end of
today’s session you will be paid in private and in cash.

It is important that you remain silent and do not look at other people’s work. If you have any questions, or need assis-
tance of any kind, please raise your hand and an experimenter will come to you. If you talk, laugh, exclaim out loud, etc.,
you will be asked to leave and you will not be paid. We expect and appreciate your cooperation.
We will now describe the session in more detail. Please follow along with these instructions on your computer screen as they are read aloud. When each screen has been read aloud, you will be instructed to press the button labeled **Click to proceed**, which will appear below the instructions on each screen.

Each of you has been assigned a participant number. Your participant number is written on the outside of the envelope on your desk. Your participant number will not change during the session. Your participant number will determine the order in which you will be called to be paid at the end of the session.

**GROUPS AND MARKETS**

For today's session there are nine (9) participants. Today’s session will last for a total of sixty (60) periods. In every period, the participants will be divided into three (3) markets, each with three (3) participants. At the beginning of each period, you will be randomly assigned to one of the three markets.

The assignment of participants to markets will be done in such a way that your chance of being in a given market in a given period does not depend upon the market assignments you received in previous periods or those you will receive in subsequent periods. Also, you will be assigned to markets in such a way that your chances of being in a market with another given participant are the same regardless of whether you were assigned to the same market as that participant in a previous period.

Your earnings for the session will be computed as follows. At the end of the session, seven (7) of the 60 periods will be selected at random by drawing numbered chips out of a cup. Each period is equally likely to be selected in this drawing. Your total earnings for the session will be determined by adding up your earnings for each of the seven periods selected in the drawing.

**THE MARKET**

Each period the experimenter will have one unit of commodity to sell in each market. The value of the commodity to you is $6.20. Prior to the start of the period, you will receive information about an opportunity to purchase a unit of the commodity outside the market. The price at which the commodity is available to you outside the market will be referred to as your **Outside Price**. Each market period, each participant will receive an Outside Price. Your Outside Price in each period is your private information, and will not be revealed to other participants, nor will the Outside Prices of other participants be revealed to you.

You will purchase exactly one unit of the commodity each period. If you purchase the unit of the commodity in the market, your earnings for that period will be calculated as

\[
\text{Your Earnings} = 6.20 - \text{Market Price}
\]

where the **Market Price** for a given period is determined by the choices of the participants in that market in that period. The Market Price for a given market in a given period is independent of the Market Prices of other markets in the same period and of Market Prices for the same market in other periods.

If you do not purchase the unit of commodity in the market, then you will purchase a unit outside the market at your Outside Price. Your Earnings for the period are then computed as

\[
\text{Your Earnings} = 6.20 - \text{Outside Price}
\]

**EARNINGS EXAMPLES**

**Example 1.** Suppose you receive an Outside Price of $5.00, and you purchase the unit of the commodity in the market at a Market Price of $4.00. Your earnings for the period will be calculated as:

\[
\text{Your Earnings} = 6.20 - \text{Market Price}
\]
Your Earnings = $6.20 - $4.00 = $2.20

Thus, your earnings for that period are $2.20.

Example 2. Suppose you receive an Outside Price of $3.00 and the Market Price in your market is $4.50, and you do not purchase the unit of the commodity in your market. In this case, since you did not purchase a unit of the commodity in the market, you purchase a unit outside the market at your Outside Price. Your earnings for the period will be calculated as

Your Earnings = $6.20 - Outside Price

Your Earnings = $6.20 - $3.00 = $3.20

Thus, your earnings for that period are $3.20.

THE CLOCK

On the screen to the left of these instructions is a display similar to the one you will use to participate in the market. The rectangle will act as a clock. On the clock are marked amounts in dollars and cents.

In each period, the clock will display your private Outside Price for that period. You will use the clock to indicate a price at which you would be willing to purchase the unit of commodity the experimenter is selling in the market.

In each period, the market will begin with the clock displaying a Clock Price of $6.20. After the market begins, every second the Clock Price will decrease by $0.10. To the left of the clock will be displayed the current Clock Price, along with a circle showing how much time remains until the next price will be displayed.

PARTICIPATING IN THE MARKET

To express your willingness to purchase the unit of the commodity in the market at the current Clock Price, you must click the button labeled Purchase located below the clock. The price at which you click Purchase will be referred to as Your Bid.

Once a market participant has clicked the Purchase button, the clock for that market will no longer tick down each second. The participant who clicked Purchase will be the one to purchase the unit of commodity in the market, and the price displayed as the current clock price at the time when Purchase was clicked will be the Market Price for that market for that period.

In the event two or more participants in the same market click the Purchase button at the same price (i.e. a tie), one of those participants will be chosen at random to purchase the unit in the market at the Market Price.

If no participant in a given market has clicked Purchase when the Clock Price reaches zero, then no participant will purchase the unit of the commodity in the market.

INTERACTING WITH THE CLOCK

You will now have an opportunity to practice clicking the Purchase button when the Clock Price is a given value.

There will be a total of three practice periods. In each period, you will be given a target price. Watch the clock as it ticks down, and click Purchase when the Clock Price reaches the target price.

You will be given different target prices for the three periods. In each practice period, the clock will start at the Clock Price of $6.20. Prior to the beginning of each practice period, there will be a five (5) second countdown. When the countdown is complete, the Clock Price shown on the clock will decrease by $0.10 each second.

On the next screen we will begin the first practice period. For this first period, try to stop the clock by clicking Purchase when the Clock Price is $4.50.

RECORD SHEET

On your screen during the session will be a record sheet similar to the one on the right of this screen.
Each period your record sheet will show your Outside Price for that period. It will also display information from previous periods. After the markets have completed each period, your record sheet will be updated with information on the Market Price for your market in that period, Your Bid (if one was made), whether you purchased the object inside or outside the market, and your earnings for that period.

While the session will consist of 60 periods, the record sheet only has space to display 25 periods at a time. After the first 25 periods the arrow buttons, located on the bottom right of the record sheet, will become active. When these are active, you may use these to scroll the record sheet and view all information from all previous periods.

**EXAMPLE PERIOD 1**

Suppose you receive an Outside Price of $5.00 and you click **Purchase** at a Clock Price of $3.50.

Also suppose that you were the only participant in your market to click **Purchase** at that Clock Price.

You would therefore purchase the unit in the market, and the Market Price would be $3.50. Your earnings would be calculated as

\[ \text{Your Earnings} = 6.20 - \text{Market Price} \]

\[ \text{Your Earnings} = 6.20 - 3.50 = 2.70 \]

On the left is an example of how the clock would appear at the end of the period given the above situation. Notice that your Outside Price, the Market Price, Your Bid, and your earnings are all labeled on the clock.

**EXAMPLE PERIOD 2**

Suppose you receive an Outside Price of $3.00 and you click **Purchase** at a Clock Price of $3.80.

Also suppose that you were the only participant in your market to click **Purchase** at that Clock Price.

You would therefore purchase the unit in the market, and the Market Price would be $3.80. Your earnings would be calculated as

\[ \text{Your Earnings} = 6.20 - \text{Market Price} \]

\[ \text{Your Earnings} = 6.20 - 3.80 = 2.40 \]

On the left is an example of how the clock would appear at the end of the period given the above situation.
Where you purchased the unit (Market since you purchased in the market);

Your Earnings for the period ($2.40, computed as $6.20 - Market Price).

EXAMPLE PERIOD 3

Suppose you receive an Outside Price of $2.00 and one of the other participants in your market clicks Purchase at a Clock Price of $4.00.

Since you did not click Purchase at that Clock Price, you do not purchase the unit in the market. Therefore, you purchase a unit outside the market at your Outside Price. Your Earnings would be calculated as

\[ \text{Your Earnings} = \$6.20 - \text{Outside Price} \]
\[ \text{Your Earnings} = \$6.20 - \$2.00 = \$4.20 \]

In this situation the clock will appear as it does on the left side of the screen.

EXAMPLE PERIOD 3

Given the scenario described on the previous page, your record sheet would look exactly like the one on the right half of the screen. For this example period 3, the record sheet displays

The period number (period 3);

Your Outside Price ($2.00);

A dash for Your Bid (indicating that you did not click Purchase);

The Market Price ($4.00);

Where you purchased the unit (Outside since you purchased outside the market);

Your Earnings for the period ($4.20, computed as $6.20 - Outside Price).

EXAMPLE PERIOD 4

Suppose you receive an Outside Price of $4.50 and that you click Purchase at a Clock Price of $3.90. In addition, suppose that another participant in your market also clicked Purchase at the Clock Price of $3.90.

In the case of a tie such as this, one of the participants who clicked Purchase at that price will be selected at random to purchase the unit in the market. Suppose the other participant is selected to purchase the unit in the market. Then you would purchase a unit at your Outside Price. Your earnings would be calculated as

\[ \text{Your Earnings} = \$6.20 - \text{Outside Price} \]
\[ \text{Your Earnings} = \$6.20 - \$4.50 = \$1.70 \]

In this situation the clock will appear as it does on the left side of the screen.

EXAMPLE PERIOD 4

Given the scenario described on the previous page, your record sheet would look exactly like the one on the right half of the screen. For this example period 4, the record sheet displays

The period number (period 4);

Your Outside Price ($4.50);

Your Bid ($3.90);

The Market Price ($3.90);

Where you purchased the unit (Outside (T) since there was a tie and you were not the participant selected to purchase in the market);

Your Earnings for the period ($1.70, computed as $6.20 - Outside Price).

DETERMINING OUTSIDE PRICES

Recall that during today’s session each participant will receive an Outside Price each period.
These Outside Prices will be randomly selected from the 40 values $0.15, $0.30, $0.45, ... $5.70, $5.85, $6.00. Each of these Outside Prices is equally likely to be chosen for each participant in each period.

The likelihood that another participant receives any of these prices is not affected by the price received by any other participant in that period, or in any previous or future periods.

This means that it is possible for you to receive the same Outside Price two or more periods in a row, and it is possible for two or more participants, even participants in the same market, to receive the same Outside Price in the same period.

**OPERATION OF THE MARKET**

Each period will begin with a five second countdown. During this time you will be able to view your Outside Price for the upcoming period and your record sheet with information from the previously completed periods.

After the countdown concludes, the Clock Price will be set at $6.20. The Clock Price will decrease by an increment of $0.10 once per second, and will stop when one or more of the participants in the market has clicked **Purchase**.

**SUMMARY**

During today’s session, you will be randomly placed into one of three markets each period, with each market having a total of three participants.

Each period you will receive an Outside Price randomly drawn from the 40 values $0.15, $0.30, ..., $5.85, $6.00 for a unit of commodity that can be purchased outside the market.

If you purchase the unit in the market, then your earnings are calculated as Your Earnings = $6.20 - Market Price.

If you do not purchase the unit in the market, then your earnings are calculated as Your Earnings = $6.20 - Outside Price.

The Market Price is the Clock Price at which a participant in a market clicks the **Purchase** button.

If two or more participants in a given market click **Purchase** at the same Clock Price, one of them will be chosen at random to purchase the unit in the market.

Your record sheet is updated each period with the information from that period. Your final earnings for the session will be determined by randomly drawing seven of the 60 periods, and adding up your earnings from those seven selected periods.

**QUESTIONNAIRE**

An experimenter will now come around the room to distribute a questionnaire which reviews the instructions we have just completed.

Please answer the questions on the questionnaire. When you have completed the questions, please raise your hand, and an experimenter will come around to check your answers.

Once all participants have answered the questions on the questionnaire correctly, we will review the answers aloud. Once this is done, there will be an opportunity for any further questions to be asked and answered. When all questions have been answered, the experimenter will start the session, and Period 1 will begin.