THE EFFECT OF SHILL BIDDING UPON PRICES: EXPERIMENTAL EVIDENCE

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Abstract

This paper explores, through a series of experiments, the effect of shill bidding upon revenues and prices in auctions. We study the practice of shill bidding in a common value framework. Our findings are consistent with the theoretical prediction that, if bidders are aware of the possibility of seller participation in an auction, shill bidding lowers profits on average. Shill bidding can alleviate the problem of the winner's curse by lowering the price and it can, thus, provide benefits to the bidders. Finally, even though there were too many bidders that submitted bids in these auctions, the number of entrants was not affected by the possibility of seller participation, which is also consistent with the theory.

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1. Introduction

There is an increasing concern over shill bidding in Internet auctions. Shill bidding (or shilling) occurs when the seller of an item poses as a bidder and submits bids in an auction in an effort to raise its price. Auction sites spend large amounts of money to prevent this activity. The persistence of shilling can affect the popularity of Internet auctions as effective trading mechanisms. Incidents of shilling have also been reported in traditional English auctions for many years (see Cassady (1967), and Lucking-Reiley (2000)). In their study of how auctions affected trade at the beginning of the 19th century, Engelbrecht-Wiggans and Nonnenmacher (1999) reveal that this practice was widespread at that time. A change in New York's legislature introduced in 1817 created disincentives for shillers. As a result, the activity subsided contributing to the city's rapid growth. Shill bidding has important implications for the success of markets and studying its effects is of direct policy relevance. Rothkopf and Harstad (1995) for example attributed the rareness of Vickrey auctions outside financial markets partly to the fear of cheating sellers.

In this paper, we report the findings of experiments that study the practice of shill bidding. We investigate its effect on the bidding behavior and revenues of the seller in common value auctions. We chose this framework because a large number of items auctioned on-line are collectibles (such as antiques stamps and sports memorabilia) and second hand goods whose value is uncertain.[1] Bidders estimate how much these items are worth based on their private information and the behavior of the other bidders. In such auctions, the seller can enter bids to mislead the actual bidders and generate aggressive bidding patterns. In the process, he runs the risk of developing a bad reputation that could persist in future transactions. Bidders often express worries about sellers' past suspect behavior.

The rapid increase of transactions over the Internet will create many more opportunities for shill bidding in the future because sellers can easily disguise their identities. Despite their large spending on this, many bidders have complained that auction sites are not doing all they can to discourage fraud. They attribute the reluctance to take action against some sellers to the fact that

[1] According to Bajari and Hortacsu (2002) approximately 50% of the listings on eBay, the most popular auction site, can be classified as collectibles. Se also Lucking-Reiley (2000) and Bajari and Hortacsu (2004).

higher prices will ultimately generate higher commissions. Do prices really increase when bidders anticipate the behavior of the seller? The recent theoretical work by Chakraborty and Kosmopoulou (2004) shows that shill bidding does not benefit the seller and is some cases it does not benefit the auctioneer either. This theory triggered our interest in the practical consequences of this action. Our experiments reveal that shill bidding lowers both prices and profits contrary to the seller's intentions. In that sense, it alleviates the problem of the winner's curse in common value auctions. The information collected from the data allowed us to explore entry decisions and the extent of observational learning.

There are important practical difficulties in using empirical data to investigate the effect of shilling on bidding behavior and profits. Detection of shill bidding is difficult in Internet auctions. Such information whenever it is available, it is typically sensitive and is kept confidential. It is also impossible to determine bidders' knowledge of the occurrence of the practice. We created a computerized auction experiment that allowed us to trace the seller's participation patterns. We could control the amount of information that is available to bidders by carefully announcing the possibility of seller participation according to profit expectations.

The paper is structured as follows. Section 2 outlines the modeling framework and some related literature. Section 3 describes the experiment, while section 4 reports and evaluates the results. Section 5 summarizes our findings.

2. Theoretical framework

We consider an open ascending auction in which the highest bidder is awarded the item at the second-highest bid price. Each bidder receives an independent common value signal s_i taking values from a uniform distribution. The value of the item is defined as the average of the n bidders' signals:

$$V = \frac{1}{n}\sum_{i=1}^{n} s_i .$$

In this auction environment (i) there is a reserve price, (ii) entry takes place simultaneously and (iii) bidders cannot reenter once they have exited. Bidders bid the expected value of the item conditional on winning and conditional on the information revealed by other bids as the auction progresses (see among others Milgrom and Weber (1982)). This modeling framework has been previously used in many theoretical and experimental papers.[2]

For simplicity, we assume that the seller has no value for the item and no information that could be useful to the bidders. He has, however, the ability to participate in some auctions—and submit shill bids—if he finds it beneficial. The bidders do not know whether the seller is shill bidding, but they have a common belief in the probability that he does.

Chakraborty and Kosmopoulou (2004) recently analyzed the possibility of shill bidding in common value auctions. They showed that the bidders take into account the potential for seller participation at the auction and revise their bids accordingly. Their work makes the following testable predictions for our framework of analysis:

(i) If bidders are aware of the possibility of seller participation in an auction, shill bidding makes the seller worse off. Sellers would prefer it if there were a well-established, strict enforcement mechanism that makes it impossible for them to participate.

(ii) A mixed participation strategy on behalf of the seller should reduce prices in an auction.[3]

3. Experimental design[4]

Subjects participated in 20 sessions that lasted for one-and-a-half hour and consisted of a series of 18 auctions each.[5] They were recruited from a wide cross-section of undergraduate students at the University of Oklahoma and each participated in one session. In each auction, there were at maximum five potential players. Each player was either a true bidder or a seller.

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[2] Experiments include Avery and Kagel (1997), Holt and Sherman (2000), and Goeree and Offerman (2002). Theoretical work includes Albers and Harstad (1991), Bikhchandani and Riley (1991), Klemperer (1998), and Bulow, Huang, and Klemperer (1999).

[3] Chakraborty and Kosmopoulou (2004) assume, in general, that the expected value of the item increases in the number of bidders with high estimates of the value. In Theorem 6, they show that the prices can increase in a mixed strategy shill bid equilibrium if ex ante (1) at most one bidder is expected to have a high signal at the auction and/or (2) the estimate of the common value increases at an increasing rate with the participation of additional bidders. In a common value auction, you don't expect ex ante that only one bidder will value the item highly and everyone else will have low estimates unless there is a rare negative correlation in the estimates of the value. When signals are uniformly distributed, as in this case, a mixed participation strategy should reduce the price and the potential for shill bidding should make the seller worse off.

[4] For more information on the design, please see the instructions and the snapshots from an experiment presented in Figures 1-12B in Appendix B.

[5] We performed 22 auctions, 4 of which were trial runs to familiarize the subjects with the auction environment.

The assignment was decided at the beginning of the session from a random draw. Our intention was to evaluate how bidders learn and how they adjust their bidding strategies to the seller's behavior. The experiments were completely computerized and in each session there were two treatments: in one the seller could not participate and in the other he could.[6] Subjects received instructions for the second treatment only after the set of auctions of the first treatment were completed. The order of treatments was changed in some sessions to check for robustness of our results.

(i) The auction format. In each auction, a single unit of a commodity was sold to the highest bidder at the second-highest bid price. We followed the "ascending clock design" in which there is a digital clock on the screen. The clock started at a particular bid (reflecting the reserve price) and moved upwards every 5 seconds. Each bidder was able to observe the clock and the process was interactive.[7]

(ii) The distribution of values. The values of all items were determined the same way. Prior to the auction, the bidders received signals revealing partial information about the value of the object. The average of the observed signals determined the value. Each signal was an integer drawn from a uniform distribution between 0 and 20. The signal and the distribution of signals were the only information available ex ante to bidders that could help them make decisions about entry. The seller did not receive any information ex ante that could be relevant to the bidders. The seller's value was zero.

(iii) The instructions. Subjects were given a set of instructions designed to help them understand the nature of each object for sale and how to calculate the common value (see appendix B). The seller was given the opportunity to bid only in some auctions and his potential

[6] In those auctions, the seller could observe the outcome of the bidding process and learn as much as every bidder would.

[7] The ascending clock design is used widely in the literature (see among others Kagel, Harstad and Levin (1987) and the Kagel (1995)). We did not use the format that specifies an ending time for these auctions for two reasons. First and foremost, in a common value auction the fixed ending time rule posed an incentive problem: bidders should wait until the last minute to avoid revealing their private information (see Lucking-Reiley (2000)). According to Bajari and Hortacsu (2004): " If all bids arrive at the last minute, a bidder will not be able to update his beliefs about the common value V using the bids of others, hence his bidding decision would be equivalent to that of a bidder in a sealed-bid second price auction." It turns out, that theoretically the fixed ending time rule would render shill bidding ineffective in equilibrium since the seller would run the risk of becoming the highest bidder of the item without having the benefit of raising the expected price conditional on sale. The second less important and more practical reason (which is relevant in traditional English auctions) is that the auctions ended in a matter of minutes.

for participation, was announced to all bidders. The seller was able to passively observe the outcome of the experiments in all auctions in which he had no ability to participate. The bidders were given an initial budget of $15 to participate in the auctions[8]. We had 100 participants overall in the 20 sessions. Subjects were given enough time to read the instructions that were subsequently read aloud to them. The instructions included examples that illustrated how the auctions worked, and how the subjects could determine their profits or losses.

(iv) The bidding. At the beginning of each auction, a reserve price (a minimum acceptable bid) was posted on the screen. After each bidder received his signal he had to decide whether or not to participate. When all bidders made their decisions the auction would start. The digital clock would appear on each screen along with information about the remaining cash balance. By clicking on a button next to the clock, marked "Bid Here," a bidder would be able to stop his clock and determine his dropout price. When a sole clock was left active, the remaining bidder obtained the object at the price shown by the clock the moment the last-but-one bidder withdrew from the auction. Subjects were paid in cash at the end of the session (See Figures 2-5B in appendix B).

(v) The information feedback. The site also displayed information about the item that was auctioned off. At any point in time, when an auction was underway, the bidding history (consisting of the dropout prices of all the bidders) was posted on the site. We concealed the identity of the bidders from each other to avoid direct identification of the seller's bid at any given auction. After each round, the true value, the winning bid, profit (or loss) and updated cash balances were reported to all bidders on their screens. The number of active bidders was not announced at the beginning, but it could be inferred from the number of dropout prices at the conclusion of each auction. This is because, in many auctions (including all Internet auctions), the actual number of participants is not known ex ante [see also the discussion in McAfee and Vincent (1992)].

The design of the auction experiment has the characteristics of the ascending clock design, an auction environment analyzed among others by Chakraborty and Kosmopoulou (2004). Bidders

[8] To cover for 'bankruptcies' and 'no-showers,' we had extra bidders (up to two) in each experimental session. The active bidders in each session were selected on a 'first-come-first-serve' basis. We did not observe any bankruptcies. Extra bidders were paid a $5 show-up fee.

could observe the ‘drop out’ prices of their competitors and learn from their bidding patterns. As bidders bid, they revealed private information about the object to be sold. Therefore, the remaining bidders could update their information about the object and bid accordingly. In each session, the possibility of seller participation was carefully announced to the bidders. It was made clear that this was the seller's choice and not a certainty. The payoff functions and the feedback information on dropout prices could help them formulate and update their beliefs about the seller's participation strategy. [9] Garvin and Kagel (1994) point out that bidders learn to adjust their strategies through their own experiences and observational learning. Cooper and Kagel (2003) emphasize the importance of getting feedback regarding the outcomes of earlier auctions. They conclude that this information will help bidders adjust their ‘judgmental failures’. The data obtained from this experiment allowed us to investigate the effect of shill bidding on prices and payoffs and bidders' learning within a session. We could investigate if the sequential format of these auctions has any effect on the bidding pattern and whether observational learning plays an important role in formulating strategies.

4. Experimental Results

In order to familiarize the subjects with the auction process and let them gain some bidding experience, we did two dry runs each time and also used up the first two paid auctions as trial experiments. From each session, we collected information for data analysis from 18 auctions, 9 with and 9 without the possibility of seller participation. We collected 81 observations from each session. We have a total of 1616 observations from 359 auctions.[10] From this set of data, we could identify the winner of each auction, the second-highest bid, the number of bidders per

[9] As an alternative to the approach we took, we thought of having the program simulate the behavior of the seller so that we could explicitly announce the probability of participation, in anticipation of optimal bidding behavior. However, since the bidder's behavior is not always optimal (according to the experimental evidence in Kagel and Levin (1986) participants’ behavior significantly differs from the Nash equilibrium behavior), such a seller's fixed strategy would not be optimal either. As a result, any conclusion drawn from such an analysis would be useless with any slight deviation from the Nash equilibrium bidding strategies. We decided instead to let the bidders and the seller make their own decisions and evaluate the outcome.

[10] In one session, however, an error occurred when a bidder entered an auction other than the one under way at the time. We did not observe a winner at this auction. The bidders' cash balance was not updated and, as a result, we omitted the auction from our analysis.

auctions, the value, the sellers' profits and participation patterns, each bidder's identity, profit, signal, dropout price, and cash balance.

Based on these observations, we traced the participation patterns and the response of the bidders to changes in the bidding environment. We analyzed the effect of shill bidding on prices and the variance of prices and examined if the entry decision of bidders was optimal or not in these auctions. We also examined the robustness of the results to changes in the environment.

4.1. Entry Decision

The number of subjects who participated and submitted bids at these auctions was larger than the number predicted by economic theory but on par with other experimental findings (Kagel and Levin (1991)). In a common value auction, a bidder should enter if the expected value of the item conditional on winning at the reserve exceeds the reserve price. If the value is the average of the bidders' signals, the expected value of the item conditional on winning for a bidder whose signal is s_i can be expressed as:

$$E[V \mid s_i \geq s_j] = \frac{s_i + (n-1)*\sum_{l=0}^{s_i-1} \frac{l}{s_i - 1}}{n}, \text{ for } i \neq j.$$

In our case, with four potential bidders, the optimal reserve price is 5.5. It was calculated to maximize profits when the bidders choose their optimal bidding strategies.[11] At this reserve, any bidder with a signal greater than or equal to 9 should enter the auction. The following table presents participation statistics at two reserve prices used to do a comparative study.

Table-1: Basic Participation Statistics

Variable	Reserve 5.5			Reserve 6.25		
	All Auctions	**Auctions without Seller**	**Auctions with Seller**	**All Auctions**	**Auctions without Seller**	**Auctions with Seller**
Average Number of Bidders	3.380 (0.772)	3.393 (0.717)	3.367 (0.827)	3.539 (0.663)	3.478 (0.707)	3.600 (0.614)
Probability of Bidder participation	0.845	0.848 (0.359)	0.841 (0.367)	0.885	0.869 (0.337)	0.9 (0.3)
Probability of Seller submitting a Bid			0.722			0.744

[11] See Appendix A for more details.

Ten sessions were performed at a reserve of 5.5. Based on the data collected in these sessions, we observed that the number of bidders who submitted bids was greater than expected by 1.146.[12] Excessive entry is likely to make shill bidding more profitable in our analysis than theory would predict. Based on the fact that the current reserve leads to high participation rates, we decided to perform ten additional experimental sessions at a marginally higher reserve price of 6.25 (see McAfee and Vincent (1992) on the issue of updating the reserve price).[13] At this reserve, optimally, only bidders with a signal greater than or equal to 10 should participate in the auctions. The results of the comparative study are presented in Tables 1 and 2.

The announcement of seller participation did not have a significant impact on the number of participants and that is in agreement with the theory. The number of legitimate bidders only changed from 3.393 to 3.367 at the reserve of 5.5 and from 3.478 to 3.600 at the reserve of 6.25. Theory predicts that the seller's potential to enter should not have an overall statistically significant effect on the probability to participate. The entry decision should be based on the comparison of the reserve price with the expected value of the item conditional on winning at the reserve. Since the seller does not have any valuable information to share with the bidders, the calculation of the expected value remains the same irrespective of his ability to participate. The probability of bidder participation at the reserve of 5.5 was 0.848 when the seller was not allowed to participate and 0.841 when he was. A test of these proportions reveals that their difference is statistically insignificant (with a z statistic of 0.258). The difference in the probability of bidder participation between the two treatments at the reserve of 6.25 is statistically insignificant as well

[12] In an attempt to uncover their entry strategies, we calculated two other measures of discrepancy between observed and expected entry numbers. The one measure shows the difference between the actual number of bidders and the number that would have entered if they calculated their returns based on an estimate of the common value conditional on their signal; this difference is 0.682. The other measure provides the difference between the actual number of bidders and those with a signal greater than 5. This was calculated to investigate whether bidders decided to enter based on a naïve direct comparison of their signal with the reserve. This last strategy seems marginally the closest approximation to the observed behavior. The discrepancy, however, between these two numbers is still large (the difference is 0.538), which makes this strategy as well an unlikely candidate for equilibrium behavior.

[13] Some researchers have speculated that the thrill of playing might be the dominant factor affecting the entry decision of some bidders. Since there is no hard evidence on what motivates bidders to enter in larger proportions than the optimal strategy would dictate, we were reluctant to raise the reserve too much in our comparative statistics exercise to avoid introducing a reserve that would be too high. A sub-optimal high reserve combined with shill bidding could artificially show that shill bidding is harmful. A sub-optimal low reserve, on the other hand, can only overemphasize the benefits of shill bidding. We kept the reserve low and still showed that shill bidding is harmful.

(with a z statistic of -1.302). The evidence in Table 1 is corroborated by the probit analysis, the results of which are presented in Table 2.

Table-2: Probit Regression Results for the Probability of Bidding

Independent Variable	**All Auctions**		**Reserve 5.5**		**Reserve 6.25**	
Constant	-0.203	-0.169	-0.224	-0.163	0.173	0.174
	(0.163)	(0.166)	(0.200)	(0.207)	(0.281)	(0.284)
Signal	0.159*	0.159*	0.156*	0.157*	0.163*	0.163*
	(0.012)	(0.012)	(0.015)	(0.015)	(0.019)	(0.019)
Potential Profit or Loss in Previous Auction		-0.020		-0.030		-0.000
		(0.017)		(0.023)		(0.027)
Order of Auction in the Sequence	0.003	0.001	0.014	0.010	-0.024	-0.024
	(0.014)	(0.014)	(0.016)	(0.016)	(0.029)	(0.029)
Seller's Potential Entry	-0.157	-0.160	-0.051	-0.075	-0.106	-0.105
	(0.151)	(0.151)	(0.187)	(0.188)	(0.304)	(0.305)
Seller Participation in the Previous Auction	0.207	0.234*	-0.280	-0.226	1.242*	1.243*
	(0.139)	(0.141)	(0.178)	(0.184)	(0.304)	(0.305)
Reserve	0.218*	0.216*				
	(0.100)	(0.100)				
Observations	1436	1436	716	716	720	720
c^2	310.28	311.55	170.32	171.93	159.41	159.41

* Denotes 95% significance and ** Denotes 90% significance.

In Table 2, we examine the probability to submit a bid as a function of bidder and auction-specific independent variables. This model allows us not only to test for differences in the probability to submit a bid across the two treatments but also to account for other observed patterns of behavior in the sequence of auctions. The detailed description of the variables used in this regression is in Appendix A. The results of the analysis reveal that the probability of submitting a bid is higher the higher the signals the bidders received. The seller's potential to enter and the observation of profit in the previous auction had no statistically significant effect on the probability to submit a bid in a current auction. These results are consistent with theory.

The observation of seller participation in an auction did not discourage entry in the subsequent auction. In online auctions, reputation mechanisms established have shown that negative feedback has adverse effects but is not a huge deterrent of activity since the number of auction participants experiences continuous growth (see Bajari and Hortacsu (2004)). Contrary to what we expected, however, participation was greater at the higher reserve price.

In conclusion, despite the fact that bidders did not make optimal entry decisions, the number of entrants was invariant to the possibility of seller participation.

4.2. The Effect of Shill Bidding on Prices and Profits

In this section, we first present a graph and basic statistics on relative bids and profits. Then we use the Maximum Likelihood Estimation procedure to statistically analyze our data.

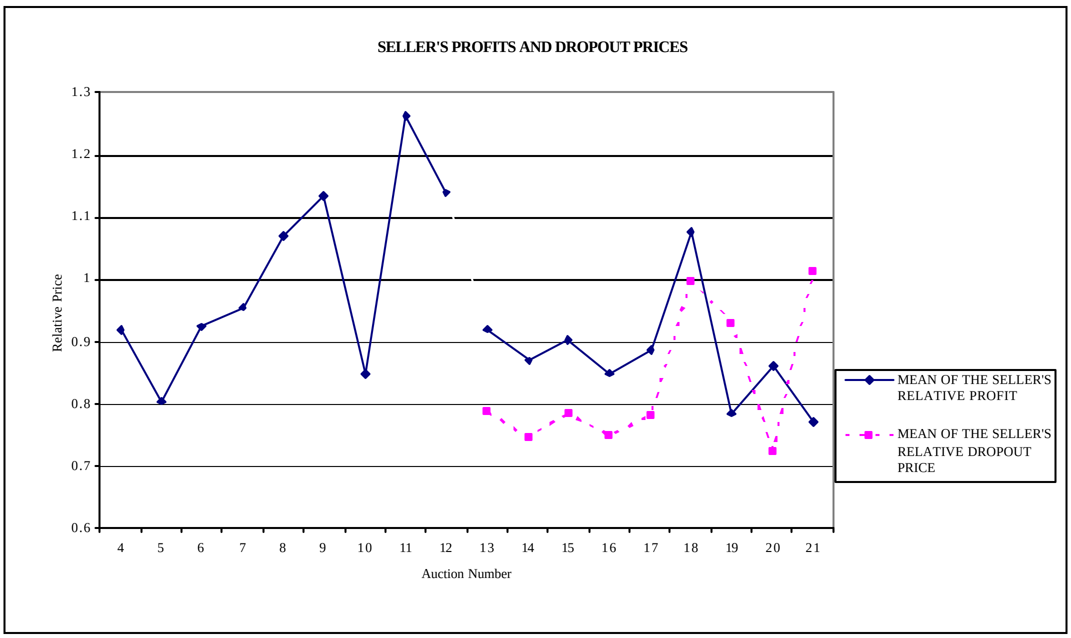

Figure 1A: Seller's relative profit and bidding behavior when the reserve was 6.25. The potential of participation was announced only in the last 9 auctions.

Figure 1A shows the seller's relative profits and dropout prices in the series of auctions performed at the reserve of 6.25. In every session, we ran 9 consecutive auctions without the possibility of seller participation followed by 9 consecutive auctions with the possibility of seller participation.[14] The profits and prices are calculated here relative to the value of each item. For

[14] A figure presenting the profit of the seller at the reserve of 5.5 would not be informative because we changed the order of announcements in some sessions to check the robustness of our results to variations in

every auction in the sequence, the estimates presented in Figure 1A are obtained by averaging out the corresponding quantities across the 10 sessions. The graph reveals that sellers' relative profits are higher, on average, in the first 9 auctions of each session when the bidders are the only ones participating. In the last 9 auctions, sellers were mixing their participation strategies; on average they submitted bids with a probability of 74.4%. There was no seller who either participated all the time or did not participate at all. Profits were lower when participation was possible. The larger drop in expected profits occurred right after the announcement of seller participation was made. The pattern in prices is similar to the pattern in profits. This is in agreement with the theoretical results reported by Chakraborty and Kosmopoulou (2004) which show that, in the present setting, the auctioneer (who cares about the price) is worse off with a shill bid equilibrium than with the no shill bid outcome.

Considering the data from all the auctions, on average, sellers submitted bids with a probability of 73.3%. Their behavior led to lower profits there as well.

Table-3: Relative prices and profits

Variable	**All Auctions**	**Auctions without Seller**	**Auctions with Seller**
Average Relative Winning Price for Bidders	1.004 (0.357)	1.026 (0.405)	0.981 (0.300)
Average Relative Profit for Bidders	-0.004 (0.357)	-0.026 (0.405)	0.019 (0.300)
Average Relative Dropout Price for Sellers			0.881 (0.368)
Average Relative Profit for Sellers	0.932 (0.369)	0.975 (0.385)	0.889 (0.347)

In fact, according to Table 3, the average relative profit of the seller went down from 97.5% to 88.9% of the value. Our test revealed that the difference is statistically significant (*t* statistic is 2.232.) The average relative winning price for the bidders at the same time dropped slightly from

the format. In half the sessions, in auctions 1-9, the seller had to be passive and in auctions 10-18 he could be potentially active. In the other half he had to be passive in auctions 1-5 and 10-13 and could be active in the remaining auctions.

102.6% of the value to 98.1%. The difference in prices across the two treatments showed to be statistically significant as well (t statistic is 2.223). Once more, the main drop was observed right after the first announcement of the potential for seller participation was made. The bidders' profits were, on average, 2.6% of the value in the auctions without seller participation and 1.9% of the value in the auctions when the potential of seller participation was announced. [15]

The basic statistics appearing in Table 3 do not provide any controls for a variety of factors that affect prices and profits. For that reason, we used the MLE procedure to identify the effect of shill bidding on the expected value and variance of prices and profits. The basic structure of the regression model is as follows:

$$y_i = XB + Z\Gamma + e_i,$$
$$e_i \sim N(0, s_i^2), \text{ where}$$
$$s_i = X\Phi + Z\Psi + g_i.$$

We use two dependent variables in our analysis: price and profit. The independent variables include two sets of controls: auction specific quantitative variables (X) and, auction specific qualitative variables (Z). We assume that the standard deviation of prices and profits depend on the same set of variables to allow for more flexibility. The description of those variables is detailed in Appendix A. We used a variable on the observed number of participants in the last auction to estimate the aggressiveness of opponents based on observed patterns of participation. We also included the order of auctions in the sequence and the profit (or loss) in a previous auction. We accounted for the seller's potential entry (shill bidding) and his participation in a previous auction. We included differences in the design, reserve, and values. In the profit equation, we also introduced the variable "Seller Wins the Auction." This variable identifies the

[15] Our analysis considers the overall effect of shill bidding on prices and profits without concentrating on comparison of individual bids to equilibrium bids. We compare entry decisions to equilibrium behavior only where such an approach is feasible. Notice that, once a bidder enters, each bid submitted is conditioned on information that is obtained by inverting the bidding function and uncovering the other bidders' signals. This process requires knowledge on our behalf of the bidders' beliefs about the probability of the seller's participation. This is information we do not have. Even if we knew the beliefs, a direct comparison of actual bids to optimal bids would be quite misleading, since a potential error in the calculation made by one bidder would propagate a series of mistakes in calculations by the rest. As a result, some optimally behaving bidders could seem to behave sub-optimally.

cases in which the seller wins the auction and forgoes the price; when it is included in the model, it allows us to isolate through the variable on potential entry announcement the effect of seller participation on the price the bidders pay. Table 4 presents the results of this analysis.

In this analysis, we recognized that, if the signals play an important role in determining the bidding strategy, then the standard deviation of prices could be related to the standard deviation of signals. The standard deviation could also be a function of the expected number of bidders in an auction, the seller's potential to enter, his participation in previous auctions, the level of the reserve price, and the potential for profit.

Table 4 presents a maximum likelihood estimation of prices and profits as a function of the observable factors described above. It suggests that the value of the item has a positive effect on the price. The number of bidders in the previous auction pushes the price up because it created expectations for patterns of greater participation. This is not consistent with the theory, but it is consistent with other experimental findings. In particular, Kagel and Levin (1986) find that, as the number of bidders increases, the price also increases.

The potential of seller participation affects bidders' beliefs and makes them bid and win at lower prices. The observation of seller shilling in previous auctions has a negative but marginally significant effect on prices. Observation of past performance through various reputation mechanisms established in web auctions have shown that negative feedback can have adverse effects. Those effects vary and may depend also on the value of the object sold (Ba and Pavlou, (2002)).

The bidders bid higher and higher in the sequence of items auctioned off in a session. There have been many studies documenting increasing and decreasing patterns of prices in sequential auctions. The most relevant study for the present framework, however, is that by Milgrom and Weber (2000) who predict that, in a model with affiliated values (an extreme form of which is having common values), there will be an increasing pattern of prices in the sequence. The change in the reserve price does not seem to have a significant effect on the average price but it has an effect on the standard deviation of prices. The higher reserve leads to lower variability in prices. The order of the treatments does not affect the outcome.

Table-4: ML Estimation Results

Independent Variable	Dependent Variable			
	Price		Profit	
Constant	3.895*	6.809*	3.833*	3.960*
	(0.601)	(0.566)	(0.671)	(0.607)
Value	0.295*		0.323*	0.282*
	(0.036)		(0.038)	(0.036)
Number of Bidders in the Previous	0.424*	0.426*	0.268**	0.360*
Auction	(0.127)	(0.138)	(0.144)	(0.123)
Potential Profit or Loss in Previous	-0.019	0.011	-0.045	-0.019
Auction	(0.041)	(0.046)	(0.044)	(0.039)
Order of Auction in the Sequence	0.129*	0.122*	0.106*	0.109*
	(0.026)	(0.028)	(0.031)	(0.025)
Seller's Potential Entry	-0.867*	-0.675*	-1.008*	-0.732*
	(0.279)	(0.306)	(0.304)	(0.267)
Seller Participation in the Previous	-0.549**	-0.464	-0.395	-0.396
Auction	(0.283)	(0.283)	(0.367)	(0.276)
Design	0.008	0.126	-0.092	0.025
	(0.316)	(0.367)	(0.335)	(0.293)
Reserve	0.154	0.250	0.247	0.113
	(0.222)	(0.281)	(0.234)	(0.204)
Seller Wins the Auctions				-9.191*
				(0.676)
Parameter Estimates of s_{v_i}				
Constant	1.784*	2.178*	0.794	1.779*
	(0.433)	(0.503)	(0.592)	(0.519)
Standard Deviation of the Signals	0.051	0.055	0.066	0.031
	(0.035)	(0.041)	(0.049)	(0.036)
Number of Bidders in the Previous	-0.107	-0.103	0.019	-0.119
Auction	(0.097)	(0.120)	(0.110)	(0.100)
Potential Profit or Loss in Previous	-0.002	0.013	0.048	0.004
Auction	(0.034)	(0.037)	(0.042)	(0.033)
Order of Auction in the Sequence	0.009	0.040	0.034	0.007
	(0.026)	(0.030)	(0.037)	(0.028)
Seller's Potential Entry	-0.081	-0.490	0.312	-0.021
	(0.293)	(0.363)	(0.524)	(0.309)
Seller Participation in the Previous	0.075	0.178	0.033	0.041
Auction	(0.246)	(0.265)	(0.526)	(0.241)
Design	0.393	-0.236	0.751	0.442**
	(0.260)	(0.252)	(0.396)	(0.246)
Reserve	-0.314	-0.836*	- 0.092	-0.207
	(0.224)	(0.226)	(0.286)	(0.202)
Seller Wins the Auctions				-0.227
				(0.279)
Observations	359	359	359	359
Wald c^2	124.65	45.75	92.77	311.14
Log Likelihood	-693.43	-735.54	-745.30	-671.27

* Denotes 95% significance and ** Denotes 90% significance.

Table 4 offers no clear indication of some significant positive effect of the standard deviation of signals on the standard deviation of the price. The seller's potential entry decision would be expected to lower the variability in the price since it could lead to less aggressive bidding behavior. This effect is, however, statistically insignificant.

The seller's profit is higher with the value of the item to the bidders, the number of bidders observed in the previous auction, and the order of auctions in the sequence. The announcement of the potential of seller participation has a negative effect on profit not only because the seller runs the risk of buying his own item but also because the bidders pay a lower price on average. In particular, when the variable "Seller Wins the Auction" is introduced in the profit equation (in the fourth column of Table 4) to isolate the instances in which the seller is awarded the item, the variable "Seller's Potential Entry" remains significant. As Chakraborty and Kosmopoulou (2004) have shown, shill bidding makes the seller worse off. Our experimental results agree with their findings. Any out-of-auction mechanism that would force sellers to abstain from participation could increase their profits. Rothkopf and Harstad (1995) presented a theoretical dynamic model of cheating in Vickrey auctions showing also significant adverse effects. In their case, bidders are not fully rational and they punish cheating whenever it can be verified. A trusted seller cheats when it pays and eventually destroys his reputation. The increase in the reserve does not have a statistically significant effect on either the expected value or the standard deviation of profits.

In Table 5, we included variables to capture the actual participation patterns of sellers. One variable controls for instances in which the seller is not allowed to participate, and another instances in which he is actually participating (a fact that is not observable by the rest of the bidders). The control group represents the cases in which the seller had the opportunity but chose to abstain from participation. Once more, the regression results suggest that the seller is better off with an enforcement mechanism that reduces his ability to participate. In particular, his payoff is the lowest when he enters and bids in the auction.

We also tested the robustness of our results to changes in the order of announcements. The MLE results indicate that it does not make any statistically significant difference in either the price or the seller's profit. The seller's revenue is lower when the potential of participation is announced. In all equations, the observation of profit or loss in the previous auction does not seem to affect either prices or profits.

Table-5: ML Regression Results

Independent Variable	Dependent Variable	
	Profit	
Constant	3.489*	3.734*
	(0.817)	(0.726)
Value	0.324*	0.275*
	(0.038)	(0.035)
Number of Bidders in the Previous Auction	0.309*	0.381*
	(0.126)	(0.110)
Potential Profit or Loss in Previous Auction	-0.038	-0.028
	(0.042)	(0.038)
Order of Auction in the Sequence	0.101*	0.113*
	(0.030)	(0.024)
Seller is not allowed to participate	0.225	0.253
	(0.352)	(0.337)
Seller is Participating in the Auction	-1.247*	-1.006*
	(0.315)	(0.298)
Design	-0.181	-0.001
	(0.314)	(0.285)
Reserve	0.276	0.051
	(0.230	(0.206)
Seller Wins the Auctions		-8.659*
		(0.721)
Parameter Estimates of σ_{v_i}		
Constant	1.100	1.238*
	(0.820)	(0.695)
Standard Deviation of the Signals	0.052	0.030
	(0.046)	(0.034)
Number of Bidders in the Previous Auction	-0.049	0.001
	(0.120)	(0.111
Potential Profit or Loss in Previous Auction	0.031	-0.016
	(0.040)	(0.032)
Order of Auction in the Sequence	0.030	0.026
	(0.035)	(0.027)
Seller is not Participating in the Auction	0.116	0.105
	(0.346)	(0.312)
Seller is Participating in the Auction	0.676	-0.367
	(0.431)	(0.251)
Design	0.753*	0.412**
	(0.363)	(0.248)
Reserve	-0.087	-0.321
	(0.263)	(0.191)
Seller Wins the Auctions		-0.063
		(0.254)
Observations	359	359
Wald χ^2	102.40	284.64
Log Likelihood	-738.63	-665.76

* Denotes 95% significance and ** Denotes 90% significance.

5. Conclusions

This paper examines the effect of shill bidding in online auctions on the seller's payoff and on price. Shill bidding makes the seller worse off. The price at the auction decreases as bidders anticipate the behavior of the seller and adjust their bidding strategies. Both of these findings are consistent with the theoretical results of Chakraborty and Kosmopoulou (2004). Even though their entry decision is invariant to the announcement of seller participation, there are too many bidders who are eager to submit bids at these auctions. Observational learning plays a role in determining bidding strategies. The observation of consistently large past participation affects their bidding. As Milgrom and Weber (2000) predicted, overall there is an increasing pattern of prices in the sequence. We conclude that the possibility of shill bidding alleviates the problem of the winner's curse in a common value auction and becomes beneficial for bidders but harmful for the seller.

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Appendix A

CALCULATION OF THE OPTIMAL RESERVE

We need to determine the minimum entering signal s that allows the seller to maximize his profit given the bidding strategies. The expected price at the auction conditional on this cutoff signal is:

$$E[p \mid s] = E[P \mid y_3 < s \le y_4] + E[P \mid y_2 < s \le y_3] + E[P \mid y_1 < s \le y_2] + E[P \mid s \le y_1]$$
$$= \left(-\frac{5(-21+s)s^4}{388962} + \frac{s^2(17220 + 1448s - 255s^2 + 7s^3)}{388962} - \frac{(-21+s)^2 s(-2080 - 90s + 9s^2)}{777924} + \frac{(104482560 - 13481368s + 198765s^2 + 42205s^3 - 2235s^4 + 33s^5)}{11668860} \right)$$

where y_1, y_2, y_3, y_4 are order statistics.

Choosing s to maximize this expression yields a value of $s = 8.57977$. Since we have discrete signals $s = 9$. Based on this we can calculate the optimal reserve to be

$$r = \frac{9 + 3 \times \sum_{i=0}^{9-1} \frac{i}{9-1}}{4} = 5.625.$$

Since the clock goes up in increments of 0.25, we set the reserve at 5.5.

DEFINITIONS OF THE VARIABLES

Variable	Description and Construction of the Independent Variable
Price	The 'Price' is the drop out price of the second highest bidder.
Seller's Profit	Seller's profit is the price minus a commission of 5% that goes to the auctioneer as payment for the services rendered. If a seller does not participate at all or if he participate and he is not the highest bidder, then the seller will receive the price minus the commission. If seller becomes the highest bidder in an auction then he will not receive any payment on this item but he will still have to pay 5% as the commission even if the item is not sold to an actual bidder.
Value	This is the value of the item to the bidders. This value is constructed as the average of the bidder's signals.
Number of Bidders in the Previous Auction	This variable represents the observed number of participants in the last auction. It allows us to control for the aggressiveness of opponents based on observed patterns of participation.
Potential Profit or Loss in Previous Auction	This variable captures the difference between the value and the price that makes up the profit or loss accruing to the winner of the previous auction.
Order of Auction in the Sequence	The variable captures effects that relate to the sequential nature of the auction in each session.
Seller's Potential Entry	This is a dummy variable that takes the value of 1 in auctions in which the potential of participation is announced and zero when the seller is not allowed to participate.
Seller Participation in the Previous Auction	This is dummy variable, which takes the value of 1 if there were 5 bidders in the previous auction and therefore, the bidders observed with certainty the shiller bidding and zero otherwise
Design	This dummy variable controls for the change in order of the treatments. For 5 of the experimental sessions performed at the reserve of 5.5 and 10 performed at the reserve of 6.25 the rules were as follows: the seller had to be passive in the first half of the auctions that took place. For 5 sessions performed at the reserve of 5.5, we changed the order of announcement to check if our results are robust. The seller had to be passive in auctions 1-5 and 10-13 and he could be active in the remaining auctions. For those five sessions the design dummy takes the value of 1 and 0 in all other sessions
Reserve	This is a dummy that takes the value of 1 when the reserve is 6.25 and zero when it is 5.5.

Seller Wins the Auctions	This is a dummy variable which takes the value 1 when seller wins the auction. This variable is introduced only in the profit equation to control for the instances in which the seller is awarded the item. Further, it allows the variable on potential entry announcement to isolate the effect of seller participation on the price the bidders pay.
The Seller is not Allowed to Participate	This variable takes the value of 1 in auctions in which we announced that the seller could not participate. This variable is used only when the seller's profit is analyzed.
The Seller is Participating	This is a dummy variable that takes the value of 1 if the seller participated in an auction. Note that, the rest of the bidders do not observe when the seller actually participates. This variable was used only for a seller's profit ML estimation.
Standard Deviation of the Signals	In each auction bidders received 4 signals. The standard deviation of these four signals is used in the maximum likelihood variance equation. This variable will be controlling for signal variability.

Appendix B (REFEREE APPENDIX)

INSTRUCTIONS

(The instructions were read to all participants.)

I. INITIAL SET OF INSTRUCTIONS

Instructions to the bidders:

Welcome to the experiment! We will hold a series of online auctions following the same rules each time. The instructions are simple. If you read them carefully, take into account the reasoning of the other players and decide sensibly, you will make some money. Your profit depends on your success. Participation is voluntary. You are by no means obliged to participate in the experiment but if you do, you will get the chance to make some money if you make the right decisions. For each point that you will obtain in the experiment you will receive a quarter.

The Game. The game will be played by groups of 4 people. If you decide to participate you will receive a starting balance of 60 points (That's $15). We will auction off 22 items, one at a time. Each item will be auctioned off to the highest bidder. The rules are slightly different than the rules of the standard auctions that you see online. Here are the differences:

The Value. Every one of the 22 items has a different value. The value of each item is determined as follows: Each person will receive a signal at the beginning of each auction. The signal could be any integer between 0 and 20. All these numbers are equally likely. A person only knows his/her own signal. The *value* of the item is the same for all bidders; it is the average of the signals received by the 4 bidders. For example, if you received a signal of 0 and the signals received by the rest of the bidders are 9, 6, and 17, the common value of the item to all bidders will be: $\frac{0+9+6+17}{4}=8$. Your signal will be shown at the top border of your screen. You will always get information about your own signal. You will not get to know the signals of the other bidders before the end of the auction. When all members of a group receive their signal, the object is auctioned off.

The Rules of the Auction. When the auction begins a reserve price (a minimum acceptable bid) will be posted on your screen. After you receive your signal you will have a minute to decide whether to participate. If you decide to participate you have to press the button that says "participation" and wait for the rest of the bidders to make a decision. This is the only chance you will get to decide whether you are going to participate and bid in this particular auction. (If you don't find it profitable to participate in this auction, based on the information that you received on this item, you can still participate in the next round of auctions.) The value of the item depends on the signal of all 4 people no matter whether they decided to participate or not.

In the middle of the screen, you will see a button that shows a bid slowly counting upwards like a clock. Every active participant sees the same clock on his or her screen. When you press this button on your screen that says "Bid Here" your clock with stop counting up and you will leave the auction. The bid at which you pressed the button is called the "dropout price". The auction will continue with the participants that have not yet pressed their own buttons. When only one person remains in the auction, this person leaves automatically and obtains the object at the price that is currently indicated i.e., the dropout price of the second highest bidder that left the auction. For example, if there are two bidders remaining active in the auction and the one decides to dropout at the price of 7, the other bidder is awarded the item at 7.

The person that manages to obtain the object receives a certain amount of points on his or her account; this amount is determined by the common value of the item to all bidders minus the bid of the second highest bidder that left the auction. In the previous example, if the (common) value of the item is 8 (i.e., the average of the signal of all four bidders) and the dropout price of the second highest bidder is 7 then the highest bidder will earn a profit of 8-7=1 that will be added to his account. If the dropout price of the second highest bidder was 11, however, the person that is awarded the item will lose 11-8 = 3 that will be subtracted from his account balance.

Bankruptcy Policy. As we mentioned before, you will have a 60-point balance in you account available for bidding. This is the maximum amount of points you can use bidding in these auctions. If at some point of time you lose all points overbidding on a series of items you will not get a chance to reenter and bid in subsequent rounds.

Useful Information on the Screen. As you decide on your strategy take into account the behavior of other participants. The dropout prices of the other participants are reported on the screen in the column that has the title bidding history. As soon as any player leaves the auction his dropout price becomes an entry in the bidding history. At the end of every round your remaining cash balance and the profit or loss will be displayed on the screen. You will also see the winning bid and the value of the item to the bidders.

To enter the experiment logon to http://129.15.117.138/NewDB/Georgia/page1.asp

Good luck!

Instructions to the seller:

For the first 12 rounds you will have the opportunity to observe the outcome in each auction, the bids and values of the items auctioned off. After the end of the first 12 auctions in the session, the rules will change and you will be given the opportunity to participate if you wish. You will receive further instructions at the end of round 12. Logon to http://129.15.117.138/NewDB/Georgia/page33.asp to observe the bidding process during the first 12 auctions.

II. ADDITIONAL INSTRUCTIONS

Instructions to Bidders:

For the next set of auctions the seller has the opportunity to enter and bid if he finds it beneficial. The seller does not have any signal that could convey additional information about the value of the item to you. Whether the seller decides to participate or not and his/her identity will not be revealed during these auctions.

Instructions to the Seller:

Your value of the item is zero and it is independent of the value of other participants. Your initial cash balance will be 60 points. For each point that you will obtain in the experiment you will receive a dime. At this point in the experiment you have the opportunity to enter and participate if you wish. Every time an item is auctioned off to one of the bidders, independent of your participation decision, you will receive the price minus a commission of 5% that goes to the auctioneer as payment for the services rendered. If you become the highest bidder in an auction you will not receive any payment on this item but you will still have to pay 5% as the commission even if the item is not sold to an actual bidder. For example, if you are the last active person at the auction and the second highest bidder dropped out at a price of 9 you will have to pay 5% of 9 which is 0.45. If you do not participate at all or if you participate and you are not the highest bidder you will receive the price minus the commission. For example, if the second highest dropout price is 6 you will receive 6 and you will pay 5% of the price to the auctioneer. As a result your net profit will be 5.7. The bankruptcy policy that applies to the bidders applies to you too.

SNAPSHOTS FROM AN EXPERIMENT

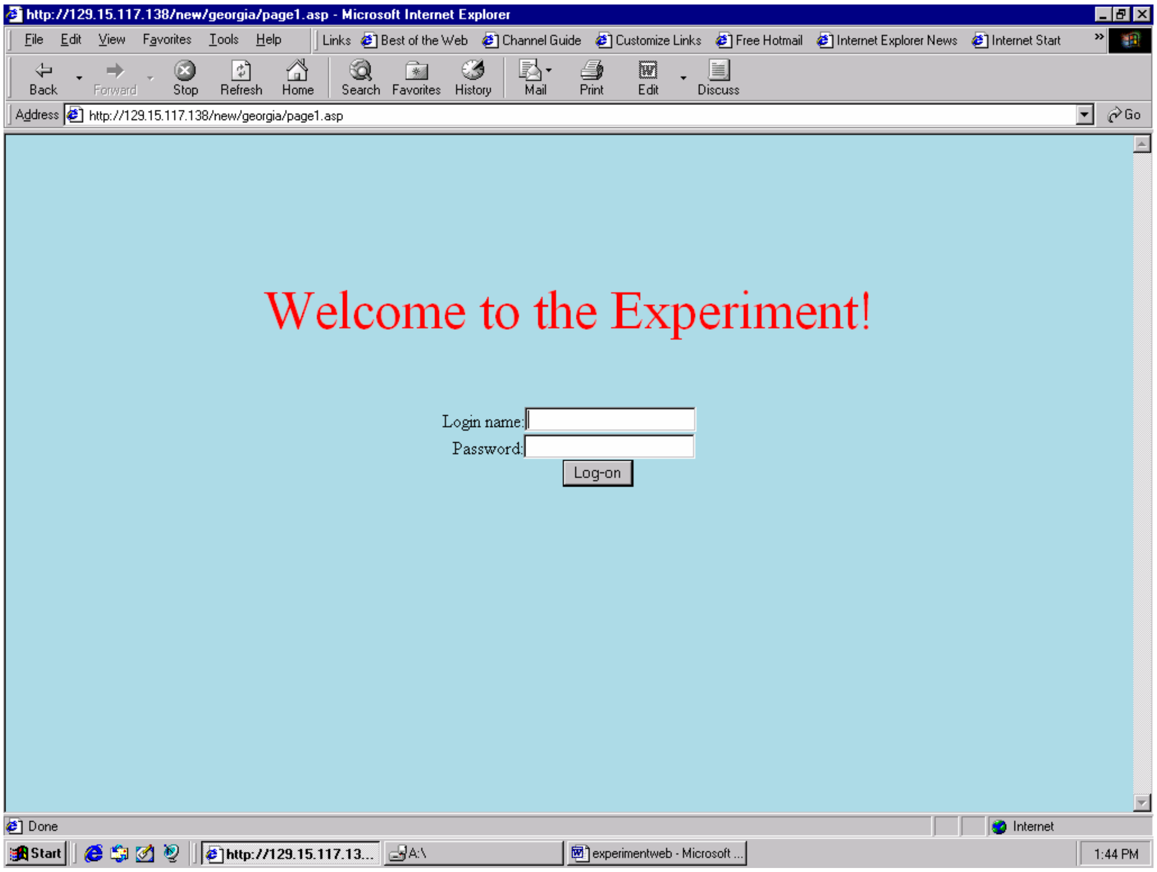

Figure1B: Bidder's page.

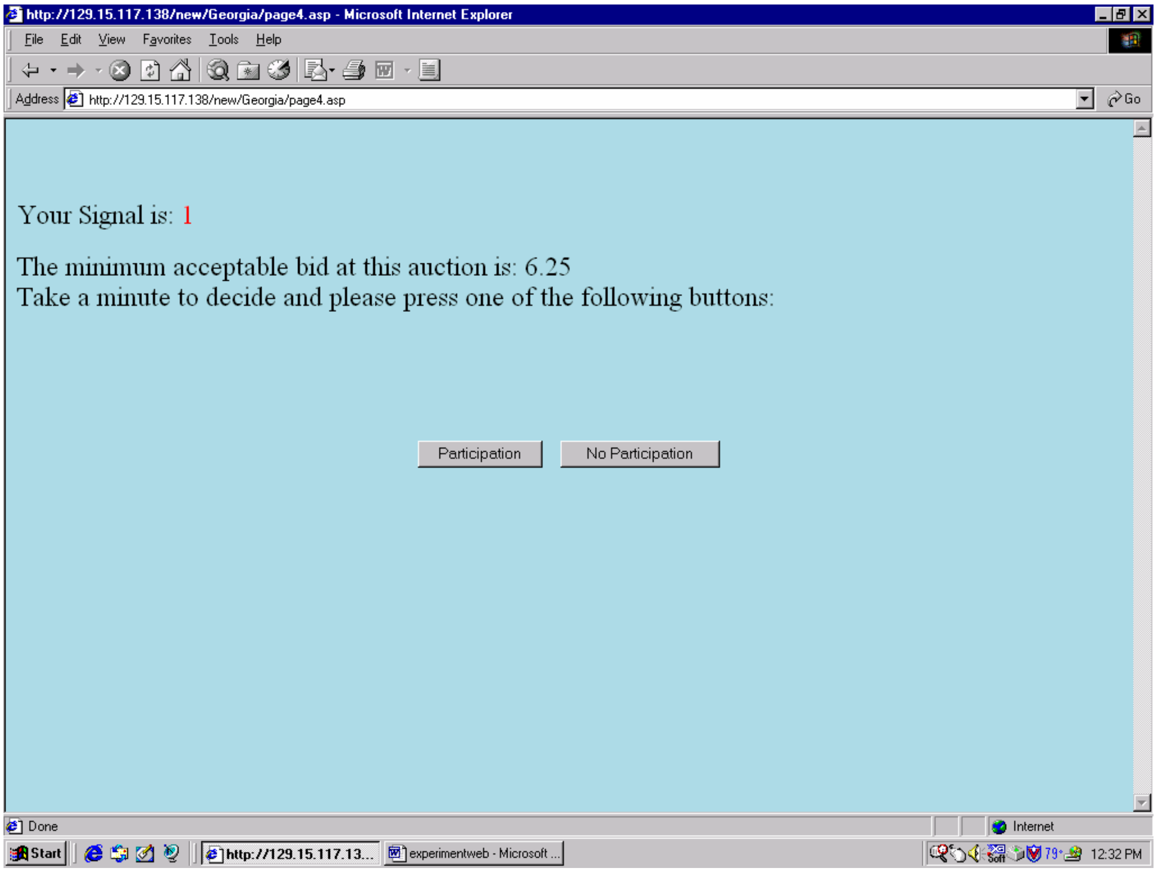

Figure 2B: After a bidder enters the session and auction number that is announced, he/she gets to see a signal and make a decision on participation.

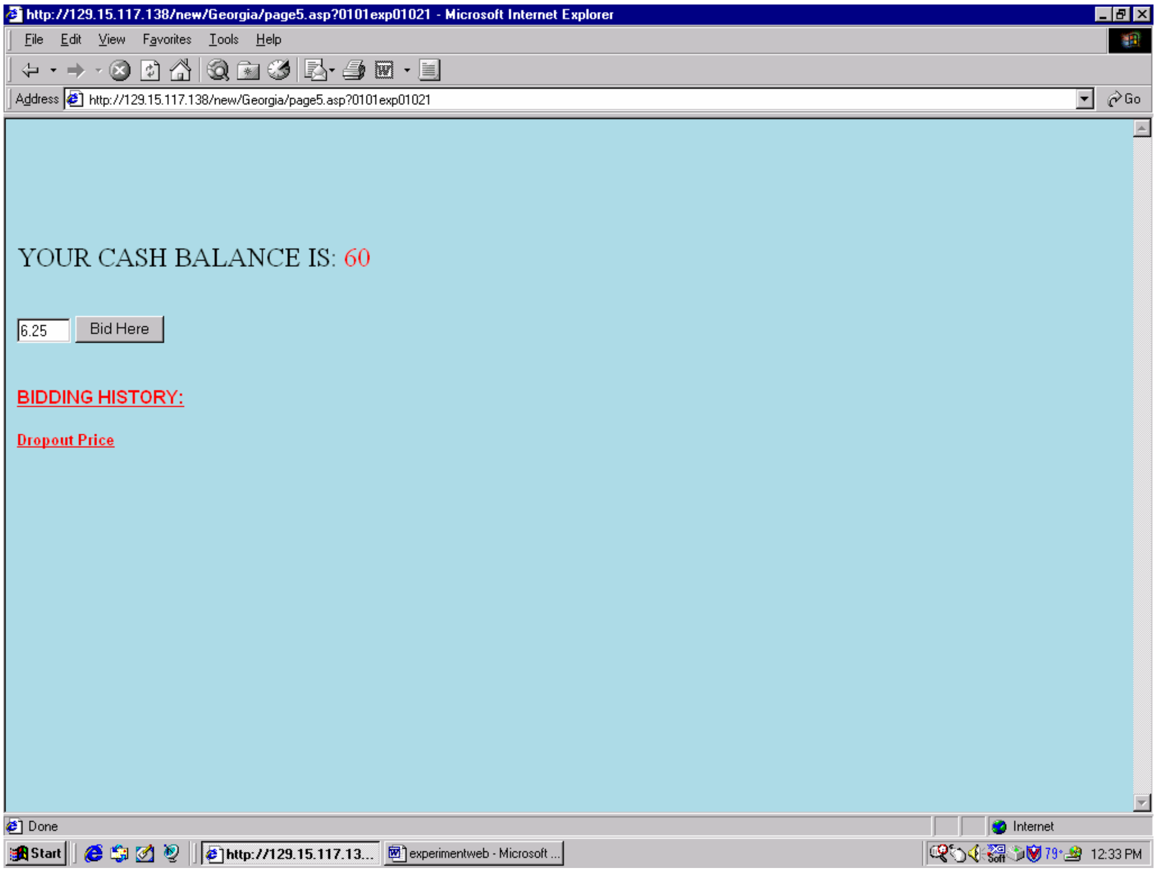

Figure 3B: A bidder who decides to participate at the auction sees the digital clock on his screen, information about his cash balance, and the bidding history as the auction progresses.

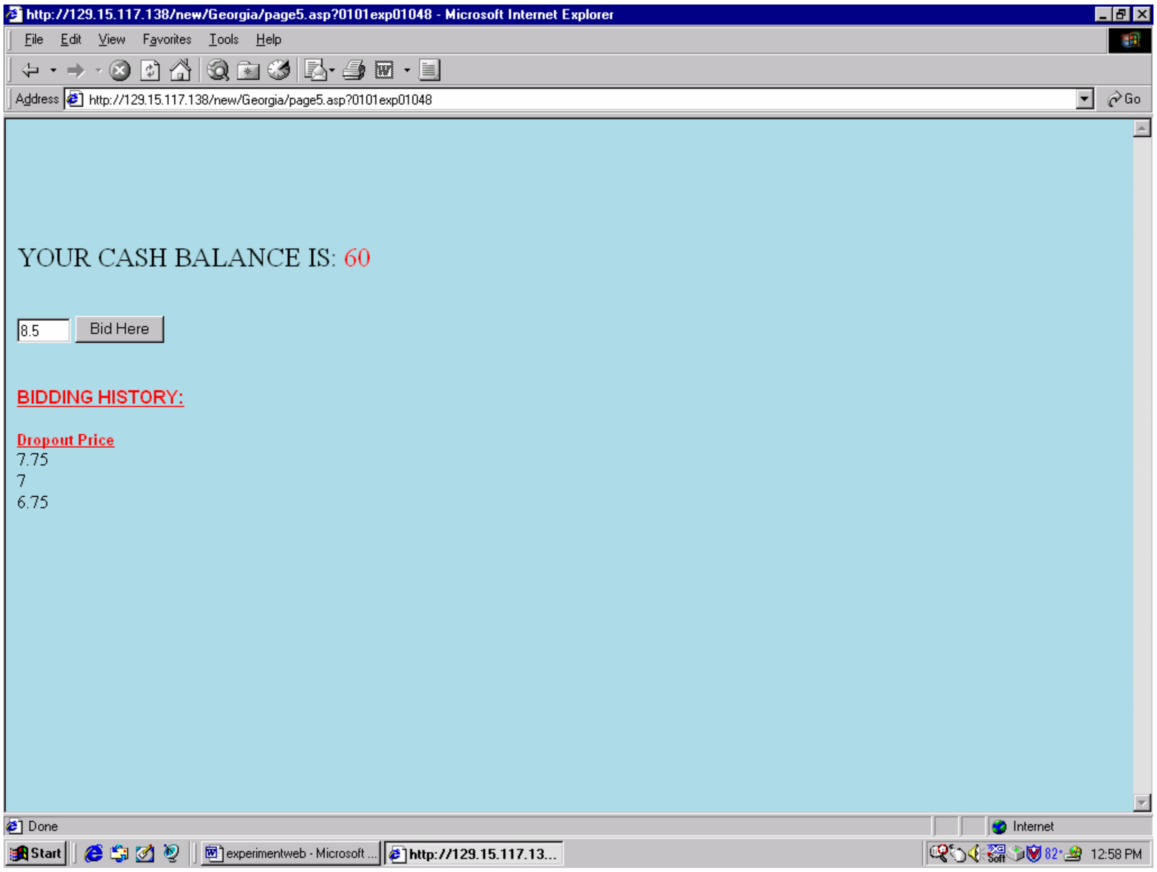

Figure 4B: As bidders drop out, their dropout prices appear on the screen of active bidders.

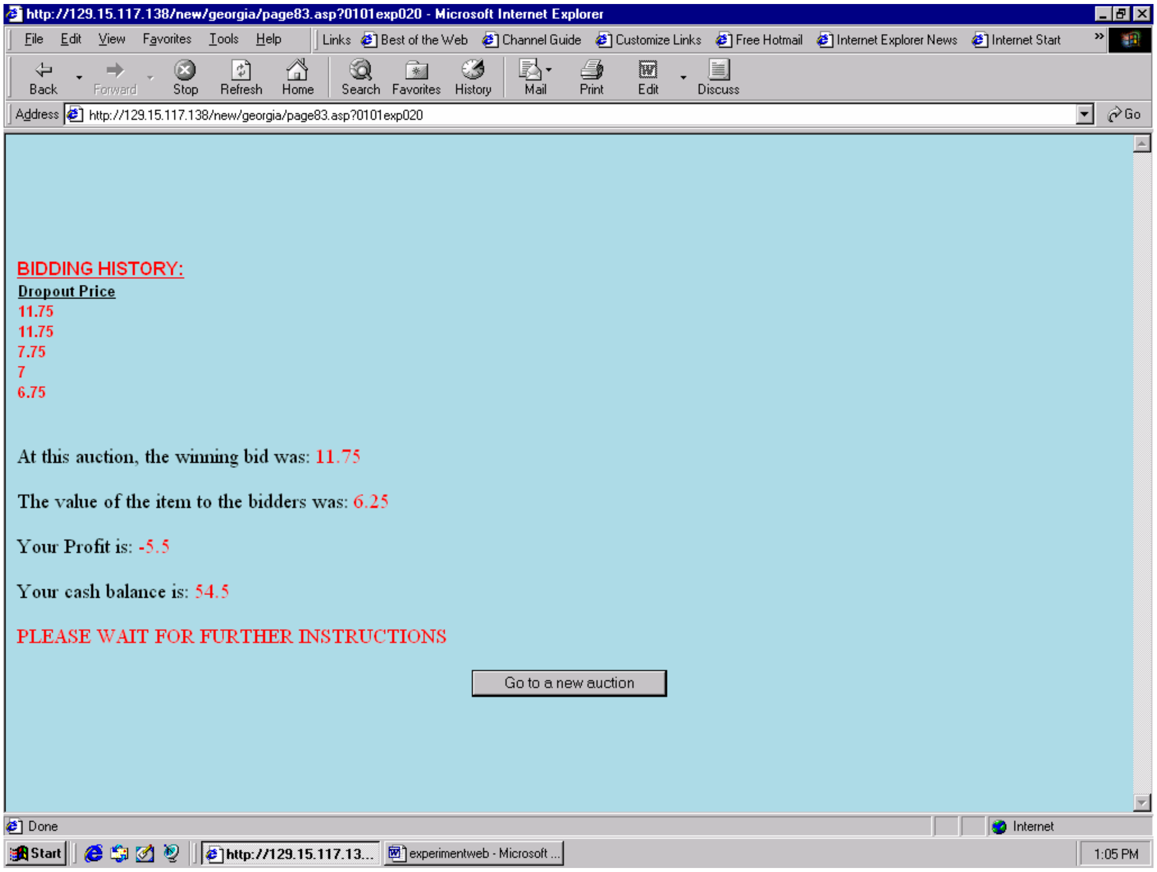

Figure 5B: When the auction is concluded, the bidding history, the winning bid, the value of the item to the bidders, the profit or loss, and the remaining cash balance appear on the screen.

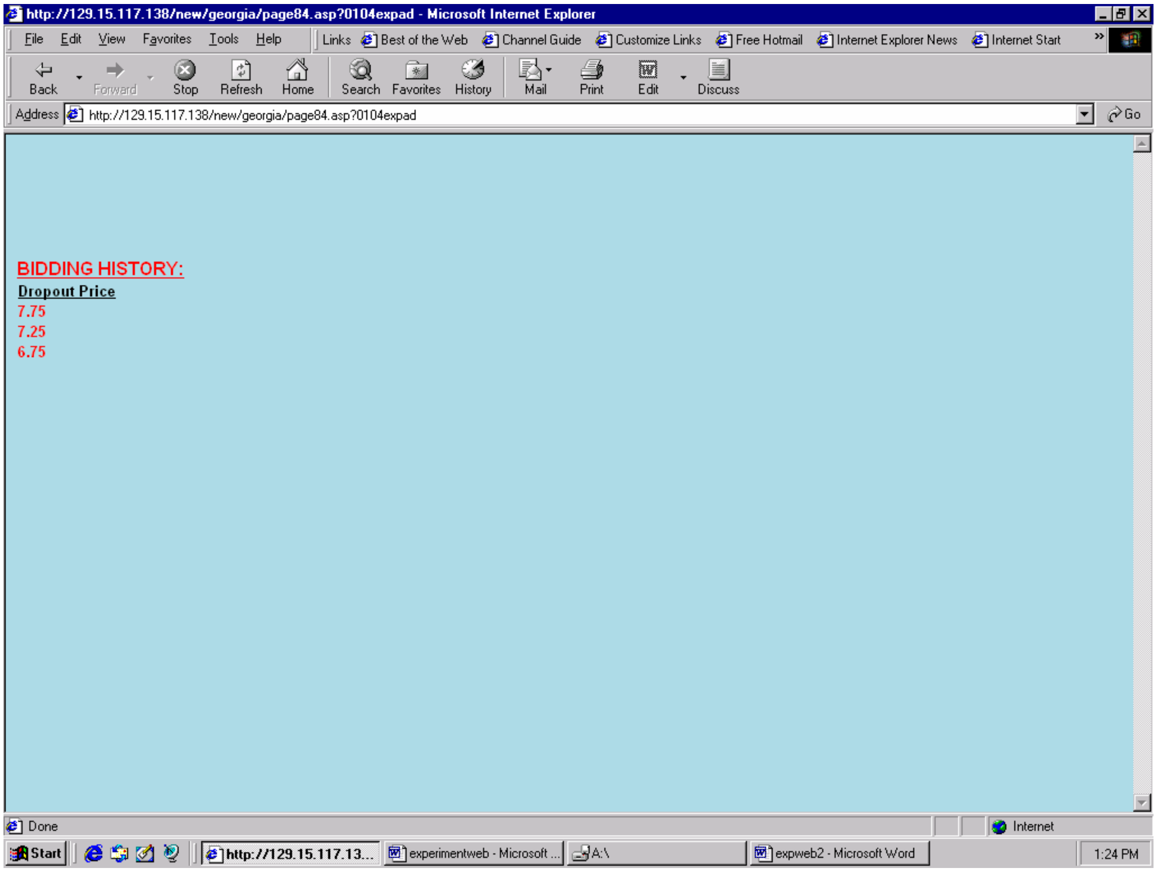

Figure 6B: A bidder who does not participate at the auction gets the same information as every other bidder but the clock will no longer be available on his screen.

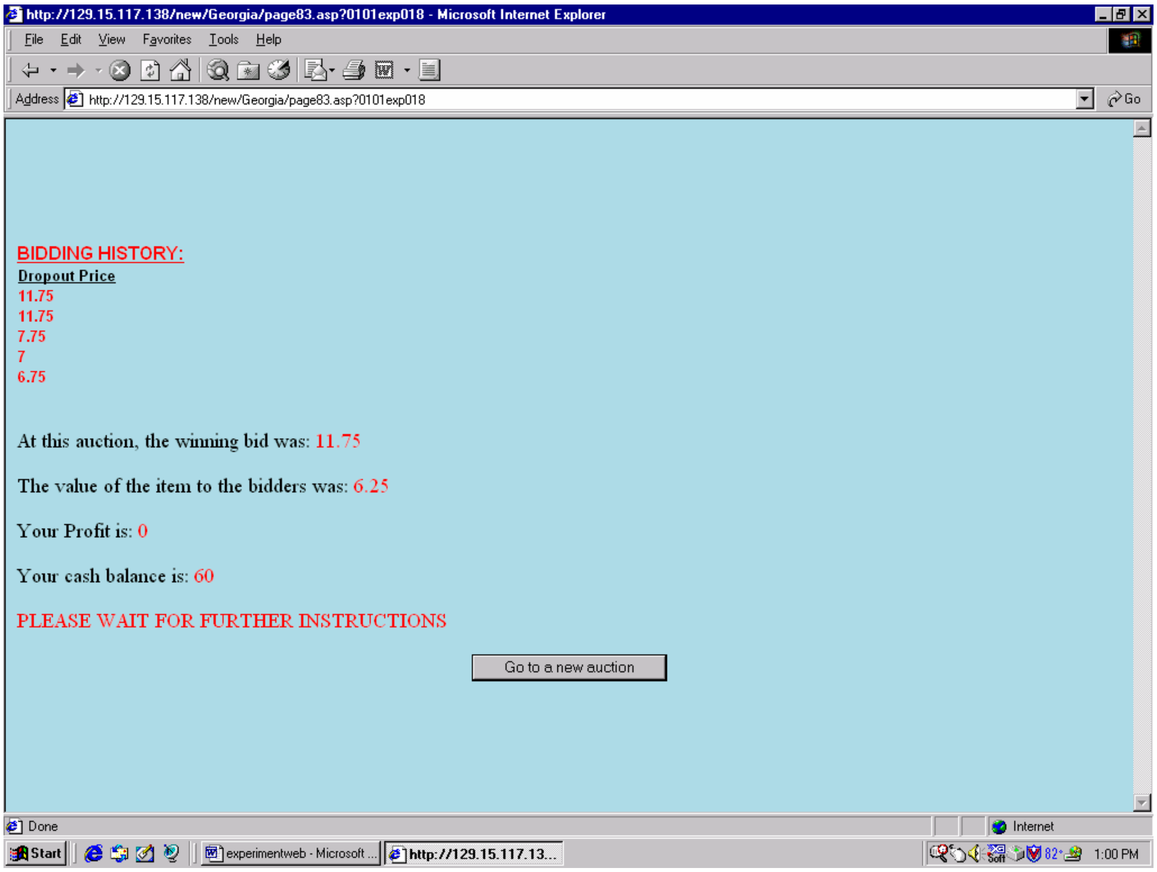

Figure 7B: At the end of every auction, those who do not participate observe the same information on the screen as those who participate.

SELLER'S OBSERVATION WINDOW

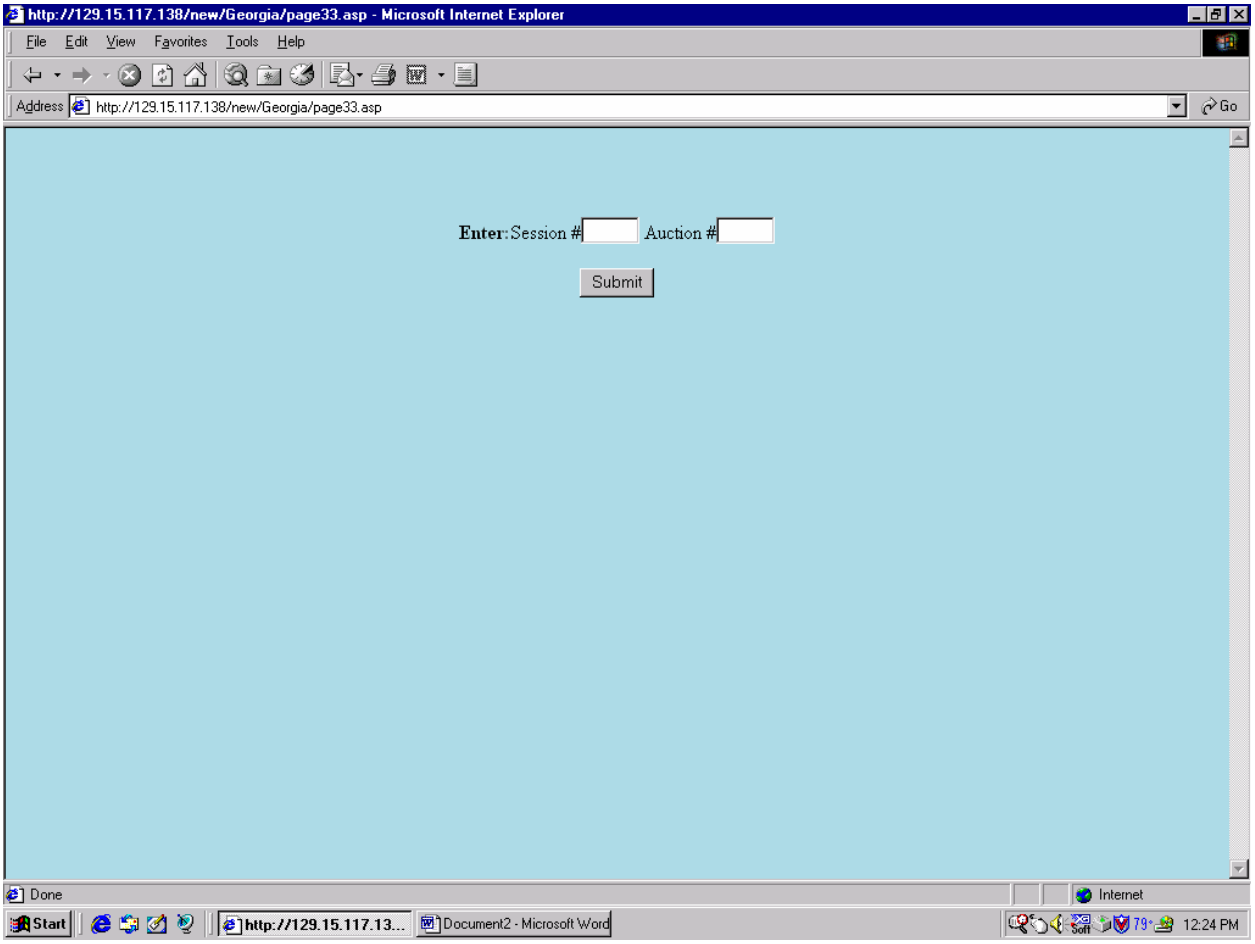

Figure 8B: When the seller is not participating, he/she gets to observe the outcome of the auction, including the bids, from the following observation window. All the information that is available to bidders is available to the seller as well (other than the bidders' signals).

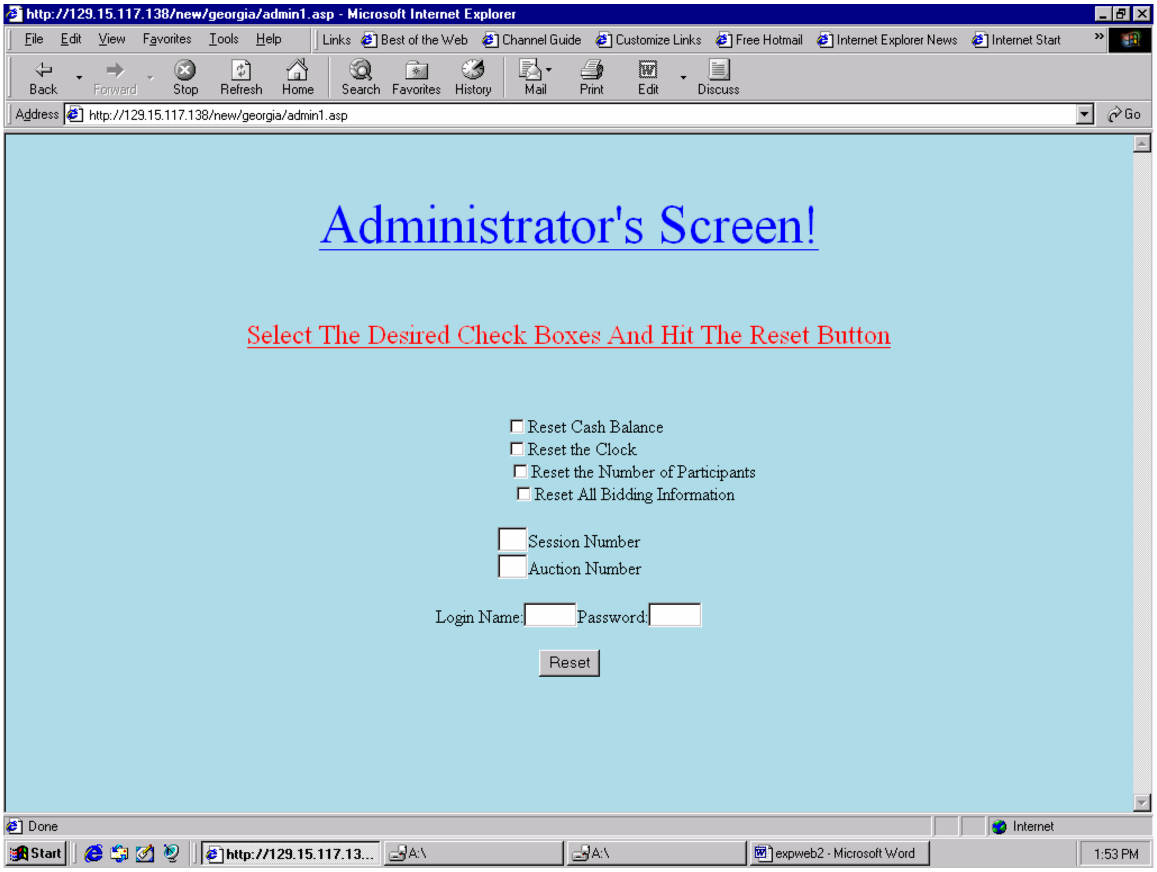

Figure 9B: This is the screen that the administrator uses to control the auction process and proceed from one auction to the other.

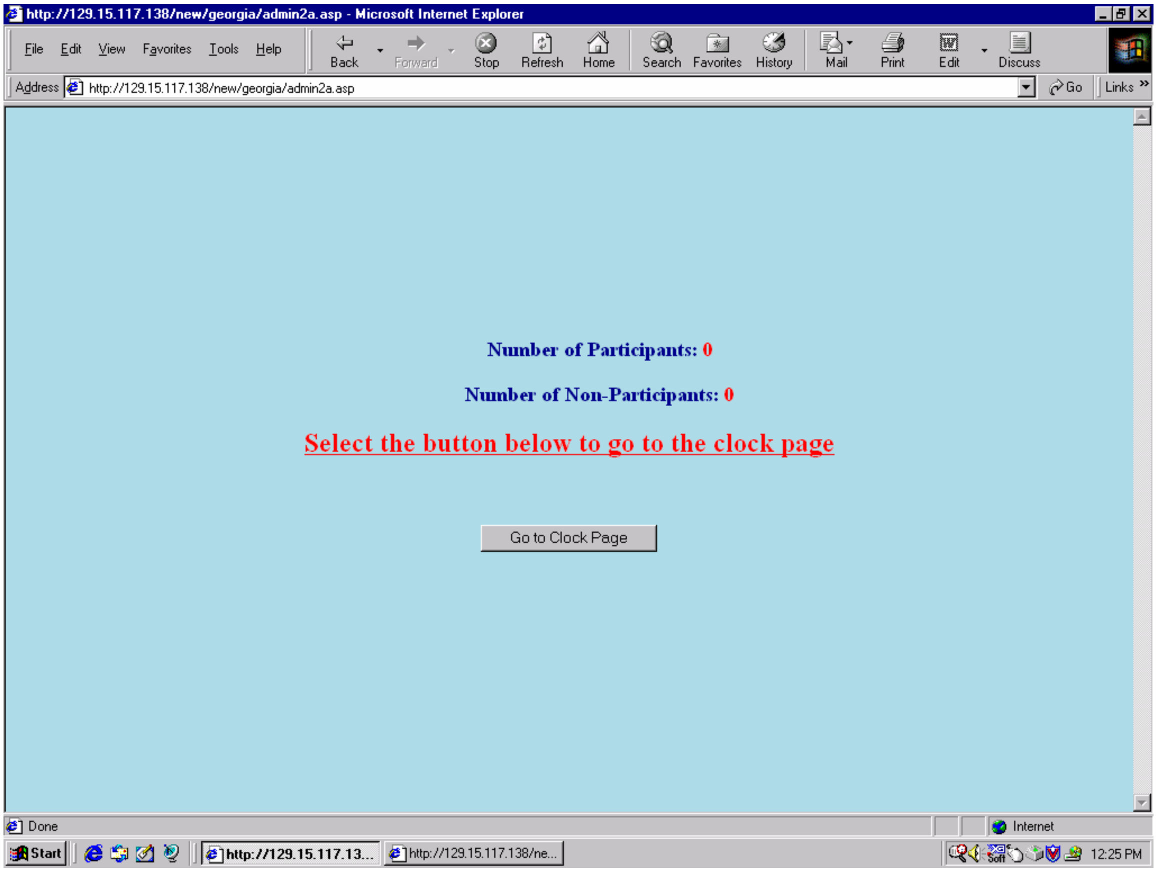

Figure 10B: Once an administrator chooses the session and auction number, he/she observes the number of people that entered to participate at the auction and can wait until all potential bidders have made up their minds to start the auction.

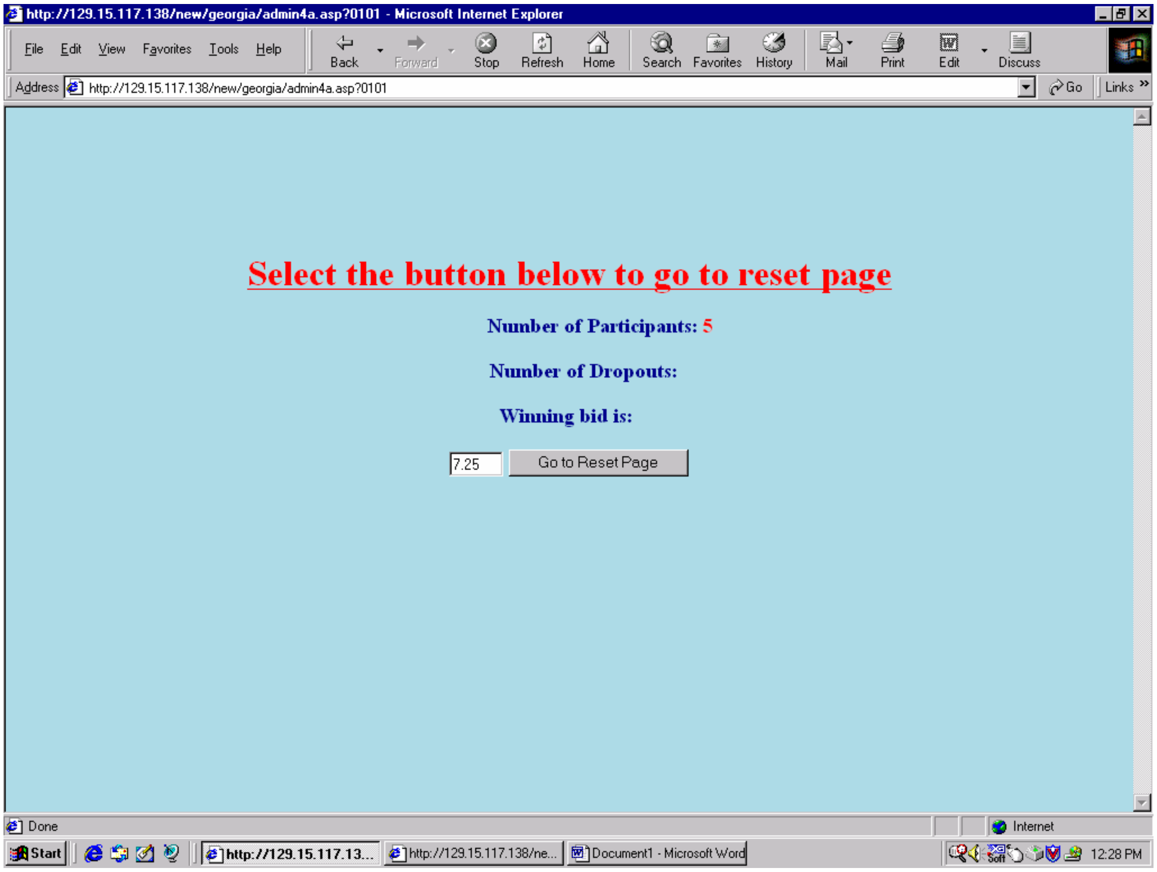

Figure 11B: The administrator can see, on this screen, how many participants are there and how many have dropped out of the auction so that he/she can continue the process without interruption in the thought process of bidders.

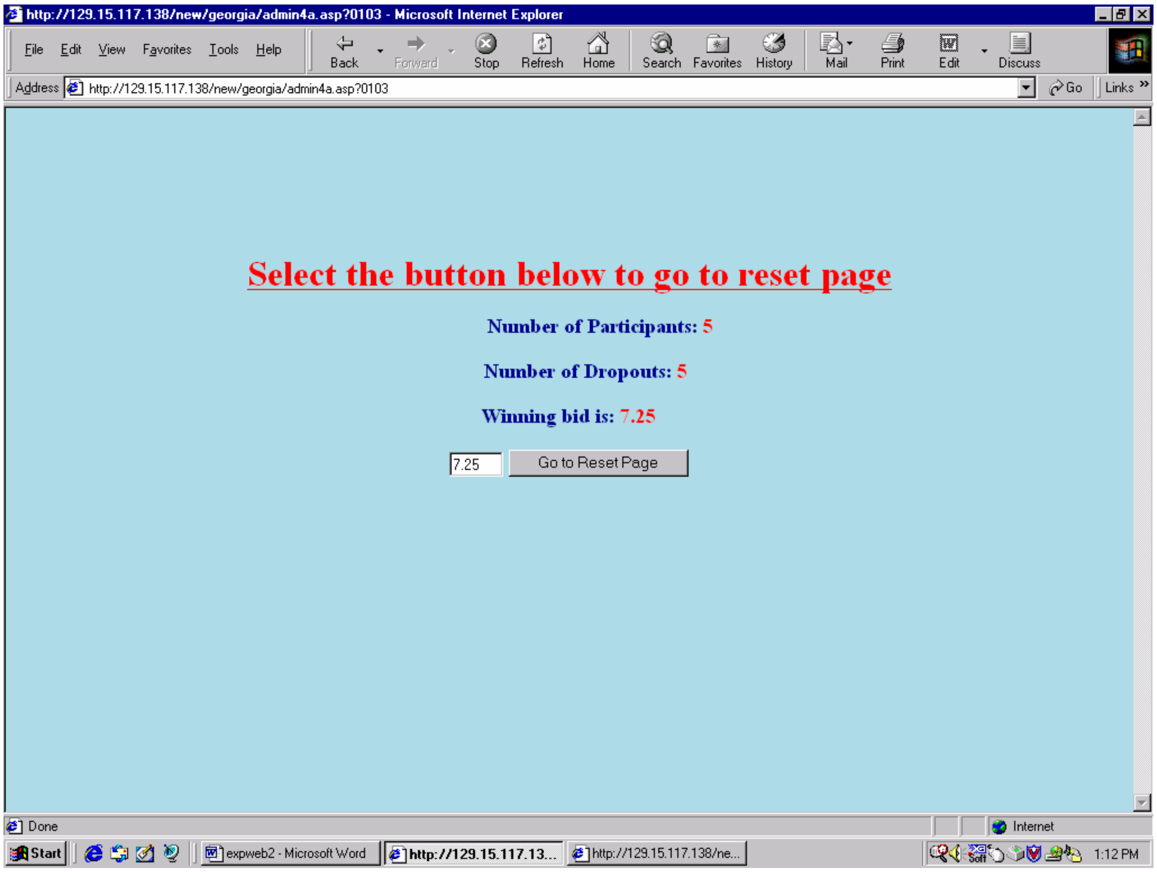

Figure 12B: Once an auction ends, the number of dropouts will equal the number of participants and the winning bid will appear on the administrator's screen.