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Behavior in Second-Price Auctions by Highly Experienced eBay Buyers and Sellers*

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Abstract

When second-price auctions have been conducted in the laboratory, most of the observed bids have been "overbids" (bids that exceed the bidder's value) and there are very few underbids. Few if any of the subjects in those experiments had any prior experience bidding in auctions. We report on sealed-bid second-price auctions that we conducted on the Internet using subjects with substantial prior experience: they were highly experienced participants in eBay auctions. Unlike the novice bidders in previous (laboratory) experiments, the experienced bidders exhibited no greater tendency to overbid than to underbid. However, even subjects with substantial prior experience tend not to bid their values, suggesting that the non-optimal bidding of novice subjects is robust to substantial experience in non-experimental auctions. A key determinant of bidding behavior was whether a subject had ever been a seller on eBay.

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1 Introduction

In a second-price auction, bidding one's value is always a dominant strategy. However, when second-price auctions (SPAs, for short) have been conducted in the laboratory a substantial proportion of the subjects overbid (i.e., they submit bids that exceed their values). There are very few underbids.[1] Why do so many subjects fail to choose the dominant-strategy value bid? And given that they don't bid their values, why is overbidding so much more prevalent than underbidding?

The subjects in the laboratory experiments were students, who typically had little if any prior experience bidding in auctions. We report on an experiment in which the subjects instead had a great deal of experience: each subject had participated in at least fifty eBay auctions. The subjects were recruited directly from eBay, and the experiment was conducted on the Internet instead of in the laboratory.

The behavior of these experienced subjects was similar in one respect to behavior observed in previous SPA experiments: just as in the laboratory experiments with inexperienced subjects, the subjects in our online experiment did not generally bid their values. However, in contrast with all previous SPA experiments, underbidding was just as prevalent in our experiment as overbidding. Moreover, it was subjects who had prior experience *selling* in eBay auctions who tended on average to underbid. Subjects who had never sold anything in an eBay auction (i.e., they had only been bidders) tended on average to overbid. This suggests that prior bidding experience does affect behavior, and that the *kind* of experience one has makes a difference.

Kagel and Levin (1993) (henceforth K&L) conducted one of the first experiments with SPAs. The subjects in their experiment were assigned independent private values for the item being auctioned. In SPAs with five bidders, 67% of the bids exceeded the bidder's value and fewer than 6% of the bids were less than the bidder's value. K&L obtained similar results in SPAs with ten bidders. Additionally, Kagel, Harstad, and Levin (1987) and Harstad (2000) report evidence of overbidding in SPAs with affiliated private values.

Kagel, Harstad, and Levin suggest that overbidding in SPAs is due to subjects' "illusion that [bidding in excess of value] improves the probability of winning with no real cost to the bidder, as the second-high-bid price is paid." (p. 1299) Moreover, they argue that the reason this behavior does not go away with repeated play

[1] Previous studies by Coppinger, Smith, and Titus (1980) and Cox, Roberson, and Smith (1982) report underbidding, but in these experiments subjects were not permitted to bid above their private values.

is that "punishment probabilities are weak, given that bidders start with the illusion that bids in excess of [value] increase the probability of winning without materially affecting the price paid, and the majority of the time the auction supports this supposition" (p. 1299). In short, subjects who overbid in SPAs are rarely confronted with the consequences of their "mistake." Hence, the learning that often occurs when laboratory subjects participate repeatedly in the same institution may not eliminate overbidding in second-price auctions.

The obstacles to learning that are inherent in SPAs may be magnified by the experimental setting: the laboratory SPA experiments were of limited duration (typically about two hours), which might not allow sufficient scope for a subject to learn that value-bidding is a good strategy. People with some experience in real-world auctions, on the other hand, might be expected to bid in a way that conforms more closely to the theory.[2]

Experience in eBay auctions might be especially relevant, because the bidding system used by eBay is a dynamic second-price auction. On eBay, auctions of a single item are conducted as ascending-price auctions in which bidders submit "proxy" bids. At the close of an eBay auction, like in a second-price sealed-bid auction, the bidder with the highest proxy bid wins the auction and pays the second-highest proxy bid (plus the bid increment). An eBay auction is, however, dynamic – throughout the auction bidders observe who is the current high bidder and the amount of the current bid (given the proxy bids made so far), and they may increase their proxy bids. eBay advises bidders to "Decide the maximum you're willing to pay and enter this amount." Elsewhere on its website eBay advises bidders to think of their proxy bid as the amount they would tell a friend to bid for them if they were unable to attend the auction in person.[3] In effect, eBay is advising bidders to follow their weakly dominant

[2] Prior experience in the laboratory can also affect behavior in SPAs. Harstad (2000) shows that subjects with prior experience in English auctions performed better in SPAs than inexperienced subjects. In a different context, J. List's (2003) beautiful field experiment provides evidence that traders who have more experience are less likely to exhibit the anomaly often referred to as the "endowment effect." V. Smith (1991) famously suggested that "... real people do not solve decision problems by thinking about them in the way we do as economic theorists. ... [They] tend to learn by watching, listening, and doing." Thus, people with substantial experience in a particular economic activity might be expected to perform better than subjects who are engaging in the activity for the first time in a two- or three-hour laboratory experiment.

[3] eBay's help page on proxy bidding has the following: "An easier way to think of this [a proxy bid] would be to think of the bidding system standing in for you as a bidder at a live auction. Let's say you need to be somewhere and can't be present to bid and you ask a friend to go to the auction

strategy in an SPA of bidding their value.[4]

We recruited subjects from eBay whose "feedback profiles" indicated that they had participated in at least fifty eBay auctions. The subjects participated in second-price sealed-bid auctions that we conducted on the Internet. Subjects were sent an invitation, by email, that provided a link to a personalized auction web page. The web page described the rules of the auction, it provided the subject with his or her private value for the item being auctioned, and it provided a form for submitting a bid.

The data from our online second-price auctions reveal that even these highly experienced eBay bidders did not generally bid their values. However, in contrast to the tendency to overbid but rarely underbid that the inexperienced bidders in laboratory experiments displayed, the experienced bidders in our online auctions exhibited no greater tendency to overbid than to underbid. The number of subjects who underbid (41% of subjects) was almost exactly the same as the number who overbid (38%). The data do suggest, however, that prior experience as a seller affects how one bids: subjects who had never sold an item on eBay exhibited a slight tendency to overbid, while subjects who had sold one or more items on eBay tended, on average, to underbid.

2 Experimental Procedures

Our goal was to recruit subjects who were highly experienced auction participants. eBay is an excellent venue for this purpose: eBay's publicly available feedback scores make it easy to identify people who have participated in a large number of eBay auctions. Every eBay user has a feedback profile: after the close of an eBay auction the winning bidder (and only the winning bidder) can leave feedback about the seller

and bid for you. You tell your friend that you are willing to pay $25 for an item you saw. The auctioneer starts the bidding at $5 and your friend bids the $5. Then another bidder bids $6 and your friend then bids $7 on your behalf. Then another bidder bids $12 and your friend bids $13 for you. This would keep going until either your friend wins the item for you at or below $25 or the bidding exceeds the $25 you were willing to pay."

[4]Whether bidders follow this advice is another matter. In practice, bidders sometimes submit multiple bids or carefully time their bid, placing it several seconds before the auction closes. Both strategies seem inconsistent with simple value bidding. Roth and Ockenfels (2002) point out that the combination of eBay's "hard" close and the uncertain processing of last-second bids can make eBay auctions strategically different from SPAs.

in the seller's feedback profile, and the seller can leave feedback in the winning bidder's profile. An eBay user's feedback score at any time is the number of positive entries in his profile minus the number of negative entries. Feedback scores typically understate a user's experience because (i) users often fail to leave feedback after a transaction, (ii) bidders who do not win the auction cannot receive feedback, and (iii) feedback cannot be reported for an auction in which the item does not sell.[5] Thus, an eBay user is likely to have participated in many more auctions than the number given by his feedback score.

The Auction

Each of our experimental auctions had 5 bidders, whose values where randomly drawn from the uniform distribution on the interval [$25,$125]. In addition to their profits or losses from bidding in the auction, subjects received a $15 reward for participating. Hence, for the highest bidder, his total earnings were $15 plus his value minus the second highest bid. (If this total was negative, the loss was forgiven and the subject was paid nothing.) The other four bidders earned just the $15 participation reward. Subjects were fully informed of how their earnings would be determined. It is easy to verify that value bidding remains a weakly dominant strategy in a second-price auction with a $15 limit on losses.

The Subjects

We recruited subjects by first downloading eBay Web pages for auctions in a specific category (Morgan silver dollars) that were listed as "Ending On The Current Day." The following day, after these auctions had closed, we examined the bid history of each auction. For every bidder in the bid history with a feedback score of 50 or higher we recorded (i) the bidder's eBay ID, (ii) his maximum bid, (iii) the number of times he had bid, and (iv) his feedback score. We continued this process until 50 unique IDs had been obtained. The process was then repeated to obtain 50 additional IDs from auctions of "Golden Age" collectable comics. We recruited subjects from these two auction categories because these auctions typically had many bidders, thereby reducing the difficulty of obtaining eBay IDs, and because bids in these auctions were in approximately the same range as the subjects' values would be in our experimental auction. Had we instead recruited subjects from eBay auctions

[5] Moreover, obtaining a negative feedback entry reduces the bidder's feedback score even though his experience has increased. Negative feedback, however, is generally a very small fraction of all feedback.

where, for example, most bids were below \$15, we might have introduced a significant bidding bias in our own auction.

A first set of auctions was conducted in a series of six sessions separated by a few days. In each session an invitation to participate in our experimental auction was sent via email to each one of the 100 eBay IDs we had collected for that session, as described above. A total of 67 people (out of 600) accepted our invitation and submitted bids.

With the highest possible value equal to five times the lowest possible value, those who were assigned lower values might have been less likely to participate in our auction. However, Figure 1 indicates that this did not happen. Figure 1 depicts the empirical *c.d.f.* of the values used when inviting subjects in each session of round 1 (drawn from the uniform distribution on [\$25,\$125]) and also the empirical *c.d.f.* of the values of the subjects who actually submitted bids at round 1. The two *c.d.f.'*s are virtually identical: the value assigned to an invitee apparently did not, on average, influence his decision whether to participate.

Figure 1 goes here.

Those who received our invitations might have been skeptical that they would actually get paid for their participation, and this might in turn have affected the bids they placed. In order to address this issue we subsequently invited our participants to a second auction, after they had actually received their first-round earnings. In this second round of auctions the rules were the same, but a new value was randomly drawn for each subject from the same uniform distribution as before. In this second round of auctions, several months after the first round, 37 of the original 67 subjects submitted bids. Bidding behavior did not appear to differ across the two rounds.

How the Auctions Worked

Each emailed invitation specified the deadline for submitting a bid, then directed the recipient to a Web page personalized uniquely to that invitee. The Web page described the rules of the auction, then asked three "quiz questions" about the auction rules, and then provided the subject with his value for the auctioned item.[6] A subject had no direct monetary incentive to answer the questions correctly, but was required to give answers to all three questions before he was allowed to submit a bid. The answers to the questions provide some indication of whether a subject understood

[6] A sample webpage is available at www.econ.ucsb.edu/~garratt/auction/sample.html. The text of the invitation email is available here: www.econ.ucsb.edu/~garratt/auction/email.html.

the rules of the auction; 70% of the subjects answered all three questions correctly and another 24% answered two of the three questions correctly.

At the end of each session the bids were placed into groups of five in the order in which they arrived.[7] The subjects' earnings were calculated, and each subject was sent an email describing the bid and value of each bidder in his auction, as well as his own earnings. Each subject was then mailed a money order containing his earnings.

3 Analysis of Bidder Behavior

Table 1 reports the number of underbids, value bids, and overbids by our subjects. The table also shows the comparable numbers for the subjects in the K&L experiment. For the sake of comparison we retain the K&L definition: a value bid is any bid within five cents of the subject's value, and underbids and overbids are bids that differ from value by more than five cents. The first conclusion we draw is that value bidding was observed no more often in our auctions than in the K&L auctions: 21% of bids in our experiment were value bids and 27% of the K&L bids were value bids.

Experiment	Under bids	Value bid	Over bid	Total
eBay	43 (41.3%)	22 (21.2%)	39 (37.5%)	104 (100%)
K&L	27 (5.7%)	127 (27.0%)	316 (67.2%)	470 (100%)

Table 1: Frequency of under, over, and value bidding

Conclusion 1: *The frequency of value bidding in our experiment is indistinguishable from its frequency in the K&L experiment. Only about one quarter of the bids are value bids in each case.*

Table 1 nevertheless indicates that bidding behavior in our auctions was dramatically different than in the K&L auctions. Subjects in the K&L auctions submitted more than ten times as many overbids as underbids (67% of bids were overbids and only 6% were underbids), which led K&L to conclude that overbidding is pervasive

[7] Each auction had five bidders, but the number of bids received in a session was typically not a multiple of five. The "remainder group" in each session was filled out with bids randomly selected from the other groups. For example, if seven bids were received, then bids 1-5 formed one group which determined the payoffs of bidders 1-5. Bids 3-7, say, formed a second group, which determined the payoffs of only bidders 6 and 7.

in SPAs and that underbidding is relatively unusual. In our auctions, however, only 38% of the bids were overbids and 41% were underbids.

Conclusion 2: *In our experiment the frequencies of overbidding and underbidding are indistinguishable from one another. There is no more tendency to overbid than to underbid.*

Our conjecture at the outset was that in SPAs bidding by people with significant experience in real-world auctions might conform more closely to the theory than bidding by inexperienced laboratory subjects. We have already seen in Conclusion 1 that the frequency of value (i.e., "correct") bidding in our data does not support this conjecture. Table 2 provides further evidence that the amount of a bidder's experience in real-world auctions does not affect bidding behavior. In Column (a) of Table 2 the magnitude (i.e., the absolute value) of subjects' bidding errors (the difference between value and bid) is regressed against the amount of a subject's experience, where experience is measured by subjects' feedback scores. The regression coefficient for feedback score does not differ significantly from zero: the amount of experience does not seem to affect bidding behavior. This is perhaps not surprising, since all of our subjects were highly experienced.

Conclusion 3: *Among our subjects, who were all highly experienced, variations in the amount of their experience have no systematic effect on their bidding behavior.*

While the *amount* of a subject's experience seems to have no effect on his behavior, the *kind* of experience a subject has appears to make a significant difference in bidding behavior. About half of our subjects had sold items on eBay, and the other half had only been bidders, never selling anything.[8,9] Furthermore, those who had been sellers typically had a great deal of experience as sellers: the median feedback count for them *as sellers* was 57. Column (b) of Table 2 shows that subjects who have experience as a seller on eBay tend to bid significantly less than subjects who have only bought, bidding $14.19 less on average. Column (c) shows that experience as a seller remains

[8] Our auctions were conducted in June 2001 and January 2002. In July 2001 eBay altered its feedback system so that new feedback indicated whether the user was a buyer or a seller in a transaction. In September 2002 we counted the number of buyer and seller feedbacks in each of our subjects' feedback profiles. We assume that this ex-post measure of the subject's type of eBay experience (buyer or seller) is representative of his experience at the time he participated in our auction.

[9] The number of subjects who had sold and the number who had only bid are 34 and 29, respectively.

significant even when controlling for the type of auction a subject was recruited from (Morgan dollar or comic), and controlling for the highest bid and the number of bids he placed in that auction.

The regression results reported in Table 2 exclude 11 bids of more than \$1000. The majority of these bids (7 of 11) were made by subjects with experience as sellers, and hence to exclude them potentially biases our conclusions regarding seller experience. To address this possibility, we examine the effect of seller experience on the frequency of under, value, or overbidding, using all 97 bids (and, in particular, including bids over \$1000) for which we can distinguish buyer and seller experience.[10] Table 3 shows that subjects who had been sellers behaved quite differently than those who had not. Subjects who had been sellers submitted 51% underbids and 32% overbids; those who had never sold submitted 30% underbids and 46% overbids, almost the exact reverse of the frequencies for those who had been sellers. We can reject at the 10% significance level (the p-value is .07) the hypothesis that the sellers' and the buyers' frequencies are realizations of independent draws from the same multinomial distribution.

Experiment	Under bids	Value bids	Over bids	Total
eBay – only buyer	13 (29.5%)	11 (25.0%)	20 (45.5%)	44 (100%)
eBay – sometime seller	27 (50.9%)	9 (17.0%)	17 (32.1%)	53 (100%)

Table 3: Frequency of under, over, and value bidding by type of experience.

Applying the Mann-Whitney rank-sum test to the entire bid distributions of sometime-sellers and only-buyers produces a similar result: the p-value of the Mann-Whitney test statistic is .093, a rejection at the 10% level that the difference of bids and values for the two groups of subjects were drawn from the same distribution. The two distributions of bid-minus-value are depicted in Figure 2, for differences of less than \$100.

Conclusion 4: *Subjects who had sold on eBay exhibited a significantly lower frequency of overbidding and a significantly higher frequency of underbidding than subjects who had bought on eBay but never sold. The two groups' distributions of bids-minus-values do not appear to be the same: those who had sold typically bid less relative to their values than those who had not sold.*

[10]Four of our subjects, who made 7 bids in total, were no longer registered users in September 2002, and hence their feedback profile was unavailable when we counted the number of buyer and seller feedbacks.

Figure 2 goes here.

Revenue and Efficiency

Our Conclusion 1, above, reinforces results obtained previously in second-price-auction experiments: bidders (even experienced eBay bidders) generally do not bid their value, as the theory suggests they should. Moreover, our Conclusion 4 indicates that bidders who are experienced as sellers bid non-optimally but differently than bidders with no selling experience.

But how great is the effect of non-optimal bidding? What is its effect on the revenue the seller will obtain in the auction? On the surplus a bidder can expect? Or on the auction's efficiency?

Seller's Revenue

In our auction and in the K&L auction, the left-most column of Table 4 shows the *ex-ante* expected revenue that would accrue to the seller in the auction – i.e., the revenue the seller can expect before bidders' values are drawn – assuming the bidders all submit bids equal to their values. The center column again shows the seller's expected revenue if bidders bid their values, but now this expectation is determined from the empirical distribution of the values actually drawn in the experiment. The right-most column shows the expected revenue to the seller when five bids are randomly drawn from the empirical distribution of the subjects' actual bids.

	Uniform Draws	*Values Actually Drawn*	
	Value Bidding	Value Bidding	Actual Bids
eBay	\$91.67	\$92.09	\$90.97
K&L	\$18.87	\$18.28	\$19.26

Table 4: Effect of suboptimal bidding on seller revenue.

While there were nearly equal numbers of underbids and overbids by the eBay subjects (Table 1), the net effect on seller revenue is slightly negative: average revenue is only \$90.97, a reduction of \$1.12, or about one percent, due to non-optimal bidding. (The average revenue calculation is possibly biased downward, however, by the bidders' \$15.00 limited liability: whenever the winning bidder's bid was more than \$15 above the second-high bid, we state seller revenue as only the second-high bid plus \$15.) In the K&L experiment the seller's average revenue, given the empirical distribution of bids, is 98 cents higher than would be expected had subjects bid their value – an increase in revenue to the seller of about five percent.[11]

Subjects' non-optimal bidding in SPAs thus appears to have only a modest effect (in expectation) on seller revenue. Note, however, that the percentage effect on the seller's *profit*, or *surplus*, would generally be larger (possibly *much* larger), since that depends also on his reservation value, or cost, for the item at auction. For example, if the seller's reservation value in our auctions were \$75 (the midpoint of the bidders' distribution of values), then the \$1.12 expected reduction in his revenue due to non-optimal bidding yields about a 6 1/2% reduction in his expected profit. The K&L 5% increase in seller revenue would similarly be larger as a percentage of his profit.

Bidders' Surplus

The effect on the bidders' expected surplus (i.e., their net earnings) from failing to bid their values is larger than the effect on seller revenue. Table 5 reports the average expected surplus (averaged across all 104 values that were actually drawn) from value bidding and from the bids the subjects actually placed. The left column reports the average expected surplus if each subject had bid his value, given the values that were actually drawn. The remaining two columns report a bidder's expected surplus if the opposing four bids are drawn at random from the actual bids placed: the center column is the average expected surplus (averaged across the 104 actual values) from value bidding; and the right column reports the average expected surplus from the bids actually placed.

	vs Value Bids	*vs Actual Bids*	
	Value Bidding	Value Bidding	Actual Bids
All bidders	\$3.84	\$2.77	\$1.05
eBay buyers	\$3.05	\$2.28	\$0.75
eBay sellers	\$4.46	\$3.14	\$1.03

Table 5: Effect of nonoptimal bidding on bidders' expected surplus.

The left column is the benchmark against which to evaluate the cost to bidders of failing to bid their values: given the values actually drawn, it tells us the expected surplus had everyone placed the bid that was optimal for him, given his own value. Thus, as a group our subjects sacrificed \$2.79 in expected surplus per bidder, more than 70% of the maximum achievable expectation, \$3.84. Given that other subjects

[11] This expected revenue calculation for K&L assumes a \$10 limit on liability.

were bidding non-optimally, the typical subject's non-optimal bid still reduced his expected surplus by more than 60%, to \$1.05 from the \$2.77 in expected surplus he could have achieved.

Efficiency

The effect of suboptimal bidding on auction efficiency is more striking. Given the empirical distribution of bid-value combinations in our experiment, the probability is only .46 that in a randomly selected group of 5 of our subjects the bidder with the highest value would also be the bidder who placed the highest bid. If we exclude from the empirical distribution the bid-value combinations in which the bid is above \$1000, this probability rises only to .56. In the first paid round of K&L's experiment, following several practice rounds, the subjects achieved an efficiency level of .69.

4 Concluding Remarks

eBay's auction institution operates much like a second-price auction. However, we find that even when highly experienced eBay participants bid in an actual second-price sealed-bid auction, they do not typically bid their values, as the theory suggests they should. Significant experience in a similar setting does not seem to help bidders learn how to bid optimally in second-price sealed-bid auctions. Thus, the non-optimal bidding previously discovered with student subjects in the laboratory appears to be a phenomenon that is robust even to substantial experience in non-experimental auctions.

In contrast with experiments in the laboratory, where subjects have been observed to typically overbid and almost never underbid, subjects in our experiment were just as likely to underbid as to overbid. Of course, this difference might be in part a result of differences in the experimental design. Since our experiment was conducted over the Internet, it necessarily used different instructions than the K&L experiment. For example, a quiz question in our instructions illustrated that a subject could lose part or all of his participation reward if he won the auction and the second highest bid was higher than his own value. This possibility was not explicitly mentioned in the K&L instructions.

However, a more likely explanation of the significantly larger propensity of subjects in our experiment to underbid is the presence of many subjects with substantial experience *selling* in eBay auctions. Subjects with experience as sellers bid significantly less in a second-price auction, on average, than subjects who have only bought on eBay. This suggests that the revenue and efficiency properties of auctions might depend in a systematic way on the backgrounds and prior experiences of the bidders.

This highlights an advantage of using eBay participants as experimental subjects: eBay provides a rich set of publicly available data on each of its auctions, and this allows the experimenter to apply data from subjects' field experience to try to explain their behavior in experiments.

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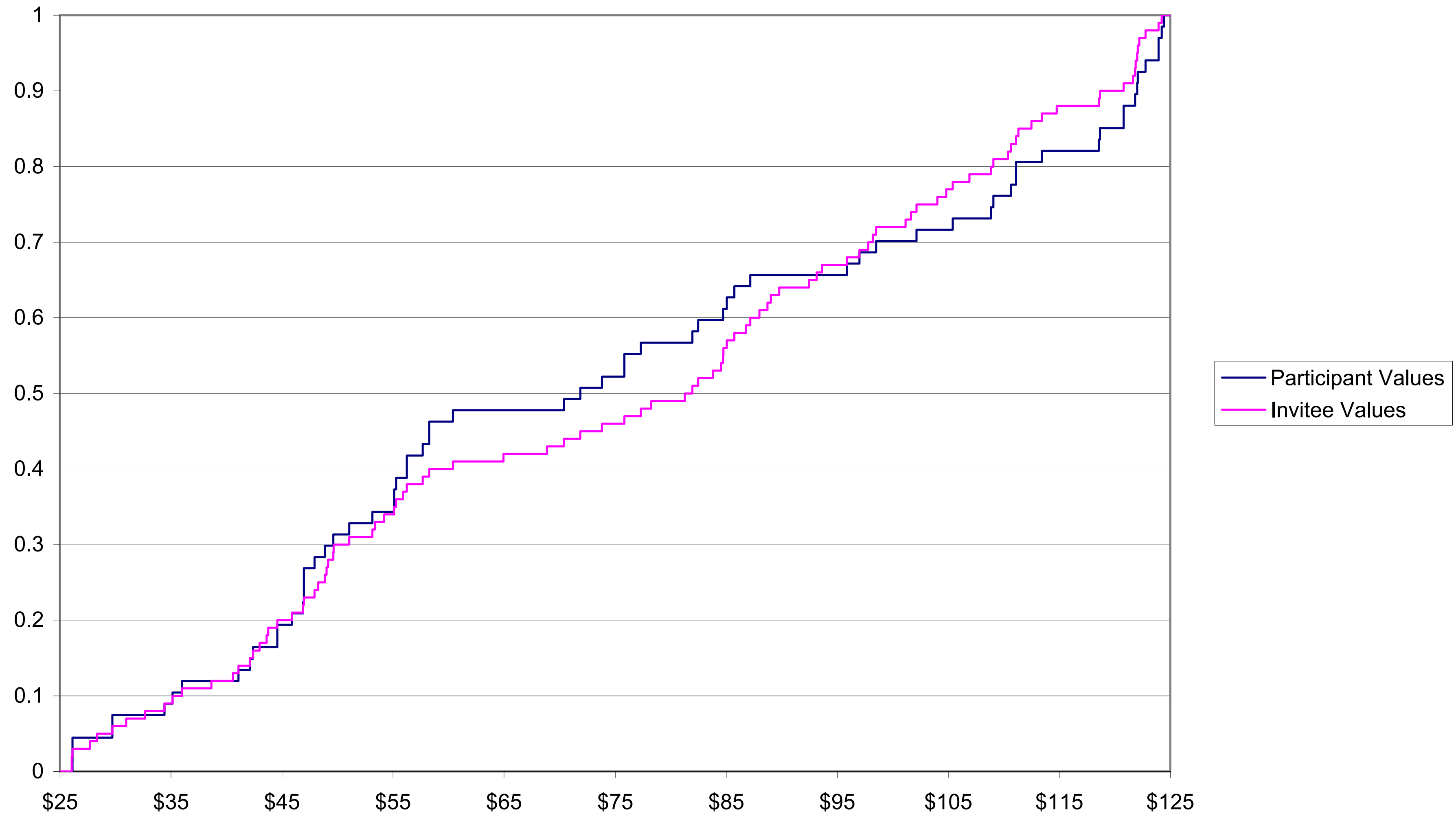
Figure 1
CDF of Invitee/Participant Values



Dependent variable	Abs. Value of Overbid	Overbid	
	(a)	(b)	(c)
Constant	21.916 (3.754)**	14.043 (9.560)	15.594 (14.272)
Value		.838 (0.118)**	0.825 (0.118)**
Feedback score	-.004 (.010)		
Log of highest bid subject placed in eBay auction			-1.462 (2.830)
Auction type: 1 if Morgan, 0 if Comic			13.682 (7.127)
Number of bids a subject placed in the eBay auction from which he/she was recruited			-1.568 (3.757)
Seller dummy: 1 if some seller feedback, 0 if only buyer feedback		-14.193 (7.067)*	-15.204 (7.458)*
Observations	93	86	86
R-squared (adj.)	-.010	.365	.375

Standard errors are in parentheses: * significant at %5 level, ** significant at the 1% level. All regressions exclude bids over $1000 (11 obs.). (b) and (c) exclude bids by four subjects for whom we were unable to obtain their buyer/seller feedback (7 obs.).

Table 2: Regression results

Figure 2

CDF of bid minus value

(for differences of less than $100)