DIVISION OF THE HUMANITIES AND SOCIAL SCIENCES
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA 91125

THE WINNER'S CURSE: EXPERIMENTS WITH BUYERS AND WITH SELLERS

Barry Lind and Charles Plott

THE WINNER'S CURSE: EXPERIMENTS WITH BUYERS AND WITH SELLERS

Barry Lind and Charles R. Plott

ABSTRACT

This paper explores the winner's curse phenomena as it was studied experimentally by Kagel and Levin. Experiments with the winner's curse are complicated by the fact that subjects can lose money and the experimenter has only a limited means of collecting it from them. Thus subjects enjoy only limited liability which has theoretical implications for behavior. In the Kagel and Levin experiments subjects were removed from the bidders' competition after losses reached a predetermined value. This experimental procedure has unknown implications for the results so ambiguity exists about whether the winner's curse was actually observed. In this study their results were replicated in an environment in which subjects were not removed. The case in which competitors are sellers is also studied. Bankruptcy cannot be a problem in sellers' competition. In both cases the winner's curse is observed. Thus the limited liability cannot be an explanation for the phenomenon reported by Kagel and Levin. In addition the paper examines the bidding behavior of all individuals and shows that this behavior does not fit any of the tested theories either on the aggregate or individual level. The "winner's curse" did not disappear over time during the conduct of the research.

THE WINNER'S CURSE: EXPERIMENTS WITH BUYERS AND WITH SELLERS

Barry Lind and Charles R. Plott*
California Institute of Technology

This paper involves a replication and extension of experiments with the "winner's curse" which were initiated in John Kagel and Dan Levin (1984, 1986) and Dyer, Kagel, and Levin (1989). The common value auction involves firms bidding for an item of unknown common value. Since the value of the item is unknown, the winners can bid more than the value and thereby lose money. The winner's curse occurs if the winners of auctions systematically bid above the actual value of the objects and thereby systematically incur losses. The phenomena is said to possibly occur in the bidding for such natural resources as mineral rights, where the value of the mineral is unknown but each firm has an estimate of the value. Due to the field nature of the data, doubts have existed as to the actual existence of the curse. The Kagel and Levin paper tested for the existence of the phenomena in a laboratory setting. The hope is that by achieving a thorough understanding of the phenomena as it might exist in simple laboratory environments economists will become better equipped to identify and study the phenomena in more complex field settings.

Kagel and Levin report the existence of a winner's curse but their experimental procedures were such that there exists an alternative explanation for what they saw. The winner's curse involves buyers which pay more than the value of an item and therefore experience a loss. Monetary losses in an experiment pose somewhat of a problem because generally the experimenter has no means of collecting money from subjects. Subjects, knowing this, have reason to believe that the downside risk on their actions are truncated and thus might be prone to more risky actions than would be the case if they were forced to suffer full losses. In order to minimize this effect, subjects are frequently given a cash stake which they can lose. Kagel and Levin provided such a stake and required the subject to leave the experiment if and when the stake was lost. One could reasonably imagine that these procedures produced a "winner's curse" (Hansen and Lott, 1988). After a loss or two the subject's reserve could be sufficiently low that prospective losses could exceed the balance. Thus inflated bids carry no additional risk. Furthermore, one could theorize that experience with the curse facilitates learning and caution. According to that theory the process of removing subjects that were bankrupt succeeded in removing subjects less prone to the curse having had the experience of losing money and thereby adjusting their behavior. Thus subjects more prone to the curse would remain in the experiment. Thus a skeptic could claim that both the existence and persistence of the winner's curse in the Kagel and Levin data were direct consequences of the way that the Kagel and Levin experimental procedures dealt with substantial losses by subjects. The technique used by Dyer, Kagel, and Levin is the same as that used in Kagel and Levin so similar questions might be raised about it as well.

The strategy of the research reported here is to look for the phenomena using procedures which avoid many of the bankruptcy problems. Two different sets of procedures are used. First, the "winner's curse" experiment in which subjects might lose money was conducted simultaneously with a second experiment in which subjects were making money. The second set of procedures involved competitors as sellers in a common value auction. The winner's curse phenomena can

appear in this setting as the sale of an item for less than it is actually worth to the seller. The seller's loss occurs as an opportunity cost only so the possibility of bankruptcy does not exist.

The experiments using these two different sets of experimental procedures produced several results which are the substance of the paper.

1. The winner's curse was observed in both experimental settings. In essence, the Kagel and Levin results were replicated.
2. Kagel and Levin's results were not a consequence of their experimental procedures.
3. The winner's curse might diminish in size or frequency but does not completely dissipate over time.
4. The winner's curse is a general phenomena exhibited by most agents.
5. Theories of "suboptimal" behavior advanced as explanations of the phenomena do not explain the data as well as does the completely rational model in which the phenomena does not exist at all theoretically.

The paper is organized as follows. In the next section, Section 1, the experimental design is outlined. In Section 2 some competing models are discussed. Section 3 contains a statement of the measurement system. The results are in Section 4. The concluding section contains a discussion of conjectures that might advance an understanding of the phenomena.

1.   EXPERIMENTAL DESIGN

The experiments were two types of common value auctions. The first type of experiment was the common value auction as conducted by Kagel and Levin in which buyers bid for an item of unknown value. Subjects agreed that if they made losses they would work them off at $10 per hour.[1] In Experiment 1 subjects participated in a sealed bid private value auction in addition to the common value auction in which the winner's curse might occur. In the second experiment subjects participated in both a common value auction in which they were buyers (Experiment 2) and also in a common value auction in which they were sellers (Experiment 3). (In other words, Experiments 2 and 3 were run simultaneously on the same subjects.) These secondary auctions constituted a source of funds which reduced the likelihood of bankruptcies in case the winner's curse was operative. These procedural changes were implemented so that subjects had full financial liability in the range of financial exposures that were likely to exist in the experiments.

The second type of experiments (Experiments 3 through 5) were common value auctions with competition among sellers as opposed to buyers. The sellers tendered offers to sell an item of unknown value. Each seller was given one item to sell. Their option was to keep the item and collect its value or sell the item and collect the revenues from the sale. The person with the lowest offer sold his item and received the ask price, while everyone else kept the item and received the value. In this common value selling auction all subjects earned positive profits including the winner, but the winner could suffer opportunity costs by selling the item for less than the amount received by all who did not sell the actual value of the item.

The experiments were conducted at Caltech using undergraduates as subjects. Most of the subjects had participated in other experiments prior to these and were familiar with the experimental environment. The subject pool serves as a partial control for the hypothesis that the curse might be due to confusion about instructions. The instructions read to the subjects are attached as the

Appendix. Prior to the experiment, the common values of the objects were determined by realization from a random number table. Given the value of the object, "clues" or "signals" were drawn for each subject independently. Each subject was given a stack of slips of paper which contained the clues to the common value of the items being auctioned. The slips were stapled so that only the clue for the current period could be observed. The subject observed the clue and then submitted a bid. After the auction all bids, signals and the common value were posted. The winner was then announced. The subject removed the top slip to expose the clue for the next period.

The clue was called a signal about the true value of the item to be auctioned. The value of the item was randomly chosen from the range $(\underline{x}, \bar{x})$. If v was the item's value, then the signals were randomly chosen over an interval $(v - \varepsilon, v + \varepsilon)$ where ε is a positive value set by the experimenter. In order to avoid the winner's curse the bidder must recognize that if he wins, and thus buys (sells) the object, then he probably has the highest (lowest) signal, which is probably above (below) the item's value. Therefore in order for the person not to lose money, (forego profits) he must bid (ask) significantly less (more) than this signal.

A total of five experiments were conducted. The first two were buyer markets which replicated one of the experimental settings of Kagel and Levin. The next three were seller markets. All experiments were conducted with seven subjects. Experiments 1 and 2 had the same set of predrawn signals and Experiments 4 and 5 had the same set of predrawn signals. The value of ε for the buying auctions was $30, and it was 200 francs in the selling auctions. The range from which v was drawn was $(\underline{x}, \bar{x}) = (\$25, \$225)$ for the buyer auctions and $(\underline{x}, \bar{x}) = (150 \text{ francs}, 1{,}500 \text{ francs})$ for the seller auctions. (The franc values were \$.0025, \$.001, and \$.007 for Experiments 3, 4, and 5, respectively.) The parameter choices reflect an attempt to unambiguously identify the curse should it exist. The models reviewed below suggest that the curse becomes more severe with larger ε and a larger number of people. The parameters are those of Kagel and Levin's that make the curse severe. Another consideration was cost. In the seller auctions all subjects (except the seller) were paid the value of the item which makes the experiments potentially expensive. For example, if the value in the seller auction had been drawn from the same distribution over dollars that it was drawn from in the buyer auction then the cost of the experiment would have been on the order of \$875 (expected value of v times 7) per period. The scaling factor that was chosen to reduce the cost keeps ε the same proportion of the range of v and also permits many periods.

2. MODELS

Assume that v is drawn from a uniform distribution. Assume that each x_i is drawn independently from a uniform distribution over the interval $[v - \varepsilon, v + \varepsilon]$. If x_i is the signal observed by individual i and the structure is common knowledge, the theoretical problem is to model how i chooses a bid as a function of x_i.

At least four models make sense. The first is the *risk neutral Nash equilibrium model* of the associated bidding game [2]. The second model is based on the hypothesis that individuals make a specific type of calculation error but still conform to the general principles of game theory. We call this the *judgmental failure model*. The third model is based on the hypothesis that people do not behave strategically. They only bid the expected value as if the situation was a simple second-price auction of a lottery and not one in which strategies might be important. The model is called the

naive model. The fourth model called the *private value model* postulates that individuals bid as if x_i was a private value of the object for each i. That is, individuals fail to understand the basic statistical relationship between value and signals.

The optimal bidding strategy according to the *risk neutral Nash equilibrium model* (RNNE) is to bid as a function of the signal (x_i). Under the buying auction the optimal strategy is

$$b(x_i) = x_i - \varepsilon + Y \qquad Y = [2\varepsilon / (n + 1)] \exp[-(n / 2\varepsilon)(x_i - (\underline{x} + \varepsilon))] \tag{1}$$

where n is the number of subjects.

Under the selling auction the RNNE optimal strategy is

$$b(x_i) = x_i + \varepsilon - Y \qquad Y = [2\varepsilon / (n + 1)] \exp[-(n / 2\varepsilon)(-x_i + (\overline{x} - \varepsilon))] \tag{2}$$

A *judgmental failure model* (JF) is postulated by Kagel and Levin for buyer auctions. The model is based on the hypothesis that individuals fail to recognize that the auction winner will be the subject with the highest signal. The Kagel and Levin *judgmental failure model* can be generalized to the seller auction. The equations for the optimal bidding strategy under the assumption that the bidder fails to recognize that the winner has the highest (lowest) signal are:

buying auction $\qquad b(x_i) = x_i - (2\varepsilon/n) + (Y/n)$ $\qquad\qquad$ (3)

selling auction $\qquad b(x_i) = x_i + (2\varepsilon/n) - (Y/n)$ $\qquad\qquad$ (4)

The above equations for the RNNE and JF models are only valid on the interval: $\underline{x} + \varepsilon < x_i < \overline{x} - \varepsilon$.
The *naive model* (N) for both the buying auction and the selling auction has the bid simply equal to the signal. The bidding strategy for both types of auctions is

$$b(x_i) = x_i . \tag{5}$$

The final model, the *private value model* (PV), holds that individual i makes the mistake of placing a private value x_i on the object and that the private value of each of the others j is independently drawn from the internal $x_j \varepsilon [x_i - \varepsilon, x_i + \varepsilon]$. By applying *risk neutral Nash* theory to that situation bidding functions can be derived. For buyers the bidding function is

$$b(x_i) = x_i - \frac{\varepsilon}{n} \tag{6}$$

and for sellers it is

$$b(x_i) = x_i + \frac{\varepsilon}{n} \; . \tag{7}$$

3. MEASUREMENT METHODOLOGY

The four theoretical models lend themselves naturally to a single measurement system. The single regression for each individual,

$$b_{it} = \alpha_i + \beta x_{it} + \gamma Y_{it} + e_{it} \; , \qquad e_{it} \sim N(0, \sigma_i) \; , \tag{8}$$

can be used as a measure of the accuracy of all four theoretical models. The equation can be used for both buying auctions and selling auctions. A summary of the restrictions on the regression equation imposed by the competing theories is included as Table 1. As can be seen, all theoretical models predict $\beta = 1$. The intercept term can be interpreted as $\delta \varepsilon$ where ε is the value of the range of the signal $\{x_i \in [v - \varepsilon, v + \varepsilon]\}$ so $\alpha = \pm 1 \varepsilon$ in the RNNE; $\alpha = \frac{2}{n} \varepsilon$ in the *judgmental failure model*; $\alpha = 0$ in the *naive model*, and $\alpha = \pm \frac{1}{n} \varepsilon$ in the *private value model*. γ is ± 1 for the RNNE; it is $\pm \frac{1}{n}$ for the JF and it is 0 for both the N and the PV.

The measurement strategy is to first apply the unrestricted regression model. The coefficients can be compared to the theoretical values of the competing models. Then models with parameters as restricted by theory will be applied. The SSE of the unrestricted model can be used with the SSE of the restricted model and compute an F-statistic (Chow test) for the hypothesis that the restrictions are not significantly different from the unrestricted measurements. The F statistic will also be used as a measure of the relative closeness of the competing models.

4. RESULTS

The results of primary interest bear on the existence of the winner's curse. Of secondary interest are results that might uncover the principles that govern individual decision behavior. The findings are summarized by five conclusions.

CONCLUSION 1. The winner's curse exists.

Evidence. The per-period profit from all auctions is used as a measure. In buying auctions the profit is the actual value of the object minus the purchase price of the auction winner. In selling auctions the profit is the sale price of the object minus the actual price received by the winner. Thus in selling auctions a negative profit is an opportunity cost incurred because the item was sold for less than it was worth to the seller.

Table 2 lists the average per-period profit from all experiments. As can be seen, the winner makes a loss on average in four of the five experiments. The table also reports the ratio of the number of auctions in which a loss occurred divided by the total number of auctions. In all cases, a

large proportion of the auctions resulted in a loss. The only possible exception to the general tendency is Experiment 4 which was characterized by a large number of attempts at collusion. In total over half of all auctions resulted in a loss.

CONCLUSION 2.   The winner's curse persists with experience but the magnitude
and frequency of losses decline with experience.

Evidence. The frequencies of losses of the auction winners are divided into ten period quartiles for every experiment in Table 3. The average size loss is also included in the table. As can be seen, the proportion of auctions in which losses occur is significantly greater than zero in all quartiles. Even after twenty or thirty auctions, the winners lose money over 25% of the time. The frequency of losses decreases after the first 10 trials in all experiments except Experiment 5.

The complete time series of profits for Experiment 5 is included as Figure 1. The figure also includes the profit that would have occurred if the agent had used the RNNE strategy. As can be seen, the winners' losses continue to occur even after thirty auctions. This experiment has a more severe curse than the other experiments. Unlike the other experiments the frequency does not decline with experience.

The first two conclusions that have been discussed so far offer answers to the questions initially posed for experimental examination. The next series of conclusions reflect questions posed in an attempt to understand why the phenomenon occurs. As was reviewed in the section above, only four theoretical models have been advanced. The first question posed was whether or not any of these four models represent the data in a statistical sense. Since the answer turns out to be negative, the next series of questions attempt to identify the "best" model and ask why it fails.

CONCLUSION 3.   All four models, RNNE, JF, N, and PV, can be rejected as a statistical
representation of the data.

Evidence. Table 4 contains the results of the Chow test described in the section above. In all cases, the statistical model with parameters as restricted by the competing theoretical models can be rejected as being significantly different from the unrestricted estimates. For example, the F-statistic for rejecting the model at a 5% confidence is 2.64 while the statistic for the RNNE for buying auctions is 30.16, and for selling auctions it is 5.27.

CONCLUSION 4.   The RNNE is the best model of the three considered and the *naive model*
is the worst.

Evidence. The pooled data in Figure 2 show the relationship between individual signals and bids. The visual impression favors the RNNE model. The scattered data in the upper left of the figure for the seller auctions are the bids of a small number of subjects who were (evidentally) signaling for collusion.

Table 5 contains the estimated coefficients from pooled data which can be compared with the predictions in Table 1. With the exception of the x_i coefficient, β, the standard errors tell the same stories as do the Chow tests discussed below. The parameter values estimated by the regression can be rejected as being equal to those of any of the four models. The β term is close to 1 but this is predicted by all models. The intercept term, α, is closest to that predicted by the RNNE.

The γ term has such a large standard error that little can be said other than the sign is in agreement with both the RNNE and the *judgmental failure model*.

The major support for the conclusion is simply a restatement of the F statistics in Table 4. If the F statistic is taken as a measure of accuracy, then the RNNE is always more accurate than its closest competitor, the *judgemental failure model*. The *private value model* ranks third and the *naive model* is the worst. The F statistics for all models were also computed for each individual. Of the 35 individual data sets RNNE was the best fit (lowest F statistic) for 25 and ten of these were not significantly different from RNNE. The JF model was best for all of the remaining ten individuals but in all cases the data were significantly different from the JF model.

CONCLUSION 5. Failure of the RNNE is *not* due to a few "irrational" people. Almost all agents
experienced the "curse" and bid consistent with "curse" behavior.

Evidence. Table 6 gives the number of times that the winning bidder had the highest signal or the second highest signal. The game theoretic model predicts that the individual with the highest signal will win the auction. In each experiment over half of the auctions were won by the subject with the highest signal. As can be seen, decisions that resulted in winning the auction were not the result of some type of impulsive move by some agent with a lower signal. Nor was it the case that bids differed so much across subjects that the fundamental game theoretic proposition that a positive relationship exists between bids and signals is destroyed. In fact, the empirical result in Table 5 that $\beta = 1$ is strong support for that part of the theory.

Table 7 gives the number of times each agent won the auction and the number of times each agent lost money as a result of winning the auction with a bid that was too high. As can be seen, the experience happens to most individuals. Of the 28 people who won two or more auctions, 20 of them lost money 50 percent of the time or more. Of the 35 subjects, only 8 never lost money.

5. CLOSING REMARKS

One question appears to be answered clearly. A winner's curse can be observed. A presumption exists about an answer to a second question. That is, it appears that the curse can persist over many experiences. A major puzzle remains. Of the models studied, the best is the *risk neutral Nash equilibrium model* but that model predicts that the curse will not exist.

Part of the difficulty with further study stems from the lack of theory about the behavior of common value auctions with risk aversion. Closed-form solutions which permit researchers to estimate models of "subrational" behavior have not been worked out. If the effect of risk aversion is to raise the bidding function as it does in private value auctions, then risk aversion together with the *judgmental failure model* might resolve the puzzle.

APPENDIX

APPENDIX — INSTRUCTIONS

Instructions for buyers auctions are those that were used by Kagel and Levine and can be found in the Appendix to their paper. Instructions were handed out to subjects and all examples were also on the chalkboard. After the instructions were retrieved by the subjects they were read aloud by the experimenter and then the following "test" was administered.

1. Buyer A gets a signal value of $105.00. He bids $100.00 but he is not the high bidder. His _____ (profit/loss) is $_____ .

2. Buyer B gets a signal value of $75.00. She bids $60.00 and she is the high bidder. The value of the item is $65.50. Her _____ (profit/loss) is $_____ .

3. Buyer C gets a signal value of $161.00. He bids $132.00 and he is the high bidder. The value of the item is $131.00. His _____ (profit/loss) is $_____ .

4. Buyer D gets a signal value of $120.00. The value of epsilon is $30.00. Therefore, Buyer D knows that the value of the item is between $_____ and $_____ .

Instructions for the seller auctions are as follows:

GENERAL

This is an experiment in the economics of market decision making. The instructions are simple and if you follow them carefully and make good decisions you might earn money which will be paid to you in cash.

In this experiment we will create a market in which you will act as sellers of a commodity in a sequence of trading periods. One unit of the commodity will be auctioned off in each trading

period. There will be several trading periods.

Your task is to submit written asks for the commodity. The precise value of the commodity at the time you make your ask will be unknown to you. Instead, each of you will receive some information regarding the value of the commodity which you may find useful in determining your ask. The process of determining the value of the commodity and the information you receive will be described below.

The currency in these markets is francs. Each franc is worth $_____ to you.

The low ask gets the item and makes a profit equal to the ask. If you do not make the lowest ask on the item, you will earn the value of the commodity.

During each trading period you will be selling in a market in which all of the other participants are also selling. After all asks have been handed in, all signals and asks will be posed on the blackboard. We will circle the low ask and post the value of the item.

The value of the auctioned commodity (V) will be assigned randomly and will lie between 150 and 1500 inclusively. For each auction, any value within this interval has an equally likely chance of being drawn. The value of the item can never be less than 150 nor more than 1500. The values V are determined randomly and independently from auction to auction. A high value of V in one period tells you nothing about the likely value in the next period. It does not even preclude the same value of V appearing in later periods.

Although you do not know the precise value of the item in any particular trading period, you will receive information which will narrow down the range of possible values. This will consist of a private information signal which is selected randomly from an interval whose lower bound is V

minus epsilon, and whose upper bound is V plus epsilon. Any value within this interval has an equally likely chance of being drawn and being assigned to one of you as your private information signal.

Throughout this experiment, the value of epsilon is 200.

PRIVATE INFORMATION SIGNALS

Although you do not know the precise value of the item in any particular trading period, you will receive information which will narrow down the range of possible values. This will consist of a private information signal which is selected randomly from an interval whose lower bound is V minus epsilon, and whose upper bound is V plus epsilon. **ANY VALUE** within this interval has an **EQUALLY LIKELY** chance of being drawn and being assigned to one of you as your private information signal. You will always know what the value of epsilon is.

For example, suppose that the value of the auctioned item is 762 and that epsilon is 200. Then each of you will receive a private information signal which will consist of a randomly drawn number that will be between 562 (V epsilon = 762 200) and 962 (V + epsilon = 762 + 100). Any number in this interval has an equally likely chance to be drawn as your signal value.

The line diagram below shows what is going on in this example.

EXAMPLE

The value of the auctioned item is 762. This is the information each seller received, and the asks each seller made:

SELLER #	SIGNAL VALUE	ASK
1	590	703
2	756	900
3	838	947
4	634	778
5	716	775
6	847	920
7	642	825

In this example Seller #1 submitted the lowest bid, so he sells the item. His profit is the sale price 703. Seller #1 received 703 while the other sellers receive the value 762.

You will note that the value V of the auctioned item must always be between your signal value minus epsilon, and your signal value plus epsilon.

Finally, you may receive a signal value below 150 or about 1500. This merely indicates that the value V of the auctioned item is close to 150 or 1500.

Your signal values are strictly private information. **DO NOT REVEAL THEM TO ANYONE ELSE.** You are **NOT** to reveal your asks or profits, nor are you to speak to any other subject while the experiment is in progress.

You will not be told the value of V until after all the asks have been collected and posted.

No one may ask less than 0 for the item, nor may anyone ask more than 1700 (which is the maximum value of V plus epsilon). In case of ties for the low ask, we will flip a coin to decide

who gets the item.

Are there any questions?

TABLE 1 — PARAMETER RESTRICTIONS IMPOSED BY

COMPETING THEORETICAL MODELS

Models	Buying			Selling		
	α	β	γ	α	β	γ
Risk Neutral Nash Equilibrium	−30	1	1	200	1	−1
Strategic Discounting	−8.6	1	0.14	57.1	1	−0.14
Naive	0	1	0	0	1	0
Private Value	−433	1	0	28.6	1	0

TABLE 2

WINNERS' AVERAGE PROFIT AND LOSS FREQUENCIES
FOR ALL EXPERIMENTS
In Dollars (Francs)

Experiment	Average Profit Per Period		Average RNNE Predicted Profit Per Period*		Number of Periods with Winners' Loss / Total Number of Periods
1. (Buyer)	-1.67	(-1.67)	11.13	(11.13)	12/20
2. (Buyer)	-3.60	(-3.60)	8.85	(8.85)	10/17
3. (Seller)	-0.022	(-8.88)	0.196	(78.44)	8/17
4. (Seller)	0.021	(20.91)	0.069	(69.28)	13/35
5. (Seller)	-0.013	(-18.55)	0.050	(70.85)	25/40

* The given RNNE equation is valid only for: $\underline{x} + \varepsilon \leq x_i \leq \bar{x} - \varepsilon$. Some of the winners' signals were not in this range, so no predicted RNNE profit is possible. Therefore this average includes only periods for which the RNNE predicted profit can be calculated.

TABLE 3 — FREQUENCY OF LOSSES FOR WINNERS IN ALL EXPERIMENTS

In Dollars (Francs)

	Experiments				
	1. Buyers	2. Buyers	3. Sellers	4. Sellers	5. Sellers
Periods 1 -10					
Number of periods of loss	8/10	8/10	5/10	6/10	5/10
Average profit per period	−7.90 (−7.90)	−8.31 (−8.31)	−0.075 (−29.80)	−0.048 (−48.20)	0.001 (1.10)
Average RNNE profit per period[a]	4.53 (4.53)	5.70 (5.70)	0.177 (70.96)	0.060 (60.44)	0.048 (68.71)
Periods 11 - 20					
Number of periods of loss	4/10	2/7	3/7	2/10	7/10
Average profit per period	4.57 (4.57)	3.12 (3.12)	0.053 (21.00)	0.032 (31.60)	−0.016 (−22.40)
Average RNNE profit per period[a]	18.47 (18.47)	13.58 (13.58)	0.212 (84.85)	0.048 (48.15)	0.037 (52.68)
Periods 21 - 30					
Number of periods of loss				3/10	5/10
Average profit per period				0.058 (58.40)	−0.004 (−6.10)
Average RNNE profit per period[a]				0.104 (104.02)	0.090 (128.91)
Periods 31 - 40					
Number of periods of loss				2/5	8/10
Average profit per period				0.063 (62.80)	−0.033 (−46.80)
Average RNNE profit per period[a]				0.065 (65.34)	0.024 (33.72)

[a] The given RNNE equation is valid only for: $\underline{x} + \varepsilon \leq x_i \leq \bar{x} - \varepsilon$. Some of the winners' signals were not in this range, so no predicted RNNE profit is possible. Therefore this average includes only periods for which the RNNE predicted profit can be calculated.

TABLE 4 — F-STATISTICS FOR HYPOTHESIS THAT PREDICTIONS OF
RESTRICTED REGRESSION ARE THE SAME AS UNRESTRICTED
REGRESSIONS (DEGREES OF FREEDOM; 5% F VALUES)

Models	Buying Auctions	Selling Auctions
RNNE	30.53 (3,226; 2.64)	5.93 (3,465; 2.61)
Strategic Discounting	133.84 (3,226; 2.64)	91.22 (3,465; 2.61)
Naive	341.12 (3,226; 2.64)	160.13 (3,465; 2.61)
Private Value	224.87 (3,226; 2.64)	122.99 (3,465; 261)

TABLE 5 — ESTIMATED COEFFICIENTS POOLED INDIVIDUALS

(Standard Errors)

Experiments 1 and 2			Experiments 3, 4, and 5		
α	β	γ	α	β	γ
−22.694	.998	.514	341.658	.863	.255
(3.156)	(.024)	(.674)	(38.335)	(.046)	(1.585)

TABLE 6

NO. OF TIMES WINNER HAD HIGHEST AND SECOND HIGHEST SIGNAL

Experiment	Highest	Second Highest	No. of Periods
1. (Buyer)	14	3	20
2. (Buyer)	9	8	17
3. (Seller)	11	3	17
4. (Seller)	21	8	35
5. (Seller)	25	7	40

TABLE 7 — NUMBER OF WINNING BIDS SUBMITTED AND

NUMBER OF TIMES LOSSES OCCURRED: BY SUBJECT, BY EXPERIMENT

Subject		Experiments				
		1	2	3	4	5
		20 Periods	17 Periods	17 Periods	35 Periods	40 Periods
1	# of winning bids	4	5	6	3	7
	# of times lost money	3	4	2	2	4
2	# of winning bids	3	1	1	6	7
	# of times lost money	2	0	0	3	4
3	# of winning bids	0	1	4	0	5
	# of times lost money	0	1	2	0	4
4	# of winning bids	5	2	1	5	4
	# of times lost money	3	2	0	2	2
5	# of winning bids	4	3	2	6	4
	# of times lost money	3	1	2	2	2
6	# of winning bids	2	2	2	12	7
	# of times lost money	0	0	2	3	4
7	# of winning bids	2	3	1	3	6
	# of times lost money	1	2	0	1	5

FIGURE 1

PER PERIOD PROFIT AND RNNE PREDICTED PROFITS FOR
EXPERIMENT 5
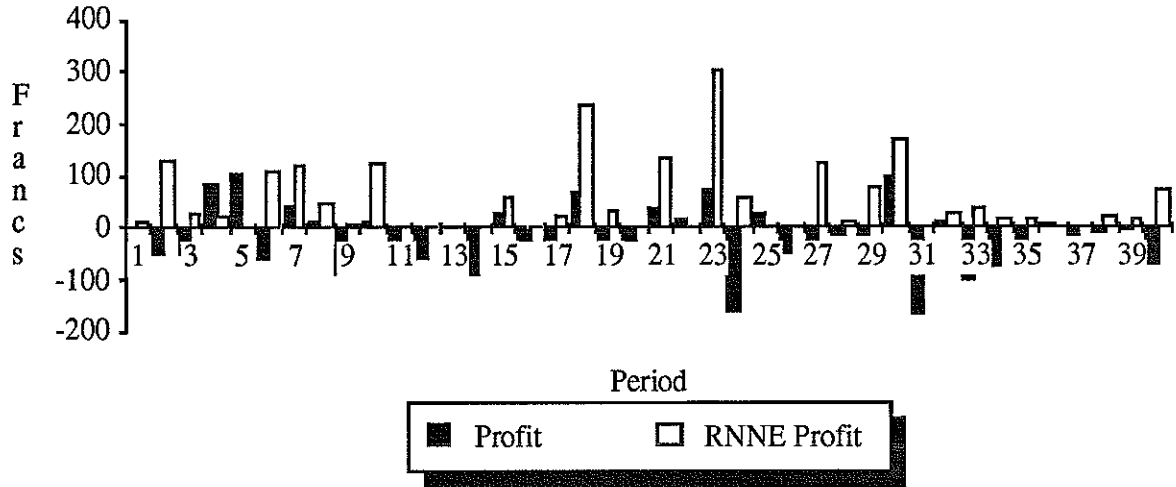
Note: In periods 5, 11, 13, 20, 22, 25, 26, 31, 36, and 37 the signal is not in the interval
$[\underline{x} + \varepsilon \leq x_i \leq \overline{x} + \varepsilon]$, which is the valid range for the given RNNE function. Therefore no
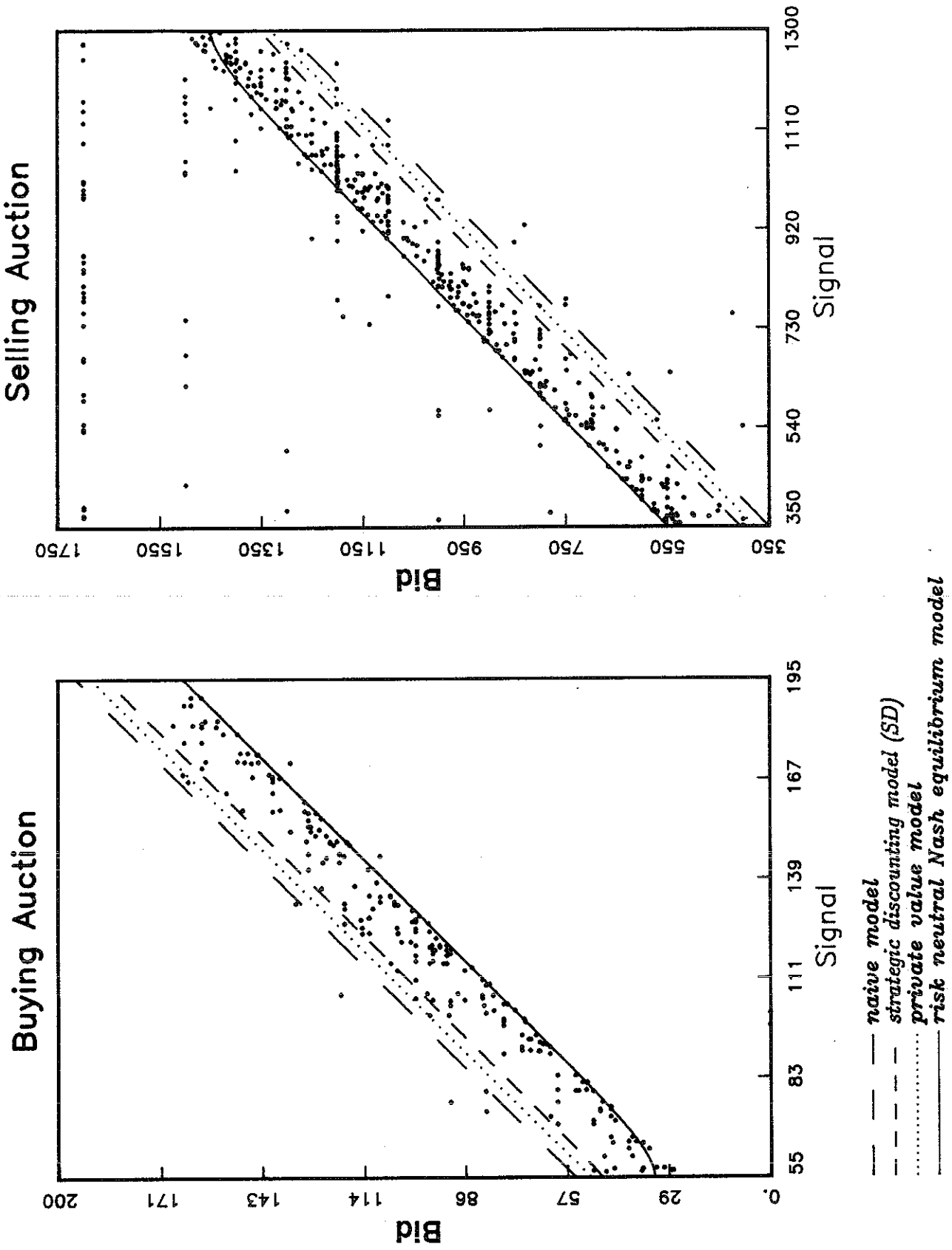RNNE predicted profits are shown.

Buying Auction

Selling Auction

— naive model
—— strategic discounting model (SD)
- - private value model
· · · · risk neutral Nash equilibrium model

Figure 2:

(Signal, Bid) Pairs for all Individuals and all Experiments

FOOTNOTES

*   Barry Lind is a senior undergraduate and Charles Plott is a professor of economics at the California Institute of Technology. The financial support of the National Science Foundation and the Caltech Experimental Economics and Political Science Laboratory is gratefully acknowledged. We also wish to thank Michael Malcom for help and suggestions with the experimental design. We also wish to thank Hsing-Yang Lee for his help with the graphics.

1.   Only one subject made sufficient loss to be required to work. He worked about one hour to cover an $8 loss.

2.   Obviously *risk aversion* is a natural extension. We have been unable to find a closed-form solution for the bidding functions.

REFERENCES

Dyer, Douglas, John H. Kagel, and Dan Levin. "A Comparison of Naive and Experienced Bidders in Common Value Offer Auctions: A Laboratory Analysis." *The Economic Journal.* March 1989, 99, 108-115.

Hansen, Robert G., and John R. Lott, Jr. "The Winner's Curse and Limited Liability: Reviewing Kagel's and Levin's Theory and Evidence." August 1988. Mimeographed.

Kagel, John H., and Dan Levin. "First-Price, Sealed-Bid, Common Value Auctions: Some Initial Experimental Results." Center for Public Policy Discussion Paper 84-1, University of Houston, 1984.

Kagel, John H., and Dan Levin. "The Winner's Curse and Public Information in Common Value Auctions." *American Economic Review*, December 1986, 76, 894-920.

Milgrom, Paul R. and Robert J. Weber. "A Theory of Auction and Competitive Bidding." *Econometrica.* September 1982, 50, 1089-1122.

Wilson, Robert. "A Bidding Model of Perfect Competition." *Review of Economic Studies.* 1977, 44, 511-518.