

# **Jump Bidding in Takeover Auctions: An Experimental Study**

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This paper presents experimental analysis of jump bidding in English auctions with entry costs. It provides support for the signaling hypothesis behind jump bidding and analyzes how the size of the entry costs affects the bidders' behavior. It also shows that jump bidding does not affect the total surplus but allows the reallocation of the surplus from the seller to the bidders. In addition, it shows that the first bidder has an advantage over the second bidder and, on average, enjoys a higher surplus.

JEL code: D44, C91; G34

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## **1. Introduction**

It is well-known that initial bids in takeover auctions are significantly higher than the pre-auction stock price of the target firms (see, e.g., Bradley, 1980; Betton and Eckbo, 2000, and Eckbo, 2009). The leading explanation for such jump bidding is based on signaling arguments. Fishman (1988) argues that acquirers need to spend a substantial amount of resources to investigate how valuable the potential acquisition is. Assuming that the potential synergy is independent across acquirers, Fishman (1988) argues that the first bidder with significantly high private value of acquisition may decide to submit the first offer at a high premium to signal his value and discourage potential competitors from entering the takeover contest. Daniel and Hirshleifer (1998) argue that placing or revising takeover bids is costly, and show that, in the presence of such bidding costs, a signaling jump bidding equilibrium in private value English auctions will arise. Hirshleifer and P'ng (1989) construct a jump bidding equilibrium in the presence of both entry and bidding costs. A more general theory of the use of jump bidding as a signaling device in two-stage auctions with affiliated values was developed by Avery (1998).

Despite the popularity of the signaling hypothesis, Eckbo (2009) notes that: “testing preemption arguments is difficult since one obviously cannot observe deterred bids”. As a result, most of the empirical support for the signaling hypothesis in takeover auctions comes from testing auxiliary predictions of the signaling models of Fishman (1988), Daniel and Hirshleifer (1998), and Hirshleifer and P'ng (1989). The existing experimental research of the reasons behind jump bidding neither considers takeover-type auctions (i.e.,

auctions with entry or bidding costs) nor provides a direct test of the signaling hypothesis in standard English auctions.

In this paper we present the results of the experimental study that is closely related to the takeover auction model developed by Fishman (1988). We show that in the presence of entry costs the first bidder places jump bids that deter the second bidder from entering. By conducting treatments with high and low entry costs, we show that first bidders in low-cost auctions place preemptive bids less often but the size of such bids is generally higher than in auctions with high entry costs. Consistent with this behavior, the second bidders in low-cost auctions enter more often and higher jump bids are required to preempt them from entering. We also analyze the wealth distribution and social welfare implications of jump bidding. We show that jump bidding leads to wealth redistribution from the seller to the bidders but has little effect on social welfare. We also document that the first bidder receives significantly higher profits than the second bidder. All this evidence is consistent with the predictions of the signaling jump bidding model of Fishman (1988).

Besides signaling, there are several alternative explanations for jump bidding. At and Morand (2008) argue that jump bidding in takeover auctions may be due to the free-riding problem among the shareholders of the target firm. In some instances, jump bidding can be explained by bidders' anticipation of the seller's hidden reserve price, and, thus, by their desire to save time and effort by not placing bids which will be refused outright (Dodonova and Khoroshilov, 2007). For a specific form of the bidders' value distribution function, jump bidding can be explained by strategic bidding where bidders place jump bids to

discourage other bidders with values in a specific region from participating in the auction (Isaac, Salmon, and Zillante, 2007). Hörner and Sahuguet (2007) constructed a two-stage auction game in which they show that, although jump bidding may be due to signaling, the signaling does not have to be monotonic. Rothkopf and Harstad (1994) show that jump bidding is optimal in the presence of a non-trivial bid increment. Finally, jump bidding may be explained by the bidders' impatience (or time cost) and desire to speed up the auction (Isaac, Salmon, and Zillante, 2005; Kwasnica and Katok, 2007).

The phenomenon of jump bidding is not limited to the takeover contests but is a common feature of other types of auctions that use (possibly, modified) English auction design, e.g., online auctions (Easley and Tenorio, 2004), government airway auctions (McAfee and McMillan, 1996; Börgers and Dustman, 2005; Cramton, 1997; Plott and Salmon, 2004), Forest Service timber auctions (Baldwin, Marshall, and Richard, 1997; Haile and Tamer, 2003), or used car auctions (Raviv, 2008). Although there is substantial empirical and experimental evidence of jump bidding, there are only a few experimental studies that investigate the reasons behind jump bidding in English auctions. Kwasnica and Katok (2007) test the impatience hypothesis and show that, when time is a valuable resource, the size of jump bids are higher when time is more valuable. Isaac and Schnier (2005) also provide an experimental support for the impatience hypothesis, and, consistent with Rothkopf and Harstad (1994), show that jump bidding is affected by the size of the bidding increment. Isaac, Salmon, and Zillante (2005) provide additional support for the impatience hypothesis, but are unable to confirm either the hypothesis that jump bidding is due to strategic or distributional reasons or the signaling hypothesis.

None of the existing experimental studies, however, test the signaling hypothesis directly (i.e., by controlling for other reasons behind jump bidding) or studied the takeover-style auctions with entry costs; this paper aims to fill that gap. The rest of the paper is organized as follows: in Part 2 we describe the Fishman (1988) takeover auction model with entry costs that is used in our experimental design; Part 3 discusses our experimental design in detail and presents the basic data description; Part 4 provides a more rigorous analysis of the data; and Part 5 concludes.

## 2. The model

Fishman (1988) develops the following private value takeover auction model with two risk-free bidders, consecutive entry, and entry costs. Prior to the auction, bidder #1 observes a “state of the world” signal  $\tilde{w} \in \{low, high\}$  and decides if he wants to spend non-refundable investigation costs  $C_1$  to find out his private value of the object  $S_1$ . This value is randomly distributed with probability distribution function  $F_1(\cdot)$ . After that, he can place an opening bid  $B_1$  at or above the current market price of the target firm  $R$ . Bidder #2 observes whether or not bidder #1 placed the opening bid  $B_1$  and, if yes, its size. Based on this information, bidder #2 decides if he wants to compete. If he decides not to compete, bidder #1 wins the object for the price equal to his opening bid. If bidder #2 decides to compete, he spends non-refundable investigation costs  $C_2$  to find out his private value of the object  $S_2$ . This value is independent on  $S_1$  and randomly distributed with probability distribution function  $F_2(\cdot)$ . After that, it is assumed that bidders will be

involved in a clock-style English auction in which the bidder with the highest value wins the auction for a price equal to the maximum between the other bidder's value and the opening bid. Fishman (1988) assumes that parameters of the model are such that: (1) no bidder will enter the auction without finding out his value of the object  $S_i$  first, (2) bidder #1 will spend investigation costs  $C_1$  if and only if  $\tilde{w} = high$ , and (3) bidder #2 will never enter the auction if he observes that bidder #1 did not bid.

Fishman (1988) looked for a signaling equilibrium in pure strategies in which bidder #1 submits a minimum bid  $B_1=R$  if and only if his value of the object  $S_1 < \bar{S}$  and submits a jump bid  $B_1 = \bar{B} > R$  if and only if  $S_1 \geq \bar{S}$ , where  $\bar{S}$  is some threshold, while bidder #2 decides to compete if and only if  $B_1 < \bar{B}$ . He found that there are multiple equilibria of this form which are characterized by the signaling function  $\bar{B}(\bar{S})$ , but only one of them (with the minimum possible  $\bar{S}$ ) satisfies the credibility requirement adopted by Grossman and Perry (1986). He shows that jump bidding has no effect on the total social welfare but leads to redistribution of the surplus from the seller to the first bidder. He also shows that a decrease in the second bidder's costs  $C_2$  will make the first bidder place jump bids less often ( $\bar{S}$  increases) but at a higher premium (higher  $\bar{B}$ ).

In this paper we provide an experimental test of the Fishman (1988) model with small simplifications. In particular, we eliminate the "state of the world" parameter and assume that bidder #1 must spend investigation costs  $C_1$  and bid for the object (indeed, in all our treatments it is optimal for bidder #1 to do so). We also assume a specific distribution function for  $S_1$  and  $S_2$ , namely, we assume they are uniformly distributed between \$0 and

\$200. We further assume that  $C_1 = C_2$  (we denote the common investigation costs by  $C$ ) and that the current market price of the target  $R = \$0$ . None of these modifications affects the essence of the Fishman (1988) model or its predictions. As a result, the subjects in our experiments participated in the following game.

### *The game*

There are two players (bidders) who compete for a fictional item. At the beginning of the auction bidder #1 spends non-refundable entry costs  $\$C$  and observes his private value of the object  $S_1$  which is uniformly distributed on  $[\$0, \$200]$  interval. Based on this information, he places an opening bid  $B_1$  that must satisfy  $0 \leq B_1 \leq S_1$ . Bidder #2 observes the opening bid  $B_1$  placed by the first bidder and must decide if he wants to enter the auction. If he decides not to enter, he receives  $\$0$  and bidder #1 wins the auction for the price equal to his initial bid  $B_1$ , i.e., bidder #1 wins  $\$(S_1 - B_1 - C)$ . If bidder #2 decides to enter the auction, he spends non-refundable entry costs  $\$C$  and observes his private value of the object  $S_2$  which is independent on  $S_1$  and uniformly distributed on  $[\$0, \$200]$  interval. After that, the bidder with the highest value wins the object for the price equal to the maximum between the other bidder's value and the opening bid, i.e., the winner wins  $\$(\max\{S_1, S_2\} - \max\{\min\{S_1, S_2\}, B_1\} - C)$  while the other bidder loses  $\$C$ .

Assuming bidders behave rationally, such design allows us to provide a clean test of the signaling hypothesis behind jump bidding and to separate it from the impatience or strategic bidding due to the distributional reasons. Indeed, one can think of this auction design as a two-stage game. In the first stage each bidder makes only one decision: the first

bidder decide on the size of his opening bid and the second bidder decides whether he wants to enter the auction. The second stage is just a forced-run English auction in which each bidder is required to bid up to his value of the object. Since this forced-run auction is instantaneous, the impatience cannot affect the bidders' decisions in the first stage of the game. To control for the irrationality in bidders' behavior, we have conducted a control treatment in which we set the entry costs  $C=0$ .

### **3. Experiment design and data description**

Using students from various departments of the same university as subjects, we have conducted three treatments: "high-cost", "low-cost", and "no-cost" (control). In the high-cost treatment we set the entry cost to \$25, in the low-costs treatment it was \$12.5, and the no-cost treatment had zero entry costs. In total, 104 students participated in the high-cost treatment, 108 students participated in the low-cost treatment, and 72 students were involved in the no-cost treatment. In the high-cost and low-cost treatments subjects were divided into 6 separate sessions; in the no-cost treatment subjects were divided into 4 sessions. In each session subjects played 40 rounds of the auction game described in the previous section. Prior to each round subjects were randomly divided into pairs and assigned their roles ("bidder #1" or "bidder #2"). At the end of each round each subject was given the information about his opponent's strategy and the outcome of the auction. Prior to the session, subjects were provided with instructions (see Appendix) and were asked to fill in a simple questionnaire that tested their understanding of the rules. The experiment was programmed and conducted with the software z-Tree (Fischbacher, 2007).

All subjects were given monetary compensation based on their performance. Subjects who participated in the high-cost treatment were given a \$25 participation allowance plus the average amount of money they won during the session; subjects who participated in the low-cost treatment were given a \$12.5 participation allowance plus the average amount of money they won during the session; subjects who participated in the control (no-cost) treatment were given the average amount of money they won during the session

To make sure that the subjects' unfamiliarity with the game and any mistakes that they made in early rounds did not affect our results, we analyzed the data from the last 20 rounds of each session only. As a result, we were left with 1040 observations for auctions with high entry costs, 1080 observations for auctions with low entry costs and 720 observations for auctions without entry costs.

Figures 1, 2, and 3 present the basic relationship between the first bidder's value  $S_1$ , opening bid  $B_1$ , and proportion of the second bidders who entered the auction. To construct these figures, we have combined the data into \$10-size intervals. Figure 1 presents the average size of the opening bid  $B_1$  as a function of the first bidder's value  $S_1$  for all treatments. Figure 2 presents the median opening bid as a function of the first bidder's value. Figure 3 presents the second bidder's entry proportions as a function of the opening bid  $B_1$  for treatments with non-zero entry costs. We do not present the entry data for the control treatment since second bidders did not enter in only 8 out of 720 auctions with no entry costs.

Without entry costs the optimal strategy of the second bidder is to enter regardless of the size of the opening bid. Given this strategy of the second bidder, the optimal strategy of the first bidder is to bid  $B_1=0$  regardless of his value  $S_1$ . Indeed, the second bidders in the control treatment follow the optimal strategy: out of 720 auctions in only 8 auctions did second bidders not enter. The behavior of the median first bidder in the control treatment is also consistent with the optimal strategy: the median jump bids for almost all intervals on Figure 2 are under \$1. However, not all of the first bidders in the control treatment behave optimally: the average opening bid is higher than zero and it increases with  $S_1$ . There are two possible explanations for this jump bidding behavior. First, subjects may be irrational or do not sufficiently comprehend the game to understand that their optimal strategy is to bid  $B_1=0$ . Second, they may attempt to signal their values in the hope that there are some irrational second bidders who may be deterred by high  $B_1$ . As the data shows, all subjects in the control treatment behaved rationally when they were assigned the role of the second bidder. As a result, although first bidders may have attempted to signal, this signaling was not able to deter competition.

The data for both treatments with entry costs supports the Fishman (1988) signaling hypothesis. In particular, the decrease in the entry proportion with the size of the opening bid (Figure 3) shows that higher bids deter competition more often. The positive relation between the size of the average opening bid and the first bidders' values (Figure 1) implies that bidders with higher values are more likely to place jump bids to signal their values. Furthermore, a stronger dependence of average  $B_1$  on  $S_1$  in treatments with entry costs

relative to the control treatment implies that first bidders had reasons to place jump bids beyond a simple irrationality. The significant discrepancy between the average and median bids in auctions with low entry costs can be explain by volatility in the first bidders' beliefs about the size of the opening bid that can deter the competition. Such a discrepancy is consistent with the Fishman (1988) model and it will be discussed later in Part 4.3 when we analyze the effect of the size of the entry costs on the bidders' behavior

## 4. Data analysis

### 4.1. *Jump bidding and signaling*

If first bidders in treatments with entry costs use successful signaling, we should observe that:

- (1) the size of the jump bid  $B_1$  should positively depend on the first bidder's value  $S_1$  and this dependence must be stronger than in the control treatment; and
- (2) entry proportions should negatively depend on  $B_1$ .

To test the latter effect, we estimate the probit and logit models of the effect of  $B_1$  on the entry proportions separately for high-cost and low-cost treatments. For the high-cost treatment, the probit model estimation of the second bidder's entry probability as a function of  $B_1$  shows a negative significant (at 1% level) dependence of the entry probability on the observed jump bid with estimated coefficient of -0.024 and the marginal probability effect of -0.009. The logit estimation shows a negative significant (at 1% level) dependence with estimated coefficient of -0.041 and odds ratio of 0.960. For the low-cost

treatment, the probit model estimated coefficient is -0.015 (significant at 1% level) with the marginal probability effect of -0.004. The logit estimation shows a negative significant (at 1% level) dependence with estimated coefficient of -0.025 and odds ratio of 0.975.

To test the former effect, we have estimated the following regression model:

$$B_1 = \beta_0 + \beta_2 S_1 + \beta_1 (S_1 \times I_{\text{costs}}) + \varepsilon, \quad (1)$$

where  $I_{\text{costs}}$  is the indicator function that is equal to one for treatments with entry costs and zero for the control treatment. We estimated regression (1) separately for high-cost treatment (using the data from high-cost and no-cost treatments) and low-cost treatment (using low-cost and no-cost data).

Note that, since opening bid  $B_1$  cannot be large than the bidder's value  $S_1$ , the standard deviation of the error term in equation (1) is not constant and it positively depends on  $S_1$ . Thus, to estimate regression model (1) we use the Weighted Least Squared (WLS) estimation method assuming the error term has the following functional form:

$$\text{Var}(\varepsilon) = \sigma^2 \times S_1^\lambda, \quad (2)$$

where  $\sigma$  and  $\lambda$  are constants.

Table 1 presents the estimation results for various values of  $\lambda$  (where \*, \*\*, and \*\*\* denote 10%, 5%, and 1% significance levels).  $\lambda=0$  corresponds to the OLS estimation in which bidders care about the absolute (\$) value of their bid while  $\lambda=2$  corresponds to the case in which bidders care about the value of their bid as percentage of the value of the object. As can be seen from Table 1,  $(S_1 \times I_{\text{costs}})$  has a positive significant (at 1% level) effect on the size of the opening bid, which is consistent with the signaling hypothesis.

Despite a relatively large sample size (1020 observations for the last 20 rounds for high-cost auctions and 1080 observations for low-cost auctions), to confirm our findings, we have conducted non-parametric Spearman and Kendall tests for the rank correlation between the first bidder's value ( $S_1$ ) and the opening bid ( $B_1$ ). We found that both Spearman's and Kendall's rank coefficients are positive and significant at 1% level.

From Figure 1 it is apparent that the relationship between the first bidder's value and the opening bid is not linear. In particular, for high-cost auctions bidders with low values (under \$50) tend to place very small opening bids which gradually increase from \$0 to \$8.78. These increases become steeper for bidders with values between \$50 and \$140 with average jump bids rising from \$8.78 to \$42.06 in this region. For bidders with values above \$150, jump bidding becomes less dependent on the value and it is spread in the \$30–\$45 region. Such behavior is consistent with the signaling hypothesis. Indeed, bidders with low value have little chance of deterring the competition, and, as a result, have little incentive to place jump bids. Bidders with values in the two middle quartiles have a better chance of deterring the second bidder from entering and are willing to place higher

opening bids. Their incentives to deter increases with their values and we observe a steeper relationship between the first bidders' values and opening bids. Bidders with values above \$150 are almost equally likely to deter the competition with large opening bids, and, as a result, the relationship between their values and opening bids becomes less strong.

To further investigate the non-linearity of the bidding function  $B_1(S_1)$  we have divided  $[\$0, \$200]$  intervals into four \$50-wide intervals and estimated the piecewise-linear regression model:

$$B_1 = \beta_0 + \sum_{k=1}^4 \gamma_k ((S_1 - 50(k-1)) \times I_k) + \sum_{k=1}^4 \beta_k ((S_1 - 50(k-1)) \times I_k \times I_{\text{costs}}) + \varepsilon, \quad (3)$$

where  $I_k$  is the indicator function that is equal to one for  $S_1 \geq 50(k-1)$ . Similar to model (1), we estimated regression (3) separately for high-cost treatment (using the data from high-cost and no-cost treatments) and low-cost treatment (using low-cost and no-cost treatments). This piecewise-linear regression model has 3 intermediate nodes at  $S_1 = \$50$ , \$100, and \$150 and, for auctions with entry costs, the slope of the effect of  $S_1$  on  $B_1$  in

interval  $S_1 \in [50(j-1), 50j]$  is equal to  $\sum_{k=1}^j \beta_k$ . The increase in the slope between two

neighboring intervals  $S_1 \in [50(j-1), 50j]$  and  $S_1 \in [50j, 50(j+1)]$  is equal to  $\beta_{j+1}$ . Tables

2a and 2b present the WLS estimation results for various values of  $\lambda$  (where \*, \*\*, and \*\*\* denote 10%, 5%, and 1% significance levels). The estimated slope for each segment of the piecewise-linear function is presented under the corresponding estimated coefficient.

As can be seen from Tables 2a and 2b, the first derivative of the bidding function  $B_1(S_1)$  for treatments with entry costs has an arch-shape. There is no significant signaling for low values: jump bids only slightly increase with values in the first quartile where the values of the first bidder are  $S_1 < \$50$  ( $\beta_1$  is small). The slope is significantly (by 2–3 times) higher in the second and third quartiles (e.g., for high-cost auctions when using WLS estimation with  $\lambda=1$  the estimated slope increases by 0.132 from 0.064 to 0.196 in the second quartile and does not significantly change until  $S_1$  reaches \$150). Finally, in the fourth quartile ( $S_1 > \$150$ ) the slope significantly (by 20–30%) decreases. Such behavior of the slope is consistent with the signaling behavior: bidders with low values  $S_1 < \$50$  do not signal, bidder with medium values  $\$50 < S_1 < \$150$  signal and the strength of their signal positively depends on their values<sup>1</sup>, and bidders with high values  $S_1 > \$150$  already provide strong enough signals to deter rational competitors, so, the strength of their signal is less dependent on their values.

#### 4.2. Social welfare and wealth distribution

If bidders were not allowed to place jump bids, the optimal strategy for the second bidder would be to enter the auction. As a result, the expected profit of each bidder will be  $\$(33.33-C)$ , the expected profit of the seller will be  $\$66.67$ , and the expected social surplus will be  $\$(133.33-2C)$ . To be able to compare auctions with different entry costs, we consider bidders' "gross" profits, i.e., their actual profits in the game plus the entry fee  $C$ . Table 3 presents the average bidder's gross profits, seller's profit, and the "gross" social surplus for each auction design.

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<sup>1</sup> Or the number of first bidders who place jump bids increases with  $S_1$ , which will lead to a positive dependence of the average jump bid on  $S_1$ .

In the absence of signaling the expected profit of each bidder is \$33.33, the expected profit of the seller is \$66.67, and the expected social surplus is \$133.33. The corresponding numbers in the auction with no entry costs are close to these numbers (the difference is not statistically significant). Fishman (1988) predicts that, when jump bidding is used as a signaling device, it has no effect on the social surplus and the second bidder's profit, but reallocates a part of the profit from the seller to the first bidder. This effect becomes stronger for higher entry costs. The data presented in Table 3 supports these predictions. The first bidder earns higher gross profit and the seller earns lower profit in auctions with entry costs than in auctions with no entry costs while the gross profit of the second bidder and the total gross social surplus is not significantly affected by entry costs. In addition, the first bidder's profit is higher and the seller's profit is lower in auctions with high entry costs than in auctions with low entry costs. The only effect that is not consistent with Fishman's (1988) prediction is a slightly lower than expected profit of the second bidder in low-cost auctions.

#### *4.3. High entry costs versus low entry costs auctions*

Fishman (1988) predicts that a decrease in entry costs makes second bidders enter more often and, hence, higher jump bids are required to deter the competition. Since high jump bids are costly for the first bidders, only bidders with very high value will place jump bids and, as a result, jump bids will be placed less often.

In the framework of the laboratory experiments there are some additional factors that can affect subjects' strategies. First, subjects may not be sophisticated enough to compute the equilibrium strategies and may play simply based on their intuition. Second, subjects own risk-aversion and risk-aversion of their opponents may affect the equilibrium. Finally, subjects may assume that their opponents are not sophisticated enough to figure out the equilibrium and, thus, even sophisticated risk-neutral subjects may find it profitable to deviate from the equilibrium strategy. As a result, it would be reasonable to assume that different first bidders may use different thresholds when deciding at which value to start using jump bidding. The size of jump bidding may also differ across subjects. For the same reason, second bidders may use different thresholds for their entry decisions.

Applying Fishman (1988) predictions to this framework, one should expect that lower entry costs will lead to higher second bidders' entry proportions for any given size of the jump bid  $B_1$ . In addition, there must be more high-premium jump bids among the jump bids that were able to deter competition.

For any given value  $S_1$ , the behavior of the first bidders will be affected in two ways. First, a decrease in entry costs makes bidders increase their threshold  $S_1$  for placing the jump bids. Hence, first bidders who use high threshold  $S_{1,H}$  to start jump bidding in auctions with low entry costs must have used a lower threshold  $S_{1,L}$  in high-cost auctions. As a result, for any given value  $S_1$ , a lower proportion of the first bidders will place jump bids in low-cost auctions than in high-cost auctions. Second, since higher jump bids are required to deter competition in low-cost auctions, for any given  $S_1$  the size of jump bids that were

intended to deter competition will increase. Combined with the lower number of jump bids placed, it will lead to uncertain (and, possibly, insignificant) effect on the average size of the opening bids but will make the distribution of the opening bids to be left-skewed.

The data presented in Figures 1 and 2 is consistent with this behavior of the first bidders. The average opening bids for auctions with high and low entry costs are close to each other while the median bids are much smaller for auctions with low entry costs. Figure 4 presents the ratios of median to mean opening bids for both types of auctions. As can be seen from this figure, this ratio is close to one for high-cost auctions and it is much smaller for low-cost auctions. It implies that in low-cost auctions, for any given  $S_1$ , there is a smaller portion of jump bids, but jump bids that were placed are placed at a higher premium.

Figure 3 shows that the entry proportion is higher in low-cost auctions for any level of the first bidders' values  $S_1$ . Indeed, the average entry ratio in low-cost auctions is 76% and it is only 64% in high-cost auctions (the difference is statistically significant at 1% level). To analyze the dependence of how the jump bids that were able to deter competition depend on the entry costs, Figure 5 presents the probability distribution function of jump bids in auctions where the second bidder did not enter. The first apparent feature of this distribution function is the high share of small bids (under \$10) that were able to deter competition. Second bidders who did not enter after observing a small (under \$10) opening bid are either very risk-averse or behave irrationally. Assuming equal proportion of "irrational" bidders among subjects in different treatments, higher share of low opening

bids that deter competition in low-cost auctions may be explained by the lower total number of deterred entries in these auctions.

To gain a better understanding of the effect of the entry costs on the size of the jump bids required to deter competition, Figure 6 presents a conditional probability distribution of jump bids that deterred competition given that their size is at least \$10. As can be seen from this figure, higher jump bids are required to deter competition in low-cost auctions than in high-cost auctions. After eliminating low jump bids (under \$10), the average jump bid that deterred competition in high-cost auctions is \$50.06 and the corresponding number for the low-cost auctions is \$61.99. The difference is significant at 1% level. This result is also consistent with Fishman's (1988) predictions.

## **5. Conclusion**

This paper provides an experimental test of jump bidding and signaling in takeover auctions. It follows the takeover auction design of Fishman (1988) which models takeover auctions as private value English auctions with entry costs and sequential entry. Fishman (1988) shows that in the presence of entry costs the first bidder with high private valuation of the object may place jump bids to signal his high value and deter potential competition.

In this paper we provide an experimental support for the signaling hypothesis behind jump bidding. We show that in the presence of entry costs the average size of the jump bids positively depends on the first bidder's private valuation of the object and that higher jump

bids are more likely to deter competition. We show that an increase in the entry costs makes second bidders enter less often and reduces the size of the jump bids required to deter competition. At the same time, higher entry costs makes first bidders use signaling through jump bidding more often but reduces the size of the jump they use to signal. Consistent with Fishman's (1988) predictions, we also show that jump bidding has no significant effect on social welfare but reallocates the surplus from the seller to the first bidder.

## **Appendix: Subjects' instructions**

You will play 40 auction games (as described below). For each game students will be randomly divided into pairs and, in each pair, one of the students will be named “bidder #1” and the other will be named “bidder #2”. Your goal is to make as much money as possible. At the end of the experiments you will be paid \$25 for participation plus the average amount of money you win during these 40 games. Please follow instructions on your screen. Note that, from time to time, you may have to wait until all the students complete the round. If you have any questions – please, ask me at any time.

### **The auction game:**

The game is a simplified version of an auction with two bidders. The auction proceeds as follows:

- Bidder #1 pays a non-refundable entry fee of \$25 and learns his “resale value”  $\$S_1$  of the object he is bidding for.  $S_1$  is a randomly drawn number uniformly distributed between \$0 and \$200.
- After learning  $S_1$  bidder #1 must place an opening bid  $B_1$  between \$0 and  $\$S_1$ .
- Bidder #2 observes  $B_1$  and must decide if he wants to enter the auction or not (note that bidder #2 cannot see  $S_1$  at this point).

Now, two scenarios are possible:

(1) *If bidder #2 does not enter the auction*, then bidder #1 wins the object for the value of his initial bid. As a result, bidder #1 earns  $$(S_1 - B_1 - 25)$$  and bidder #2 earns \$0 for this round.

(2) *If bidder #2 enters the auction*, then he pays a non-refundable entry fee of \$25 and learns his “resale value”  $S_2$ , which is a randomly drawn number uniformly distributed between \$0 and \$200 and independent on  $S_1$ . It is assumed that at this point bidders will start the standard bidding process and will bid optimally, i.e., will bid as long as the current price is lower than the bidder’s resale value. To simplify the game, this “bidding process” will be substituted by its outcome. Namely:

(a) if  $S_1 > S_2$ , then bidder #1 wins the object. Since the auction will start from  $B_1$  and bidder #2 will bid up to  $S_2$ , the final price will be  $\max(B_1, S_2)$ . As a result, bidder #1 earns  $$(S_1 - \max(B_1, S_2) - 25)$$  and bidder #2 loses \$25;

(b) if  $S_1 \leq S_2$ , then bidder #2 wins the object. Since the auction will start from  $B_1$  and bidder #1 will bid up to  $S_1$ , the final price will be  $\max(B_1, S_1) = S_1$ . As a result, bidder #2 earns  $$(S_2 - S_1 - 25)$$  and bidder #1 loses \$25.

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Figure 1: Average jump bid

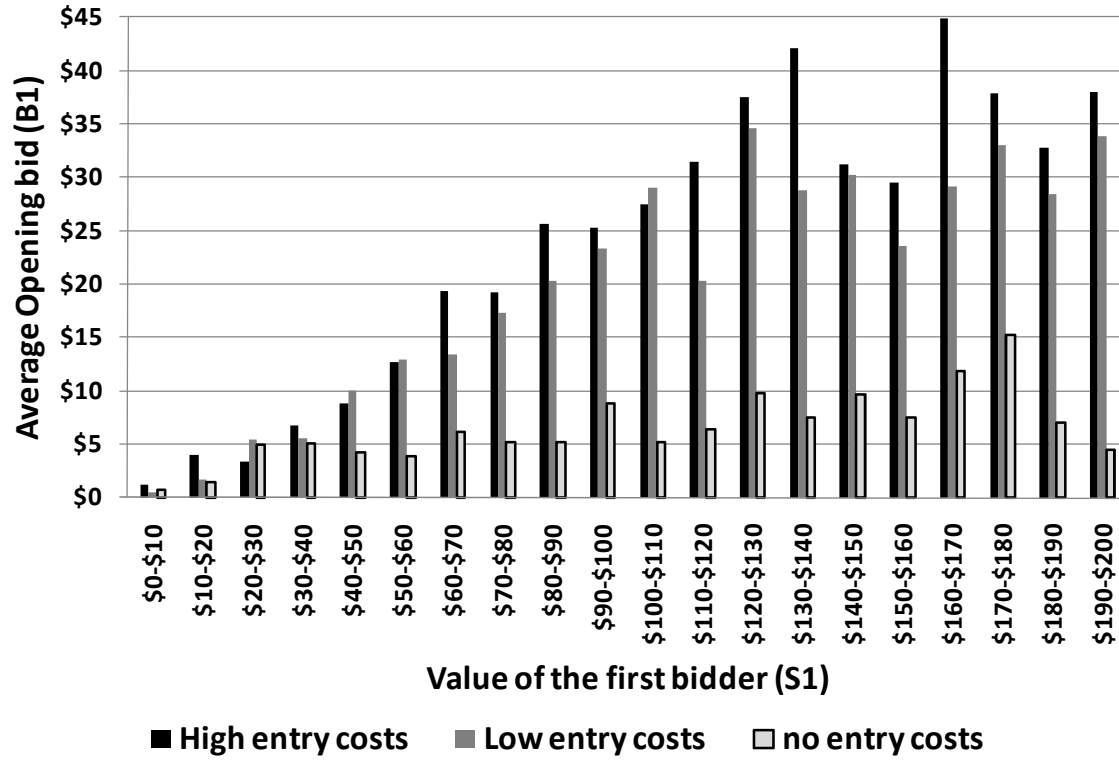
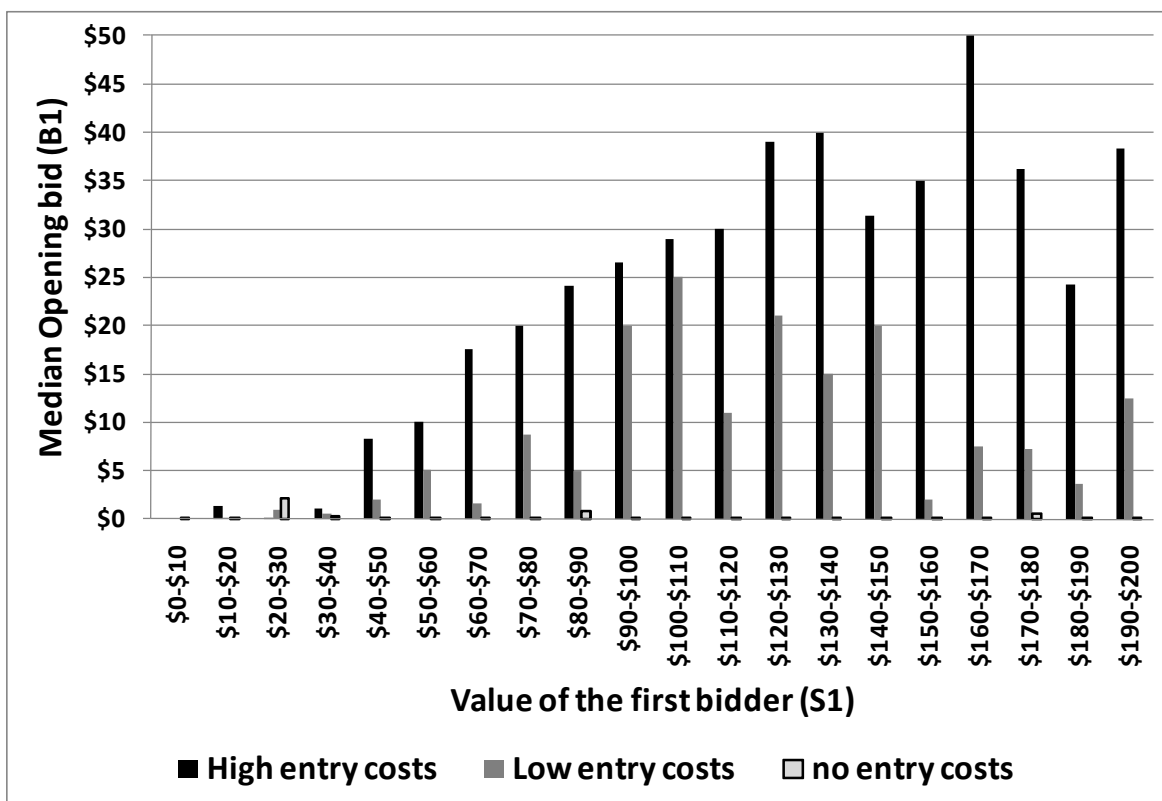


Figure 2: Median jump bid



**Figure 3: Entry proportion**

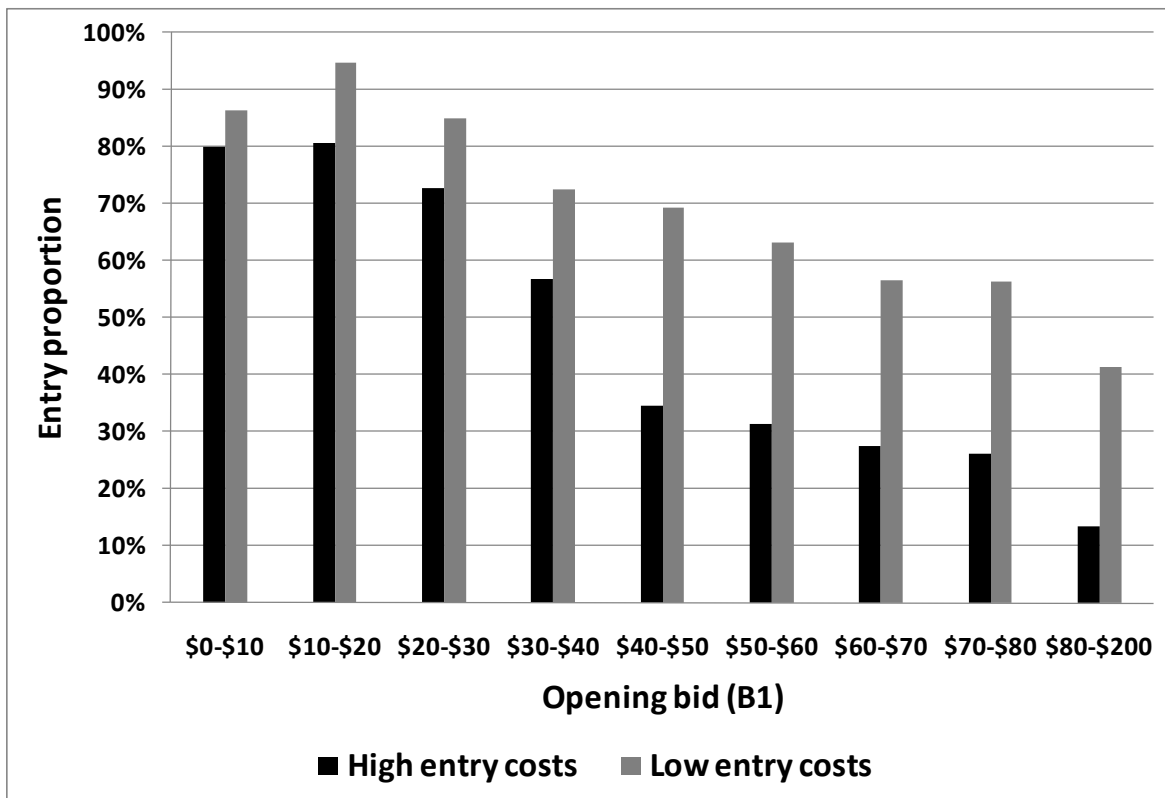
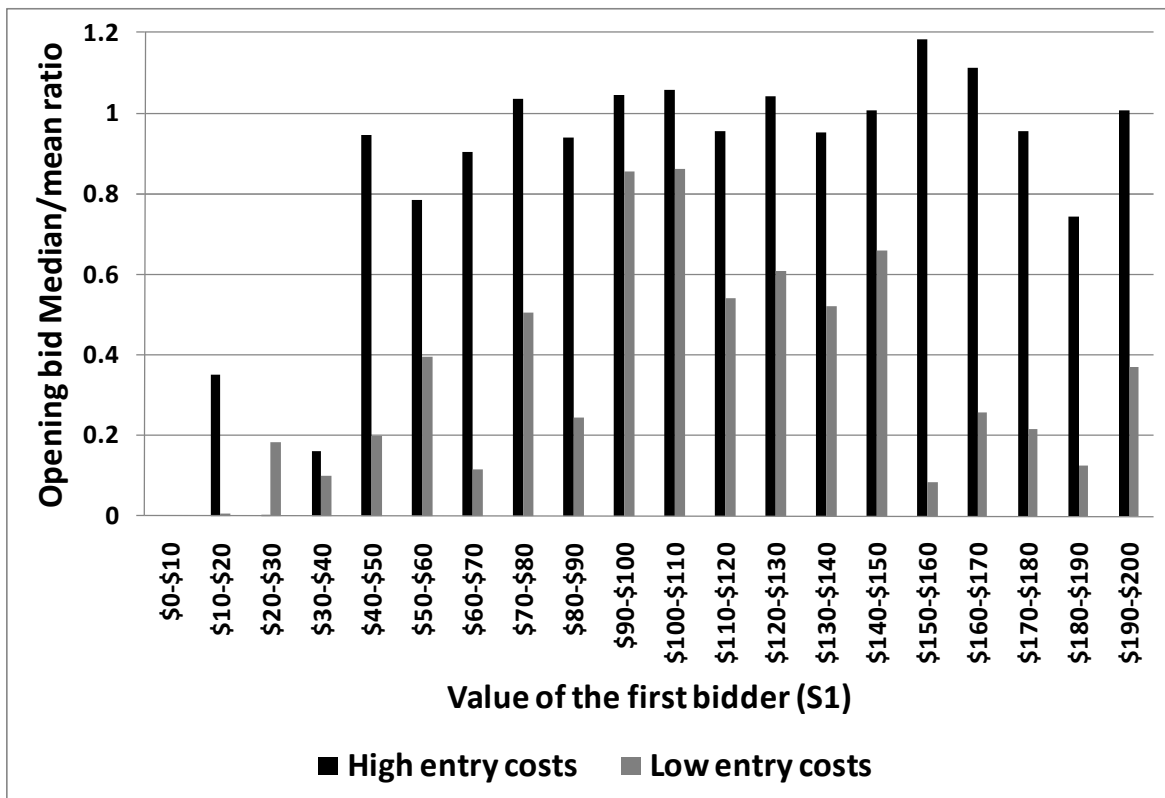
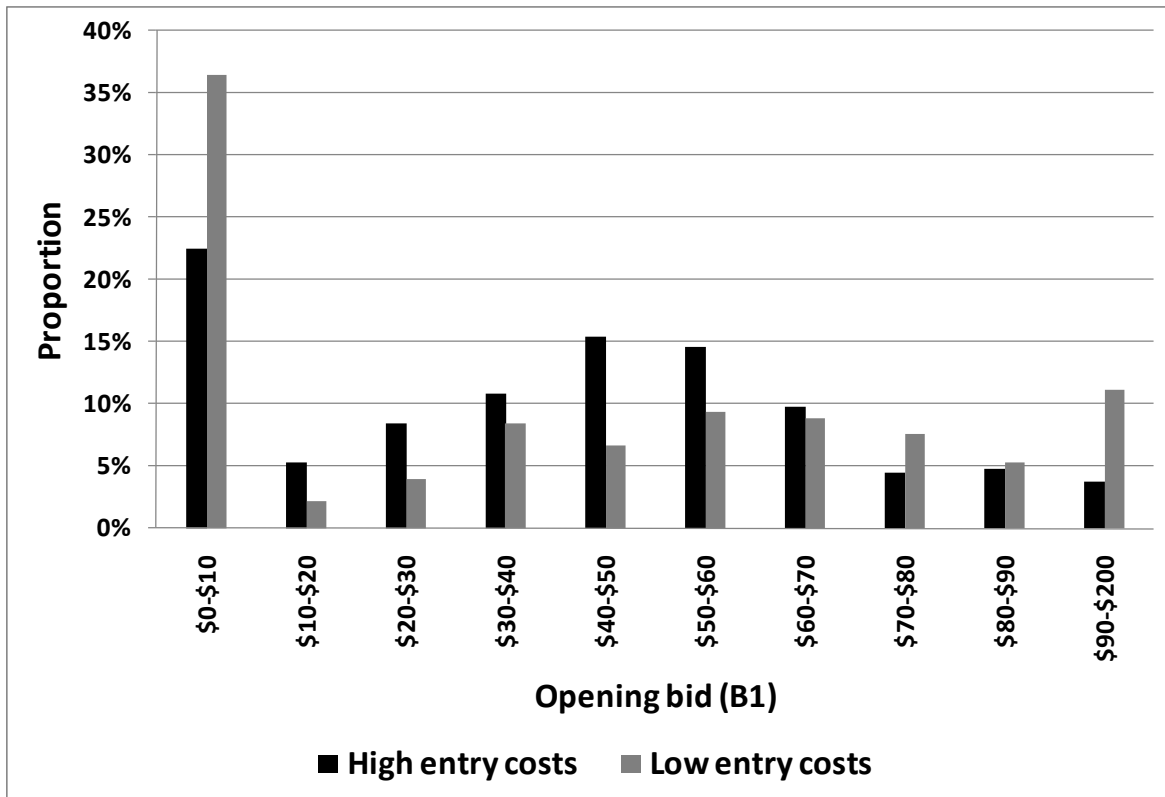


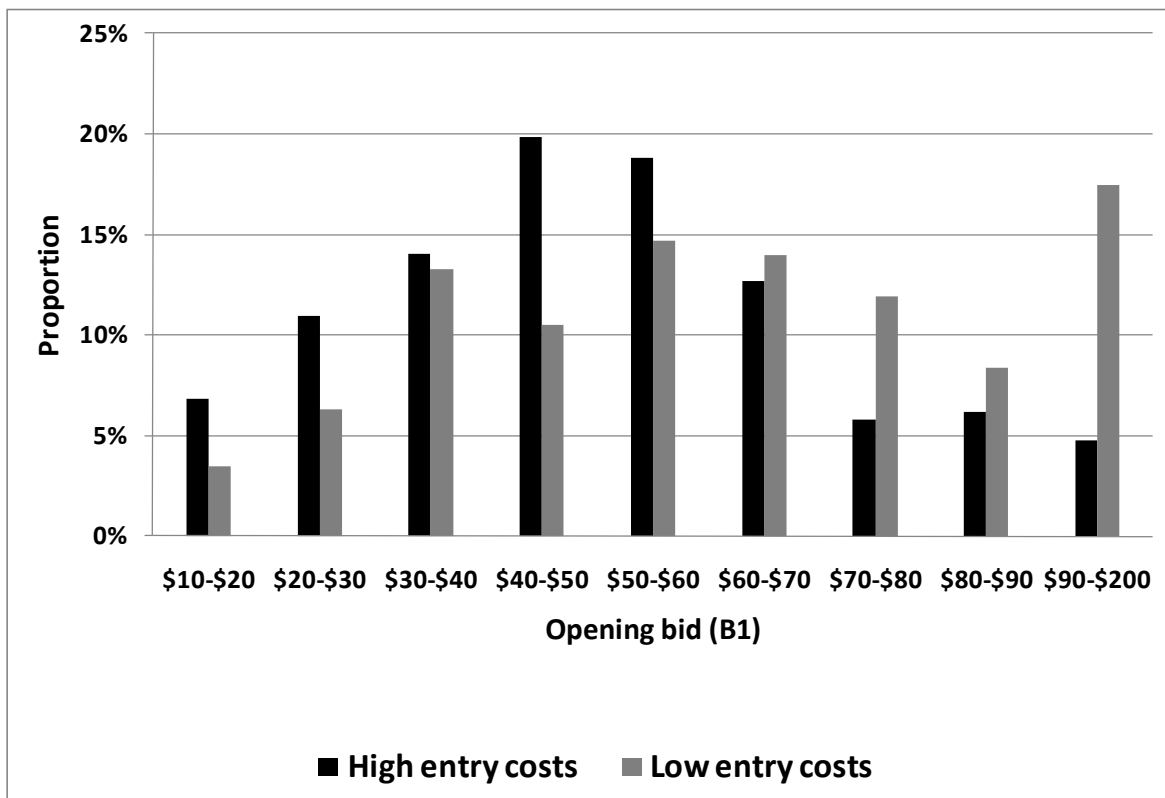
Figure 4: Median-to-mean jump bid ratio



**Figure 5: Probability distribution function  
of jump bids that deter competition**



**Figure 6: Conditional Probability distribution function  
of jump bids that deter competition**



**Table 1: The first bidder's values and jump bidding: simple regression model**

|                               | WLS estimation of equation (1) for high-costs treatments<br>with $Var(\varepsilon) = \sigma^2 \times S_1^\lambda$ |               |             |               |             |
|-------------------------------|-------------------------------------------------------------------------------------------------------------------|---------------|-------------|---------------|-------------|
|                               | $\lambda=0$                                                                                                       | $\lambda=0.5$ | $\lambda=1$ | $\lambda=1.5$ | $\lambda=2$ |
| constant                      | 2.490**                                                                                                           | 0.925         | 0.132       | -0.001        | -0.001      |
| $S_1$                         | 0.040***                                                                                                          | 0.054***      | 0.063***    | 0.070***      | 0.079***    |
| $S_1 \times I_{\text{costs}}$ | 0.174***                                                                                                          | 0.176***      | 0.175***    | 0.170***      | 0.158***    |
| R-sq adj.                     | 29%                                                                                                               | 36%           | 46%         | 49%           | 45%         |
|                               | WLS estimation of equation (1) for low-costs treatments<br>with $Var(\varepsilon) = \sigma^2 \times S_1^\lambda$  |               |             |               |             |
|                               | $\lambda=0$                                                                                                       | $\lambda=0.5$ | $\lambda=1$ | $\lambda=1.5$ | $\lambda=2$ |
| constant                      | 2.760**                                                                                                           | 1.061         | 0.141       | -0.001        | 0.029       |
| $S_1$                         | 0.038***                                                                                                          | 0.052***      | 0.063***    | 0.070***      | 0.078***    |
| $S_1 \times I_{\text{costs}}$ | 0.138***                                                                                                          | 0.139***      | 0.139***    | 0.135***      | 0.122***    |
| R-sq adj.                     | 17%                                                                                                               | 23%           | 33%         | 36%           | 34%         |

**Table 2a: The first bidder's values and jump bidding:  
piecewise regression model for auctions with high entry costs**

|                          |               |              | WLS estimation of equation (3) with $Var(\varepsilon) = \sigma^2 \times S_1^\lambda$ |                          |                         |                         |                         |
|--------------------------|---------------|--------------|--------------------------------------------------------------------------------------|--------------------------|-------------------------|-------------------------|-------------------------|
|                          |               |              | $\lambda=0$                                                                          | $\lambda=0.5$            | $\lambda=1$             | $\lambda=1.5$           | $\lambda=2$             |
|                          |               | const.       | -1.994                                                                               | -4.313                   | -5.044**                | -5.158***               | -5.054**                |
| Control Treatment Effect | [\$0,\$50]    | $\gamma_1$   | 0.082<br>slope=0.082                                                                 | 0.111**<br>slope=0.111   | 0.124***<br>slope=0.124 | 0.128***<br>slope=0.128 | 0.127***<br>slope=0.127 |
|                          | [\$50,\$100]  | $\gamma_2$   | -0.020<br>slope=0.062                                                                | -0.038<br>slope=0.073    | -0.046<br>slope=0.078   | -0.050**<br>slope=0.078 | -0.048**<br>slope=0.079 |
|                          | [\$100,\$150] | $\gamma_3$   | -0.010<br>slope=0.052                                                                | -0.015<br>slope=0.058    | -0.017<br>slope=0.061   | -0.017<br>slope=0.061   | -0.018<br>slope=0.061   |
|                          | [\$150,\$200] | $\gamma_4$   | -0.007<br>slope=0.045                                                                | -0.008<br>slope=0.050    | -0.008<br>slope=0.053   | -0.007<br>slope=0.054   | -0.007<br>slope=0.054   |
| Main Treatment Effect    | [\$0,\$50]    | $\beta_1$    | 0.069<br>slope=0.069                                                                 | 0.066<br>slope=0.065     | 0.064*<br>slope=0.064   | 0.063**<br>slope=0.063  | 0.065***<br>slope=0.065 |
|                          | [\$50,\$100]  | $\beta_2$    | 0.129*<br>slope=0.198                                                                | 0.131**<br>slope=0.196   | 0.132***<br>slope=0.196 | 0.131***<br>slope=0.194 | 0.127***<br>slope=0.192 |
|                          | [\$100,\$150] | $\beta_3$    | 0.007<br>slope=0.205                                                                 | 0.009<br>slope=0.208     | 0.012<br>slope=0.208    | 0.014<br>slope=0.208    | 0.017<br>slope=0.209    |
|                          | [\$150,\$200] | $\beta_4$    | -0.050***<br>slope=0.155                                                             | -0.050***<br>slope=0.158 | -0.052**<br>slope=0.156 | -0.052**<br>slope=0.156 | -0.052*<br>slope=0.157  |
|                          |               | R-sq<br>adj. | 30%                                                                                  | 37%                      | 47%                     | 50%                     | 46%                     |

**Table 2b: The first bidder's value and jump bidding:  
piecewise regression model for auctions with low entry costs**

|                          |               |              | WLS estimation of equation (3) with $Var(\varepsilon) = \sigma^2 \times S_1^\lambda$ |                         |                         |                         |                         |
|--------------------------|---------------|--------------|--------------------------------------------------------------------------------------|-------------------------|-------------------------|-------------------------|-------------------------|
|                          |               |              | $\lambda=0$                                                                          | $\lambda=0.5$           | $\lambda=1$             | $\lambda=1.5$           | $\lambda=2$             |
|                          |               | const.       | -7.533                                                                               | -8.179**                | -7.715***               | -6.917***               | -5.787**                |
| Control Treatment Effect | [\$0,\$50]    | $\gamma_1$   | 0.114<br>slope=0.114                                                                 | 0.127**<br>slope=0.127  | 0.130***<br>slope=0.130 | 0.130***<br>slope=0.130 | 0.122***<br>slope=0.122 |
|                          | [\$50,\$100]  | $\gamma_2$   | -0.038<br>slope=0.076                                                                | -0.047<br>slope=0.080   | -0.051<br>slope=0.079   | -0.051*<br>slope=0.079  | -0.044*<br>slope=0.078  |
|                          | [\$100,\$150] | $\gamma_3$   | -0.015<br>slope=0.061                                                                | -0.017<br>slope=0.063   | -0.017<br>slope=0.062   | -0.018<br>slope=0.061   | -0.018<br>slope=0.060   |
|                          | [\$150,\$200] | $\gamma_4$   | -0.009<br>slope=0.052                                                                | -0.009<br>slope=0.054   | -0.008<br>slope=0.054   | -0.007<br>slope=0.054   | -0.007<br>slope=0.053   |
| Main Treatment Effect    | [\$0,\$50]    | $\beta_1$    | 0.082<br>slope=0.082                                                                 | 0.074<br>slope=0.074    | 0.062<br>slope=0.062    | 0.049<br>slope=0.049    | 0.036<br>slope=0.036    |
|                          | [\$50,\$100]  | $\beta_2$    | 0.075<br>slope=0.157                                                                 | 0.083<br>slope=0.157    | 0.093**<br>slope=0.155  | 0.105***<br>slope=0.154 | 0.118***<br>slope=0.154 |
|                          | [\$100,\$150] | $\beta_3$    | 0.012<br>slope=0.169                                                                 | 0.014<br>slope=0.171    | 0.016<br>slope=0.171    | 0.017<br>slope=0.171    | 0.020<br>slope=0.174    |
|                          | [\$150,\$200] | $\beta_4$    | -0.052**<br>slope=0.117                                                              | -0.054**<br>slope=0.117 | -0.055**<br>slope=0.106 | -0.057**<br>slope=0.114 | -0.058**<br>slope=0.116 |
|                          |               | R-sq<br>adj. | 18%                                                                                  | 24%                     | 34%                     | 37%                     | 35%                     |

**Table 3: Social surplus and wealth distribution**

|                    | <b>High-costs<br/>(HC)</b> | <b>Low-costs<br/>(LC)</b> | <b>No costs<br/>(NC)</b> | <b>HC<br/>minus<br/>NC</b> | <b>LC<br/>minus<br/>NC</b> | <b>HC<br/>minus<br/>LC</b> |
|--------------------|----------------------------|---------------------------|--------------------------|----------------------------|----------------------------|----------------------------|
| <b>Bidder #1</b>   | \$44.95                    | \$40.21                   | \$34.96                  | \$9.99***                  | \$5.25**                   | \$4.74**                   |
| <b>Bidder #2</b>   | \$34.98                    | \$29.55                   | \$33.05                  | \$1.93                     | -\$3.50                    | \$5.43***                  |
| <b>All bidders</b> | \$79.94                    | \$69.76                   | \$68.01                  | \$11.93***                 | \$1.75                     | \$10.18***                 |
| <b>Seller</b>      | \$55.91                    | \$61.96                   | \$65.91                  | -\$10.00***                | -\$3.95*                   | -\$6.05***                 |
| <b>Total</b>       | \$135.85                   | \$131.72                  | \$133.92                 | \$1.93                     | -\$2.20                    | \$4.13*                    |