

An Experimental Study of Auctions with a Buy Price Under Private and Common Values*

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Abstract

eBay's Buy It Now auctions allow a seller to list their auctions with a "buy price" at which a bidder may purchase the item immediately and end the auction. When values are common, there is theoretically no revenue advantage to offering a buy price, while when values are private a buy price can be advantageous for the seller when bidders are risk averse. We report the results of laboratory experiments designed to determine whether in practice a buy price is advantageous to the seller. We find that a suitably chosen buy price raises seller revenue both when values are private and when values are common, although the effect is not statistically significant in the later case. We also find that a buy price reduces the variance of seller revenue. A behavioral model which incorporates the winner's curse and the overweighting by bidders of their own signal explains the common value auction data better than the rational model.

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1 Introduction

In a “buy it now” auction the seller sets a fixed price termed a “buy price” at which a bidder may purchase the item, thereby ending the auction immediately. If no bidder accepts the buy price, then in the ascending bid auction that follows, the bidder with the highest bid wins and pays the second highest bid. The buy-now auction format has proven to be extremely popular. eBay introduced its buy-now auction format in 2000 and by the end of 2001 about 40% of all eBay auctions were “buy-now” auctions (see Hof (2001)).

Several theoretical explanations for the popularity of buy prices have been provided for private-value auctions. Reynolds and Wooders (2003) show for both eBay and Yahoo auctions that when bidders are risk averse then a suitably chosen buy price raises seller revenue; in this case the buy price extracts a risk premium from bidders who wish to avoid uncertainty over whether they win and the price that they pay. Mathews (2003) shows for eBay auctions that when bidders are impatient, then a seller can increase his revenue by setting a buy price; in this case the buy price extracts a premium from a bidder who ends the auction early. Mathews and Katzman (2006) consider eBay auctions with risk-neutral bidders and risk averse sellers, in which case a buy price may be advantageous for the seller as it reduces the variance of seller revenue.

In the present paper we investigate experimentally the properties of eBay buy-now auctions in both pure private value and pure common value settings. For private value auctions our objective is to determine whether a buy price raises seller revenue and whether it reduces the variance of revenue, as theory suggests it can.¹ There are several reasons for being interested in common value buy-now auctions. First, the use of a buy price has starkly different implications for seller revenue in private and common value settings. In a private value setting, seller revenue is increasing in bidder risk aversion. In contrast, in the common value setting we consider here, there is no buy price that raises seller revenue and revenue is decreasing in bidder risk aversion. Second, in some eBay auctions a common value model may be more appropriate than a private value model. Bajari and Hortaçsu (2003), for example, argue that a common value model is correct for eBay coin auctions.²

¹Since there is no meaningful delay in laboratory experiments, we do not provide insights whether a buy price can be used to exploit bidder impatience.

²They find the sale price is decreasing in the number of bidders, which is consistent with common values.

We find that the use of a buy price has a positive and statistically significant effect on seller revenue in private value auctions. Based on the bidders' decisions whether to accept or reject the buy price, we estimate an index of absolute risk aversion of $\alpha = 1.11$, which is significantly different from risk neutrality. We also find that the use of a buy price yields a statistically significant reduction in the variance of seller revenue. Hence we find, consistent with theory, that a buy price is advantageous to the seller when either the bidders or the seller are risk averse.

In contrast to the theoretical prediction, the use of a buy price in common value auctions also had a small positive (although statistically insignificant) effect on seller revenue. Behavior in common value auctions departed from predicted behavior in several respects. The buy price set in the experiment is accepted with high frequency, although theoretically it is always rejected if bidders are risk neutral or risk averse. In addition, in the ascending bid phase of the auctions, bidders drop out earlier when the buy price is rejected than they do in identical auctions where no buy price has been offered. Finally, in the ascending bid phase of the auctions, bidders tend to overbid relative to equilibrium when they have low signals and underbid when they have high signals. This last finding is consistent with prior studies of ascending bid common-value auctions without a buy price. We also find the variance of seller revenue is statistically significantly lower in the buy-now auctions.

In order to better explain the common value data, we develop and estimate a behavioral model of common value buy-now auctions. In the model a bidder fails to condition his value for the item on winning, both when deciding whether to accept the buy price and when deciding whether to drop out in the ascending bid phase of the auction (i.e., a bidder suffers from the "winner's curse" when making either type of decision). The model also allows bidders to overweight their private information, and we find that overweighting of own signal is statistically significant. The behavioral model explains all the departures from the rational model mentioned above.

Section 2 presents the experimental design. The theoretical background on buy-now auction is presented in Section 3. Section 4 presents our experimental results for both the private value and common value auctions. In Section 5 we estimate a behavioral model of common value buy-now auctions. Section 6 concludes.

2 Experimental Design

We conducted experiments for the four treatments shown in Table 1. In the private value (henceforth PV) treatments, each bidder’s value for the item was an independent draw from the $U[0, 10]$ distribution. In the common value (henceforth CV) treatments each bidder’s *signal* was an independent draw from the $U[0, 10]$ distribution; the value of the item was the same for each bidder and equal to the average of the signals.

We conducted both ascending bid auctions and buy-now auctions. In the ascending bid auctions the price increased by \$.25 per second so long as at least one bidder remained active. At any point a bidder could choose to exit the auction by clicking on a “Drop Out” button. Bidders did not observe the number of bidders remaining in the auction, i.e., they did not observe when a rival bidder dropped out. The auction ended when only one bidder remained, the remaining bidder won the auction and paid a price equal to the amount at which the last bidder dropped out.³ There was no reserve price, and the clock began ascending from a bid of \$.05.

The buy-now auctions had two stages. At the first stage the four bidders simultaneously decided whether to accept or reject the buy price. The buy price was \$8.10 in the private value auctions and \$5.60 in the common value auctions. If a bidder accepted the buy price, then he won the item at the buy price and the auction ended.⁴ If all the bidders rejected the buy price, then at the second stage the item was sold via the ascending auction described above.

The experiments were conducted at the University of Arizona where subjects were recruited in groups of eight. Each group of 8 subjects was split into two groups of four bidders, and each group of four bidders participated in 30 periods of an auction.⁵ We refer to a single group of four bidders participating in 30 rounds of a given auction format as a “session.” We conducted six sessions for each of the four treatments, and hence a total of 96 subjects participated in the experiments. The bidders values/signals were determined randomly once, i.e., the same set of values/signals was used in all 24 sessions. Table 1 summarizes our experimental

³This auction format is sometimes referred to as a Japanese, or button, auction.

⁴If more than one bidder accepted the buy price, then the item was randomly allocated to one of the accepting bidders.

⁵The composition of a group was fixed over the course of a session but, to minimize the potential for repeated game effects, the subjects were not informed of this fact.

design.

		Buy Price	Number Sessions	Periods/ Session	Bidders/ Session	Dist. of Values/Signals
PV	Ascending	na	6	30	4	$U[\$0, \$10]$
	Buy-now	\$8.10	6	30	4	$U[\$0, \$10]$
CV	Ascending	na	6	30	4	$U[\$0, \$10]$
	Buy-now	\$5.60	6	30	4	$U[\$0, \$10]$

Table 1 - Experimental Design

In common value auctions it has been observed in prior experiments that subjects sometimes go “bankrupt,” with their accumulated earnings becoming negative. Bankruptcy affects a bidder’s incentives as he is no longer liable for his losses. A low but positive balance also affects a bidder’s incentives as he can lose at most his current balance if wins an auction and the price exceeds the item’s value. In our experiment a bidder was declared bankrupt as soon as his current balance fell below \$5.⁶ A bankrupt bidder exited the experiment and would be replaced by an additional subject who was standing by. In the common value sessions each subject began with an initial balance of \$10 and, in fact, none of our subjects went bankrupt over the course of the experiment.

3 Theoretical Background

There are n bidders who are assumed to have constant absolute risk aversion (CARA) with utility function $u(x) = (1 - e^{-\alpha x})/\alpha$, where $\alpha \geq 0$ is the index of risk aversion. Since $\lim_{\alpha \rightarrow 0} u(x) = x$, then $\alpha = 0$ corresponds to risk neutrality. Let B denote the buy price in a buy-now auction. Denote by $F(v)$ the cumulative distribution function of values/signals with support $[v, \bar{v}]$. Let $G(v) = F(v)^{n-1}$ be the *c.d.f.* of the highest of $n - 1$ values/signals. The densities of F and G are denoted by f and g , respectively.

⁶The \$5 amount was chosen as it is the most a bidder can lose as a result of winning an auction (when his rivals follow the symmetric equilibrium). With risk-neutral bidders, the highest equilibrium drop out price is \$7.50 (for a bidder whose signal is \$10.00) and hence the winning bidder pays at most \$7.50. In this case, the value of the item is at least $(\$10.00 + \$0 + \$0 + \$0)/4 = \$2.50$ and hence a winning bidder loses at most \$5.00.

PRIVATE VALUE AUCTIONS

We begin by showing that a suitably chosen buy price raises seller revenue in private value auctions. Consider a bidder whose value is v in an ascending bid auction. It is a dominant strategy for such a bidder to remain active until the current bid reaches his value (at which point he drops out), irrespective of his attitude toward risk. Hence if the bidder wins the auction, he makes a (random) payment z , where z is the maximum of his rivals' values. The certainty equivalent payment, denoted by $\delta_\alpha(v)$, is defined by

$$u(v - \delta_\alpha(v)) = E[u(v - z) | \underline{v} \leq z \leq v],$$

where z is distributed according to G . In other words, a bidder with value v is indifferent between winning the auction (and making a random payment of z) and winning and paying the certain amount $\delta_\alpha(v)$. It's easy to verify that $\delta_\alpha(v)$ is increasing in v and $\delta_\alpha(v)$ is increasing in α for $v > 0$, i.e., as a bidder becomes more risk averse he is willing to pay more to avoid the uncertain payment of the auction.

We now compare seller revenue in a buy-now auction with buy price $B > \delta_0(\bar{v})$ to revenue in an ascending bid auction. If no bidder accepts the buy price, then revenue is clearly the same for both auctions. If a bidder with value v accepts the buy price, then seller revenue is B . If the same bidder had won in an ascending bid auction, then expected seller revenue would be

$$E[z | \underline{v} \leq z \leq v] = \delta_0(v) \leq \delta_0(\bar{v}) < B,$$

where the equality holds by definition of $\delta_0(v)$, the weak inequality holds since $\delta_0(v)$ is increasing in v , and where the strict equality holds by our choice of B . Hence to show that the buy-now auction raises more revenue we need only show that the buy price is accepted with positive probability.

A buy price B is accepted with positive probability provided that $B < \delta_\alpha(\bar{v})$. To see this, note that if all other bidders reject to the buy price, then a bidder with value \bar{v} obtains a payoff of $u(\bar{v} - B)$ by accepting the buy price, whereas he obtains only

$$E[u(\bar{v} - z) | \underline{v} \leq z \leq \bar{v}] = u(\bar{v} - \delta_\alpha(\bar{v})) < u(\bar{v} - B)$$

if he rejects the buy price. Hence it is not an equilibrium for all bidders to reject such a buy price. Since $\delta_\alpha(v)$ is increasing in α , then for $\alpha > 0$ there is a range of buy prices, (i.e., B satisfying $\delta_0(\bar{v}) < B < \delta_\alpha(\bar{v})$), that raise seller revenue. Reynolds and Wooders (2003) establish that for any buy price B in this range there is a unique

symmetric equilibrium cutoff c^* such that a bidder with value $v > c^*$ accepts the buy price, while a bidder with value $v < c^*$ rejects it.⁷ The buy price is accepted with higher probability as bidder risk aversion increases, i.e., c^* is decreasing in α .

In our experimental design $\delta_0(\$10) = \7.50 , and hence any buy price which exceeds $\$7.50$ and which is accepted with positive probability raises seller revenue. Figure 1 below shows seller revenue as a function of the buy price for the case of $\alpha = 1$. In this case, the equilibrium cutoff is $\$9.11$, the buy price is accepted (by one or more bidders) with probability 0.31, and the seller's expected revenue is $\$6.29$.⁸ A buy price which exceeds $\$8.60$ is rejected by all bidder types and hence for such a buy price the seller's expected revenue is $\$6.00$, the same as in an ascending bid auction.

Figure 1 goes here.

COMMON VALUE AUCTIONS

In an ascending bid common value auction without a buy price, the symmetric equilibrium bidding function when bidders have index of risk aversion α , denoted by $b_\alpha(x)$, satisfies

$$E[u(v - b_\alpha(x)) | x_1 = x, z = x] = 0,$$

where $v = (x_1 + \dots + x_n)/n$ is the true value of the item and $z = \max\{x_2, \dots, x_n\}$ is the highest signal of a rival bidder.⁹ (See Milgrom and Weber (1982).) When bidders have CARA then

$$b_\alpha(x) = \frac{1}{\alpha} \ln \left[\frac{1}{E[e^{-\alpha v} | x_1 = x, z = x]} \right], \quad (1)$$

which reduces to $b_0(x) = \frac{n+2}{2n}x$ when bidders are risk neutral. Note that in common value auctions bidders drop out earlier as they become more risk averse; in particular, $b_\alpha(x) < b_0(x)$ for $x > \underline{v}$.

We characterize equilibrium in a common-value buy price auction by a cutoff c such that a bidder accepts the buy price if his signal exceeds c and rejects it otherwise.

⁷The condition $\delta_0(\bar{v}) < B < \delta_\alpha(\bar{v})$ is sufficient for the buy price B to raise seller revenue when bidders have index of risk aversion α . A buy price below $\delta_0(\bar{v})$ may also yield more revenue to the seller than no buy price at all.

⁸The value of α solving $\delta_\alpha(10) = 8.10$ provides the smallest index of risk aversion for which the buy price is accepted by some type of bidder. In particular, if $\alpha > 0.403$ then the theoretical model predicts a buy price of $\$8.10$ is (i) accepted with positive probability and (ii) raises expected seller revenue.

⁹Since bidders do not observe the drop out prices of their rivals, the auction is strategically equivalent to a second-price sealed-bid auction.

Suppose that a bidder's signal is x and all his rivals employ the same cutoff c . Then his payoff to accepting the buy price is

$$U^A(x, c) = \sum_{l=0}^{n-1} \left[\binom{n-1}{l} F(c)^{n-1-l} (1-F(c))^l \frac{1}{l+1} u_l(x, c) \right],$$

where u_l is the expected utility to a bidder of winning the item at price B when his own signal is x , l rival bidders have a value below c , and $n-l-1$ rivals have signals above c .¹⁰

Consider a bidder with signal x who rejects the buy price. He wins the ascending bid auction (and pays $b_\alpha(z)$ where z is the highest signal of a rival bidder) if he has the highest signal (i.e., $z < x$) and no other bidder accepts the buy price (i.e., $z < c$). Hence, his payoff to rejecting the buy price is

$$U^R(x, c) = \int_{\underline{v}}^{\min\{x, c\}} \left[\int_{\underline{v}}^z \cdots \int_{\underline{v}}^z u \left(\frac{x+z+\sum_{l>2} x_l}{n} - b_\alpha(z) \right) \frac{f(x_3)}{F(z)} dx_3 \cdots \frac{f(x_n)}{F(z)} dx_n \right] g(z) dz.$$

A cutoff c^* is a **symmetric Bayes Nash equilibrium** if $U^R(x, c^*) > U^A(x, c^*)$ for all $x \in [\underline{v}, c^*)$ and $U^R(x, c^*) < U^A(x, c^*)$ for all $x \in (c^*, \bar{v}]$. Shahriar (2005) establishes that a symmetric BNE exists under general conditions when bidders have constant absolute risk aversion.

Note that the equilibrium dropout price $b_\alpha(x)$ is the same in the ascending bid auction and in the ascending bid phase of the buy-now auction reached after B is rejected. Intuitively this is because in an ascending bid common value auction a bidder drops out at the bid where he is indifferent between winning or losing the auction, conditional on the highest signal of a rival (z) being equal to his own signal. Hence, a bidder whose signal is $x < c$, and who observes that all his rivals reject the buy price, can infer that $z < c$. This has no effect on his dropout price since he forms it by conditioning on $z = x$ (which is less than c).

Figure 2 below illustrates the equilibrium cutoff for our experimental design in two cases, when bidders are risk neutral and when bidders have index of risk aversion of $\alpha = 1$.¹¹ When bidders are risk neutral, the equilibrium cutoff is $c = \$9.96$. In

¹⁰In particular

$$u_l(x, c) = \int_c^{\bar{v}} \cdots \int_c^{\bar{v}} \int_{\underline{v}}^c \cdots \int_{\underline{v}}^c u \left(\frac{x + \sum_{j>1} x_j}{n} - B \right) \frac{f(x_2)}{1-F(c)} dx_2 \cdots \frac{f(x_{k+1})}{1-F(c)} dx_{l+1} \frac{f(x_{l+2})}{F(c)} dx_{l+2} \cdots \frac{f(x_n)}{F(c)} dx_n.$$

¹¹In each case numerical calculations establish that there is only one symmetric equilibrium in cutoff strategies.

particular, a bidder with a signal $x > \$9.96$ obtains a higher payoff accepting the buy price (since $U_{\alpha=0}^R(x, 9.96) > U_{\alpha=0}^A(x, 9.96)$) than rejecting it, when all his rivals employ a cutoff of $\$9.96$. A bidder with a signal $x < \$9.96$ obtains a higher payoff rejecting the buy price. With index of risk aversion $\alpha = 1$, the equilibrium cutoff is $c^* = \$10$ and the buy price is rejected by all bidders (i.e., $U_{\alpha=1}^R(x, 10) > U_{\alpha=1}^A(x, 10)$ for all $x \leq 10$).

Figure 2 goes here.

As illustrated in Figure 2, when values are common then bidders are less likely to accept the buy price as they become more risk averse. In our experiment, no bidder had a signal above $\$9.96$ and hence, according to the theory, no risk neutral or risk averse bidder will accept the buy price.

Figure 3 below shows seller revenue as a function of the buy price for the cases $\alpha = 0$ and $\alpha = 1$. If $\alpha = 0$ then any buy price above $\$5.63$ is rejected, whereas if $\alpha = 1$ then any buy price above $\$4.98$ is rejected. In both cases, the introduction of a buy price reduces seller revenue if the buy price is accepted with positive probability. Furthermore, seller revenue is lower when bidders are risk averse than when they are risk neutral.

Figure 3 goes here.

Risk aversion has dramatically different effects in private and common value buy-now auctions. In private value auctions, seller revenue and the probability the buy price is accepted both increase as bidders become more risk averse. In common value auctions an increase in risk aversion has the opposite effect.

4 Results

PRIVATE VALUES

The left panel of Table 2 shows the seller's mean per-period revenue, the standard deviation of revenue, and auction efficiency in each of the six private value buy-now sessions. The buy price was accepted in 81 of the 180 auctions. The right panel of Table 2 shows the same data for the six sessions of private value ascending auctions. Averaging across all 6 sessions, seller revenue was $\$6.06$ in the ascending auctions,

which is less than the mean revenue of \$6.47 in the buy-now auctions.¹²

Buy-now, $B = \$8.10$				Ascending					
Session	Rev.	s.d.	Rev.	Efficiency	Session	Rev.	s.d.	Rev.	Efficiency
1	\$6.33	\$1.84		86.67	7	\$6.20	\$1.97		100.00
2	\$6.50	\$1.91		96.67	8	\$6.04	\$2.06		93.33
3	\$6.55	\$1.84		93.33	9	\$5.98	\$2.00		90.00
4	\$6.50	\$1.91		93.33	10	\$6.17	\$2.08		96.67
5	\$6.25	\$1.82		80.00	11	\$6.11	\$2.08		86.67
6	\$6.72	\$1.88		86.67	12	\$5.86	\$2.25		93.33
Mean	\$6.47	\$1.87		89.44	Mean	\$6.06	\$2.07		93.33

Table 2: Revenue and Efficiency with and without a buy price

The lowest revenue achieved in a buy-now auction (\$6.25) exceeds the highest revenue achieved in any ascending auction (\$6.11). Applying the Mann-Whitney U test to the two samples, we can reject at the 1% level the hypothesis that the revenues of each auction format are drawn from the same distribution. Table 2 also shows that the standard deviation of revenue is lower in the buy-now auctions, a difference that is significant at the 1% level. Thus, a risk averse seller has an additional motive for offering a buy price.

An auction is efficient if the bidder with the highest value wins. Theoretically, the ascending bid auction is 100% efficient since the bidder with the highest value wins the auction. The introduction of a buy price, however, reduces auction efficiency since when more than one bidder accepts the buy price then the item is allocated randomly to one of these bidders. Table 2 shows that the introduction of a buy price leads only to a modest reduction in auction efficiency (from 93.33% to 89.44%). Applying the Mann-Whitney U test we cannot reject that hypothesis that the efficiency of the two auction formats is the same.

In private value buy-now auctions where the buy price has been rejected, it is a dominant strategy in the ascending bid auction that follows for a bidder to remain active until the bid reaches his value. It's possible, however, that the revenue advantage of the buy price comes from more aggressive bidding when the buy price is offered but rejected. Table 3 compares the buy-now auctions in which the buy price was

¹²Since values are distributed $U[0, \$10]$, *ex-ante* expected revenue is \$6.00. Conditional on the values actually used in the experiment, mean theoretical revenue is \$6.19, which is slightly more than the \$6.06 actually obtained.

rejected to *identical* ascending auctions, i.e., auctions where the bidders values are same in each case.¹³ Consider, for example, the first row of Table 3. The buy price was rejected in 18 of the Session 1 auctions and in these auctions mean seller revenue with \$5.16. We compare revenue in these auctions with the 18 identical auction in Session 7 where the bidders had the same values. The mean revenue in these auctions was \$5.28. Since Sessions 1 and 7 use different subjects, the revenues \$5.16 and \$5.28 are independent draws from the same distribution under the null hypothesis that bidding behavior is unchanged following the rejection of the buy price.

Buy-now, $B=\$8.10$			Identical Ascending		
Session	B rejected	B accepted	Session	B rejected	B accepted
1	\$5.16 (18 auctions)	\$8.10	7	\$5.28 (18 auctions)	\$7.57
2	\$5.81 (21 auctions)	\$8.10	8	\$5.67 (21 auctions)	\$6.89
3	\$5.19 (16 auctions)	\$8.10	9	\$5.09 (16 auctions)	\$7.00
4	\$4.67 (14 auctions)	\$8.10	10	\$4.71 (14 auctions)	\$7.43
5	\$5.01 (18 auctions)	\$8.10	11	\$5.05 (18 auctions)	\$7.70
6	\$4.65 (12 auctions)	\$8.10	12	\$4.28 (12 auctions)	\$6.91
Mean	\$5.14 (99 auctions)	\$8.10	Mean	\$5.09 (99 auctions)	\$7.24

Table 3: Seller Revenue Conditional on Acceptance/Rejection of Buy Price

Mean seller revenue when the buy price is rejected (\$5.14) is nearly identical to seller revenue in the identical ascending bid auctions (\$5.09). Using the Mann-Whitney U test, we cannot reject that the two samples are drawn from the same distribution. Thus there is no evidence that bidding behavior differs following the rejection of the buy price. Conditional on the buy price being accepted, it increases revenue by \$.86 (= \$8.10-\$7.24) beyond what the seller would have obtained without a buy price.

Further insights into the effect of introducing a buy price are revealed by Figure 4, which shows the empirical *c.d.f.* of revenue in the 180 buy-now auctions and the 180 ascending auctions.

Figure 4 goes here.

A buy price reduces the likelihood that seller revenue is either very low or very high. Introducing a buy price of \$8.10 reduces by about 10% the chance that the seller will obtain less than \$6.00. On the other hand, in an ascending auction the seller

¹³This comparison is possible since the same set of 120 values/signals (4 bidders per auction and 30 auctions) were used in all sessions.

has nearly a 25% chance of a revenue of more than \$8.10, while with a buy price the seller almost surely obtains at most \$8.10.¹⁴ In the data, these two effects are roughly a wash for the seller. The advantage to the buy price comes from auctions where revenue would have been between \$6.00 and \$8.10. In almost all of these auctions a bidder took the buy price and the seller obtained \$8.10.

The index of bidder risk aversion can be estimated from the bidders' decisions to accept or reject the buy price. (The bidders' dropout prices are uninformative when estimating α since in an ascending bid auction it is a dominant strategy for a bidder to drop out when the bid reaches his value, independently of α .) If a bidder's value is v and rivals all employ the same cutoff c , then his payoff to the accepting the buy price is

$$U^A(v, c; \alpha) = u(v - B)Q(F(c)),$$

where $Q(F(c))$ is the bidder's probability of winning the item when all his rivals employ the cutoff c .¹⁵ His payoff to rejecting the buy price is

$$U^R(v, c; \alpha) = \int_0^{\min\{v, c\}} u(v - z)g(z)dz.$$

Let $c^*(\alpha)$ denote the equilibrium cutoff when bidders have index of risk aversion α , i.e., $c^*(\alpha)$ is the value of c solving $U^A(c, c; \alpha) = U^R(c, c; \alpha)$. For a bidder with value v , the difference in the payoff between accepting or rejecting the buy price is denoted by $\Delta(v; \alpha)$, where

$$\Delta(v; \alpha) = U^A(v, c^*(\alpha); \alpha) - U^R(v, c^*(\alpha); \alpha).$$

Let D_i^t be a dummy variable indicating whether bidder i in auction t accepted the buy price, and let v_i^t be the value of bidder i in auction t . Our econometric model is that

$$D_i^t = \begin{cases} 1 & \text{if } \Delta(v_i^t; \alpha) \geq \varepsilon_i \\ 0 & \text{if } \Delta(v_i^t; \alpha) < \varepsilon_i, \end{cases}$$

¹⁴In a buy-now auction it is theoretically possible for seller revenue to exceed B . In particular, if both the highest and second highest values are below the equilibrium cutoff but above B , then all bidders reject the buy price and the price in the ascending bid auction that follows is the second highest value.

¹⁵It is easy to show that

$$Q(F(c)) = \sum_{l=0}^{n-1} \binom{n-1}{l} \frac{1}{l+1} F(c)^{n-1-l} (1-F(c))^l = \frac{1-F(c)^n}{n(1-F(c))}.$$

where ε_i is $N(0, \sigma_1)$. The likelihood function for the t^{th} buy-now auction is

$$L^t = \begin{cases} 1 - \prod_{i=1}^4 \left[1 - \Phi \left(\frac{\Delta(v_i^t; \alpha)}{\sigma_1} \right) \right] & \text{if } D_i^t = 1 \text{ for some } i \\ \prod_{i=1}^4 \left[1 - \Phi \left(\frac{\Delta(v_i^t; \alpha)}{\sigma_1} \right) \right] & \text{otherwise,} \end{cases}$$

where Φ and ϕ are, respectively, the *c.d.f.* and *p.d.f.* of the standard normal. Maximizing $\frac{1}{T} \sum L^t$ with respect to α (and σ_1) yields the estimate $\hat{\alpha} = 1.11$ (0.003) and an equilibrium cutoff of $c^*(\hat{\alpha}) = 9.03$ (0.002), where the standard deviations are given in parentheses.

COMMON VALUES

The left panel of Table 4 shows the seller's average per-period revenue in the six common value buy-now auction sessions. The buy price was accepted in 142 of the 180 auctions. The right panel shows the seller's average revenue in the six ascending auction sessions.

Buy-now, $B = \$5.60$			Ascending		
Session	Rev.	s.d. Rev.	Session	Rev.	s.d. Rev.
1	\$5.05	\$0.85	7	\$4.84	\$0.85
2	\$5.46	\$0.51	8	\$4.64	\$0.97
3	\$5.23	\$0.85	9	\$5.11	\$1.15
4	\$5.43	\$0.47	10	\$5.37	\$1.03
5	\$5.35	\$0.78	11	\$4.81	\$0.79
6	\$5.00	\$1.08	12	\$5.49	\$1.36
Mean	\$5.25	\$0.76	Mean	\$5.04	\$1.03

Table 4: Revenue With and Without a Buy Price

Introducing the \$5.60 buy price raises revenue an average of \$.21 per auction, but this difference is insignificant according to the Mann-Whitney U test (p -value of 0.197). Introducing the buy price reduces the standard deviation of seller revenue; we can reject at the 5% level that the standard deviation of revenue is the same in the two auction formats. The reduction in the standard deviation of seller revenue is apparent in Figure 5, which shows the empirical *c.d.f.* of revenue in the 180 common value buy-now auctions and the 180 common-value ascending auctions.

Figure 5 goes here.

Theoretically, the price at which a bidder drops out in the ascending bid auction is the same whether there is no buy price or whether there was a buy price but it was rejected by all the bidders. In each case a bidder’s drop out price is given by (1), and hence in auctions where the buy price is rejected seller revenue should be the same as if no buy price had been offered.

Table 5 compares seller revenue in the two auction formats, conditional on whether the buy price is rejected or accepted, and is constructed in the same fashion as Table 3. Mean seller revenue in the 38 auctions where the buy price was rejected was \$3.93. Contrary to the theory, seller revenue was on average \$.67 higher in auctions where no buy price was offered, but which were otherwise identical. Hence bidders tend to drop out earlier in the ascending bid auction when the auction had a buy price. Applying the Mann-Whitney U test, we can reject at the 10% level the null hypothesis that the two samples are drawn from the same distribution.

Session	Buy-now, $B=\$5.60$		Session	Identical Ascending	
	B rejected	B accepted		B rejected	B accepted
13	\$4.33 (13 auctions)	\$5.60	19	\$4.29 (13 auctions)	\$5.28
14	\$4.15 (3 auctions)	\$5.60	20	\$3.90 (3 auctions)	\$4.72
15	\$3.39 (5 auctions)	\$5.60	21	\$4.21 (5 auctions)	\$5.28
16	\$4.31 (4 auctions)	\$5.60	22	\$4.66 (4 auctions)	\$5.47
17	\$3.10 (3 auctions)	\$5.60	23	\$4.05 (3 auctions)	\$4.89
18	\$3.81 (10 auctions)	\$5.60	24	\$5.68 (10 auctions)	\$5.39
Mean	\$3.96 (38 auctions)	\$5.60	Mean	\$4.63 (38 auctions)	\$5.15

Table 5: Seller Revenue Conditional on Acceptance/Rejection of Buy Price

The revenue advantage of the buy price comes from the auctions where the buy price is accepted. The seller obtains \$5.60 when the buy price is accepted, which is \$.45 higher than what he obtains on average in the identical ascending bid auctions.

Figure 6 shows observed drop out prices in the ascending bid auctions. Comparing dropout prices to the risk-neutral rational bidding function $b_0(x) = \frac{3}{4}x$, it is apparent that bidders overbid for low signals (i.e., drop out too late) but underbid when they have high signals. The figure does not conclusively show underbidding for high signals since there is a selection bias – we don’t observe the highest drop out price in an auction.

Figure 6 goes here.

To better understand behavior in the ascending bid common value auctions, we estimated linear bid functions using a censored regression. In each auction we observe the dropout prices of three bidders, but not the dropout price of the bidder who wins the auction. We assume that the bid of the i -th bidder, $i \in \{1, 2, 3, 4\}$, in auction t is given by

$$b_i^t = \gamma + \beta x_i^t + \varepsilon_i^t,$$

where x_i^t is the signal of bidder i in auction t , and ε_i is distributed according to $N(0, \sigma_2)$. For auction t , let $k^t \in \{1, 2, 3, 4\}$ be the winner of the auction t , i.e., bidder k^t has the highest (but unobserved) dropout price, and let \bar{b}^t be the highest observed dropout price. The censored regression likelihood function is given by

$$L = \frac{1}{T} \sum_{t=1}^T \ln \left[\left[1 - \Phi \left(\frac{\bar{b}^t - \gamma - \beta x_{k^t}^t}{\sigma_2} \right) \right] \prod_{i \in \{1, 2, 3, 4\} \setminus \{k^t\}} \frac{1}{\sigma_2} \phi \left(\frac{b_i^t - \gamma - \beta x_i^t}{\sigma_2} \right) \right],$$

where Φ and ϕ are, respectively, the c.d.f. and p.d.f. of the standard normal, and where T is the number of auctions.

Table 6 reports the results of maximum likelihood estimation on the data from the ascending bid auctions and from the ascending bid phase of auctions with a buy price.¹⁶

	Ascending	Buy-now (B rejected)	z -test (p -value)
γ	2.80 (0.112)	1.84 (0.171)	0.08
β	0.43 (0.016)	0.35 (0.0470)	0.64

Table 6: ML Estimated Bidding Functions

The estimated intercept (γ) and the slope (β) are each significantly different from zero in the both types of auctions. One can reject the null hypothesis that γ is the same for both types of auctions (p -value of 0.08) – overbidding by bidders with low signals is reduced following the rejection of a buy price. One cannot reject that β is the same for both types of auctions (p -value of 0.64) – the rejection of the buy price has no statistically significant effect on the responsiveness of bids to signals. Taken together, these results suggest that bidders employ lower dropout prices following the rejection of the buy price, a finding which is consistent with Table 5, but which is inconsistent with rational bidding.

¹⁶Subject dummies were included when estimating these coefficients.

The results for common values auctions depart from the rational bidding theory in four significant ways. (i) The buy price is accepted too frequently. For the signals received by bidders in our experiment, the buy price should never be accepted if bidders are either risk neutral or risk averse. In fact it was accepted in 79% of all auctions. (ii) Subjects bid less in auctions where the buy price has been rejected than in identical auctions where no buy price is offered. (iii) Subjects overbid relative to theoretical predictions when they have low signals, but underbid when they have high signals. (iv) The buy price raises seller revenue rather than reducing it. In the next section we introduce a model which explains all these features of the data.

5 A Behavioral Model

In this section we introduce a behavioral model in order to explain the results from the common value buy-now auctions. We first focus on the bidding behavior in these auctions, and then consider the decision to accept or reject the buy price.

BIDDING IN COMMON VALUE AUCTIONS

The expected value (EV) bidding model is a simple model of the winner's curse in common-value auctions. According to this model, bidders fail to condition on having the highest signal when they win the auction; instead, they bid (when risk neutral) up to their expected value of the item conditional on only their own signal. The EV bidding function, when bidders have index of risk aversion α , is denoted by $b_\alpha^{EV}(x)$ and satisfies

$$E[u(v - b_\alpha^{EV}(x)) | x_1 = x] = 0.$$

We also consider the possibility that bidders may overweight their own signal when calculating the value of the item. We denote the EV bidding function augmented with overweighting of own signal by $b_\alpha^{EV+}(x)$. It satisfies

$$E \left[u \left(\frac{\lambda x_1 + x_2 + \dots + x_n}{n} - b_\alpha^{EV+}(x) \right) | x_1 = x \right] = 0,$$

where λ denotes the degree to which a bidder overweights (if $\lambda > 1$) or underweights (if $\lambda < 1$) his own signal. If $\lambda = 1$ this model reduces to the expected value bidding model.

In a buy-now auction, the ascending bid phase of the auction is only reached if all the bidders reject the buy price at the first stage. Hence, in the ascending bid phase

of the auction a bidder will condition on all of his rivals having a signal below the equilibrium cutoff c . A bidder who correctly conditions on his rivals' signals being less than the cutoff, but who fails to condition on his signal being highest when he wins, will bid according to $b_\alpha^{EV}(x, c)$ defined by

$$E[u(v - b_\alpha^{EV}(x, c)) | x_1 = x, z \leq c] = 0.$$

If in addition the bidder overweights his own signal, then he bids according to $b_\alpha^{EV+}(x, c)$ defined by

$$E \left[u \left(\frac{\lambda x_1 + x_2 + \dots + x_n}{n} - b_\alpha^{EV+}(x, c) \right) | x_1 = x, z \leq c \right] = 0.$$

In contrast to the rational model, the EV and EV+ model both predict less aggressive bidding following the rejection of the buy price, so long as $c < \bar{v}$ ($= \$10$).

Table 7 shows the theoretical bidding functions for three alternative bidding models (rational, EV, and EV+) for the parameterization of our experiment and it shows, for comparison, the estimated bid functions from Table 6. For simplicity, the table provides the risk-neutral bidding functions, in which case all three bidding functions are linear.¹⁷ The rational bidding function has a zero intercept, while the EV and EV+ bidding functions both have positive intercepts and hence predict overbidding by bidders with low signals. However, the intercept is lower in both models if the buy price is rejected when bidders employ a cutoff $c < \$10$. In the EV+ model bidders overweight their own signals and hence the bidding function is steeper than in EV model.

	Ascending	Buy-now (B rejected)
Rational	$b_0(x) = \frac{3}{4}x$	$b_0(x, c) = \frac{3}{4}x$ for $x \in [0, c)$
EV	$b_0^{EV}(x) = \frac{3}{8}(10) + \frac{1}{4}x$	$b_0^{EV}(x, c) = \frac{3}{8}c + \frac{1}{4}x$
EV+	$b_0^{EV+}(x) = \frac{3}{8}(10) + \frac{1}{4}\lambda x$	$b_0^{EV+}(x, c) = \frac{3}{8}c + \frac{1}{4}\lambda x$
Estimated	$b(x) = 2.80 + .43x$	$b(x) = 1.84 + .35x$

Table 7: Risk-neutral Bidding Functions (cutoff of c)

¹⁷The EV+ bidding function for the ascending bid phase of a buy-now auction is computed as

$$b_0^{EV+}(x, c) = E \left(\frac{\lambda x_1 + x_2 + x_3 + x_4}{4} | x_1 = x, z \leq c \right) = \int_0^c \int_0^c \int_0^c \frac{\lambda x + x_2 + x_3 + x_4}{4} \frac{1}{c^3} dx_2 dx_3 dx_4 = \frac{3}{8}c + \frac{1}{4}\lambda x.$$

For the bidding functions reported on the last row of Table 7, the estimated intercepts are positive and statistically significant, both in the ascending auctions and the ascending bid phase of the buy-now auctions, which is inconsistent with the rational model.¹⁸ For the ascending bid auction, the estimated intercept of 2.80 is less than the theoretical risk-neutral intercept in the EV and EV+ model of $\frac{3}{8}(10) = 3.75$. The theoretical intercept is decreasing in the index of bidder risk aversion, and the 2.80 estimate implies an index of risk aversion of $\alpha = 1.32$. For both the ascending auction and the buy-now auction, the estimated slopes (0.43 and 0.35, respectively) are greater than $\frac{1}{4}$, which suggests that bidders overweight their own signals. The 0.43 estimate for the ascending auctions implies a value of $\lambda = 1.72$.¹⁹ Since the data suggests that bidders suffer from the winner's curse and they overweight their own signals, henceforth we focus on the EV+ model.

THE DECISION TO ACCEPT OR REJECT THE BUY PRICE

Next we investigate whether the winner's curse and overweighting of own signal can explain the high frequency with which the buy price is accepted. Suppose that all of a bidder's rivals follow the cutoff strategy c , with each bidder accepting the buy price if his signal exceeds c and rejecting it otherwise. A bidder who accepts the buy price wins for sure if all his rivals have values below c and wins with probability $\frac{1}{1+l}$ if exactly l of his rivals have value above c . A rational bidder accounts for the fact that if he accepts the buy price, he is more likely to win as more of his rivals have values below c . We suppose instead that bidders are also subject to the winner's curse when accepting the buy price, with a bidder whose signal is x computing the expected utility to accepting the buy price as

$$U^A(x, c; \lambda, \alpha) = E \left[u \left(\frac{\lambda x_1 + x_2 + \dots + x_n}{n} - B \right) \mid x_1 = x \right] Q(F(c)),$$

¹⁸The equilibrium rational bidding function has a zero intercept for any level of risk aversion, hence the rational bidding function does not explain the observed overbidding for low signals even if bidders are risk averse.

¹⁹When bidders have index of risk aversion α , then the equilibrium bid function in the EV+ model of the ascending auction is

$$b_\alpha^{EV+}(x) = -\frac{1}{\alpha} \ln \left(\int_0^{10} \int_0^{10} \int_0^{10} e^{-\alpha \left(\frac{x_2 + x_3 + x_4}{4} \right)} \frac{1}{10^3} dx_2 dx_3 dx_4 \right) + \frac{\lambda}{4} x.$$

Hence λ can be inferred from the estimate of β (since $\beta = \lambda/4$) and, similarly, α can be inferred from γ . When there is a buy price, then the intercept depends on both α and c ; hence α can no longer be inferred from γ .

where $Q(F(c))$ is the bidder's probability of winning the item when all his rivals employ the cutoff c . A bidder computes the expected utility of rejecting the buy price as

$$U^R(x, c; \lambda, \alpha) = E \left[u \left(\frac{\lambda x_1 + x_2 + \cdots + x_n}{n} - b_\alpha^{EV+}(z, c) \mid x_1 = x, z \leq c \right) G(\min\{x, c\}) \right].$$

Such a bidder correctly calculates the probability of ultimately winning the auction if he rejects the buy price. He also conditions on all his rivals' signals being less than c if no bidder accepts the buy price. However, consistent with the winner's curse, he fails to condition on his signal being highest when bidding in the ascending bid auction.

Let $c^*(\lambda, \alpha)$ denote the equilibrium cutoff in the EV+ model, i.e., $c^*(\lambda, \alpha)$ is the value of c solving $U^A(c, c; \lambda, \alpha) = U^R(c, c; \lambda, \alpha)$.²⁰

We use maximum likelihood techniques to estimate α and λ from the buy-now auction data. In each auction we observe whether a bidder accepts the buy price. If no bidder accepts the buy price, then we observe the dropout price of each bidder (except the winning bidder) in the ascending bid auction. Define

$$\Delta(x; \lambda, \alpha) = U^A(x, c^*(\lambda, \alpha); \lambda, \alpha) - U^R(x, c^*(\lambda, \alpha); \lambda, \alpha)$$

as the difference between the payoff to accepting and rejecting the buy price when all of a bidder's rivals employ the cutoff $c^*(\lambda, \alpha)$. Let D_i^t be a dummy variable which equals 1 if bidder i in auction t accepts the buy price and which equals zero otherwise. The econometric model underlying our estimation is

$$D_i^t = \begin{cases} 1 & \text{if } \Delta(x_i^t; \lambda, \alpha) \geq \varepsilon_i^t \\ 0 & \text{if } \Delta(x_i^t; \lambda, \alpha) < \varepsilon_i^t, \end{cases}$$

where ε_i is $N(0, \sigma_1^2)$. We assume that bidder i 's bid in auction t is given by

$$b_i^t = b_\alpha^{EV+}(x_i^t, c^*(\lambda, \alpha)) + \eta_i^t,$$

where η_i^t is distributed $N(0, \sigma_2^2)$.²¹ Let $k^t \in \{1, 2, 3, 4\}$ be the winner of the auction t , i.e., bidder k^t has the highest (but unobserved) dropout price, and let \bar{b}^t be the highest observed dropout price.

²⁰ A proof that such a c^* exists is available on request.

²¹ In particular

$$b_\alpha^{EV+}(x_i^t, c^*(\lambda, \alpha)) = \frac{\lambda}{4} x_i^t - \frac{1}{\alpha} \ln \left(\int_0^{c^*(\lambda, \alpha)} \int_0^{c^*(\lambda, \alpha)} \int_0^{c^*(\lambda, \alpha)} e^{-\alpha \left(\frac{x_2 + x_3 + x_4}{4} \right)} \frac{1}{c^*(\lambda, \alpha)^3} dx_2 dx_3 dx_4 \right).$$

The likelihood function for auction t is given by

$$L^t = \begin{cases} 1 - \prod_{i=1}^4 \left[1 - \Phi \left(\frac{\Delta(x_i^t; \lambda, \alpha)}{\sigma'_1} \right) \right] & \text{if } D_i^t = 1 \text{ for some } i \\ \prod_{i=1}^4 \left[1 - \Phi \left(\frac{\Delta(x_i^t; \lambda, \alpha)}{\sigma'_1} \right) \right] \left[1 - \Phi \left(\frac{\bar{b}^t - b_\alpha^{EV+}(x_{k^t}^t, c^*(\lambda, \alpha))}{\sigma'_2} \right) \right] & \text{otherwise} \\ \quad \times \prod_{i \in \{1, 2, 3, 4\} \setminus \{k^t\}} \frac{1}{\sigma_2} \phi \left(\frac{b_i^t - b_\alpha^{EV+}(x_i^t, c^*(\lambda, \alpha))}{\sigma_2} \right) & \end{cases}$$

Maximizing $\frac{1}{T} \sum L^t$ with respect to α and λ (and σ'_1 and σ'_2) yields the following maximum likelihood estimates.

	Estimate (standard dev.)
$\hat{\alpha}$	1.0141 (0.294)
$\hat{\lambda}$	1.6693 (0.219)
$c^*(\hat{\alpha}, \hat{\lambda})$	7.4028 (0.001)

Table 8 - ML Estimates for EV+

We can reject the null hypothesis that bidders are risk neutral. The estimated value λ is significantly different from 1, with the results suggesting that bidders do indeed overweight their own signals.

We conclude this section by comparing the predictions of the rational model and the EV+ model. Recall that under the rational model, in equilibrium the \$5.60 buy price is always rejected and seller revenue is \$4.50 if bidders are risk neutral (and less if bidders are risk averse). In contrast, in the data the buy price was taken in 79% of all auctions and mean seller revenue was \$5.25. Based on our parameter estimates, in the equilibrium of the EV+ model the buy price is taken in 63% of the auctions and seller revenue is \$5.10. Figure 7 shows the empirical c.d.f. of seller revenue in the common value buy-now auctions, and the predicted c.d.f. of revenue for the estimated model.

Figure 7 goes here.

It shows that EV+ model explains the seller revenue data well. However, the EV+ model does not fully explain the high rate at which the buy price is accepted and the high revenue sellers obtain in common value buy-now auctions.

6 Conclusion

In this study we conducted lab experiments to test the theoretical models of eBay's Buy It Now auctions. We test these predictions using both private and common values frameworks. Consistent with the theoretical predictions for private value auctions, we find that a suitably chosen buy price raises revenue and reduces the variance of revenue. Hence a buy price is advantageous for a risk neutral or risk averse seller. On the other hand, in contrast to the theoretical predictions for common value auctions, a buy price did not lower seller revenue and was accepted by the bidders with high frequency. We develop a behavioral model for common values auctions with a buy price that incorporates the winner's curse and overweighting of a bidder's own signal. We find that this behavioral model explains the data far better than the rational model. We conclude that such a model rationalizes a seller's decision to post a buy price when the bidders have common values.

Although there is abundant field data on buy-now auctions, experimental tests of the theory offer several advantages. In a laboratory test the experimenter controls whether values are private or common, as well as the distribution of values. In field auctions, in contrast, bidder values may have both common and private attributes. As illustrated in this paper, this is important since the theoretical predictions of the effect of buy prices differ substantially in the two settings. Bidder impatience may also be important in field auctions, while in the lab we can eliminate impatience as a factor.

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Figure 1
Expected Seller Revenue as a Function of the Buy Price, $\alpha=1$

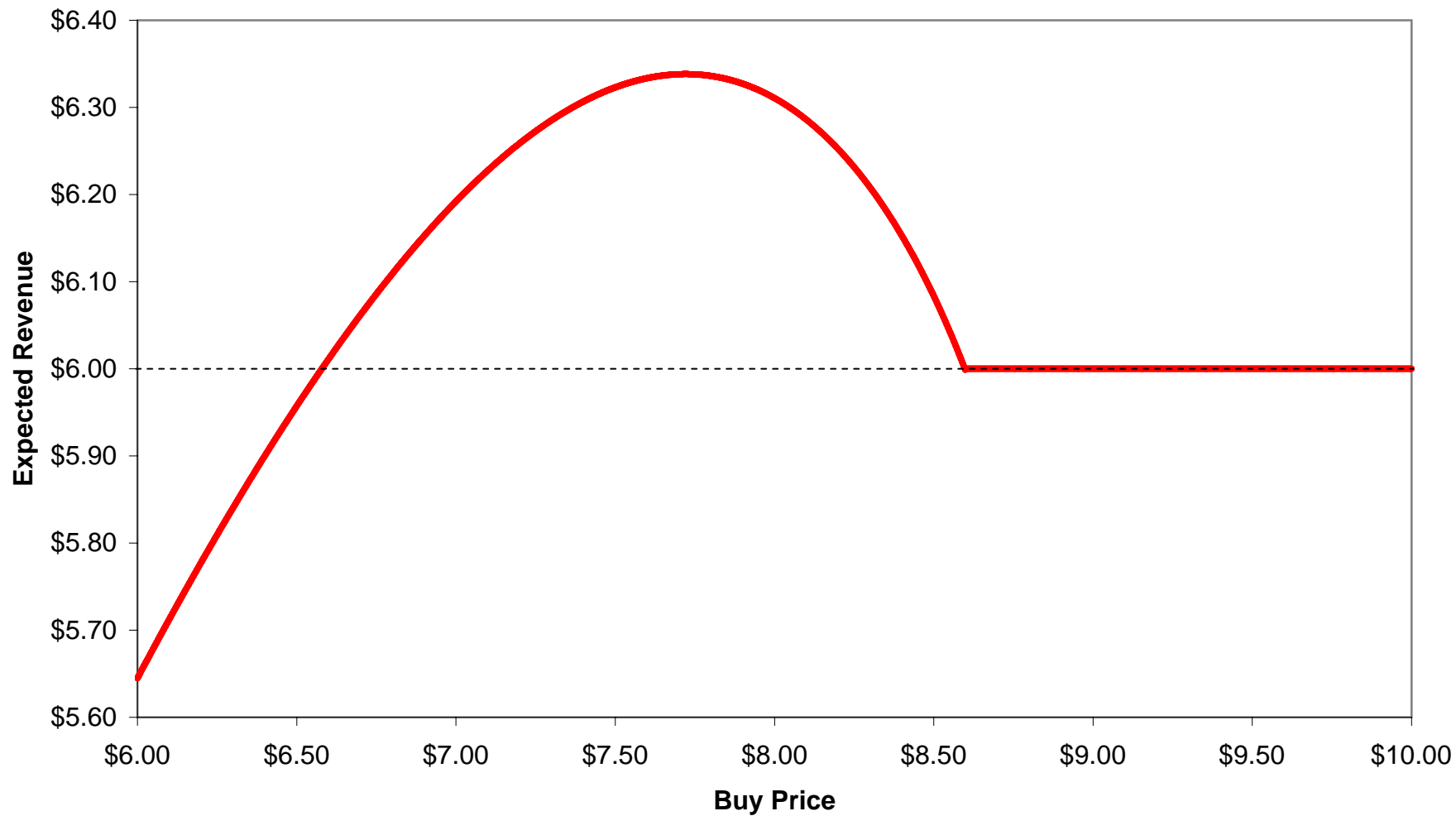


Figure 2
Expected Utility as a Function the Bidder's Signal

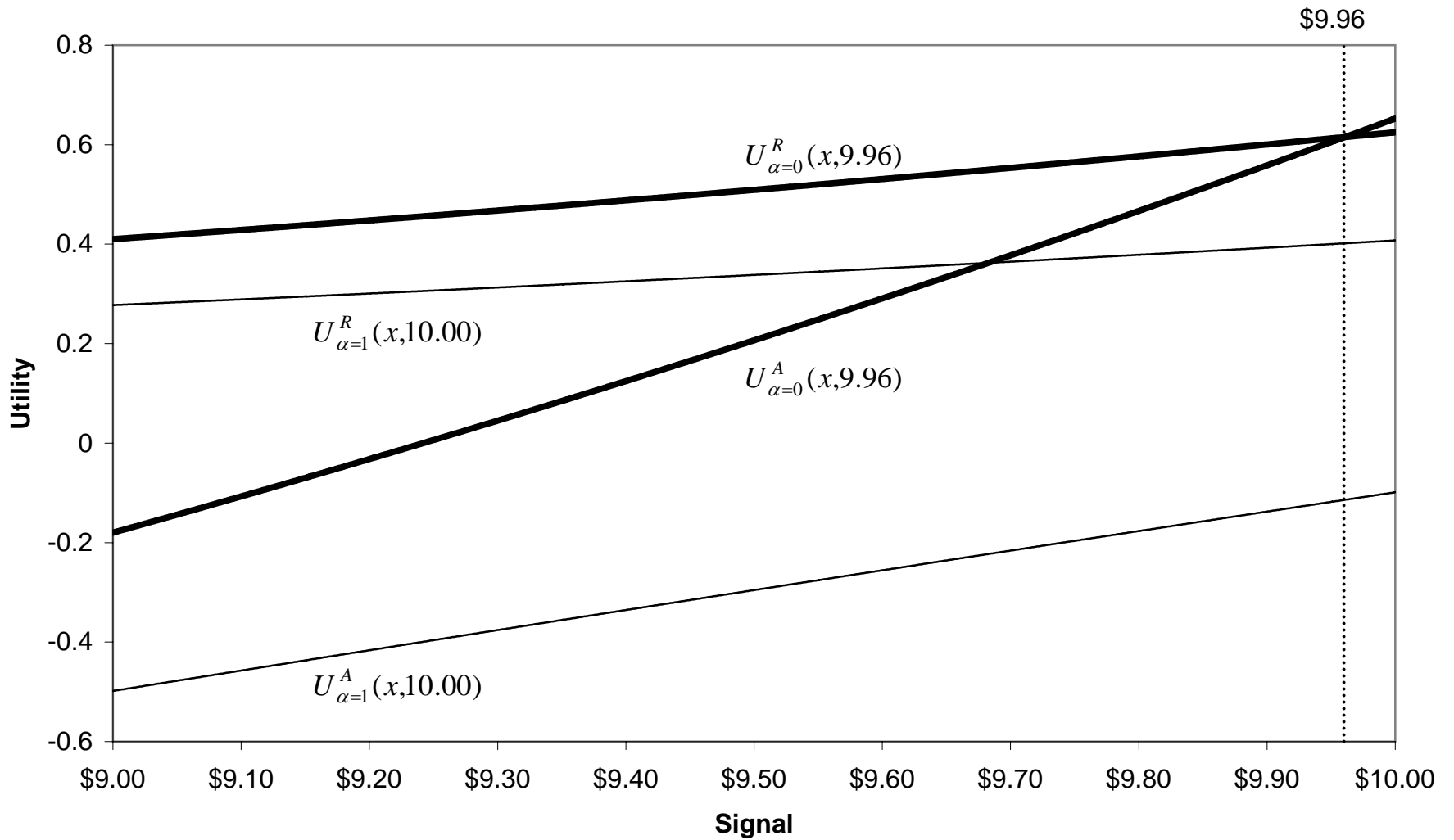


Figure 3
Expected Seller Revenue as a function of the buy price, $\alpha=0$ and $\alpha=1$

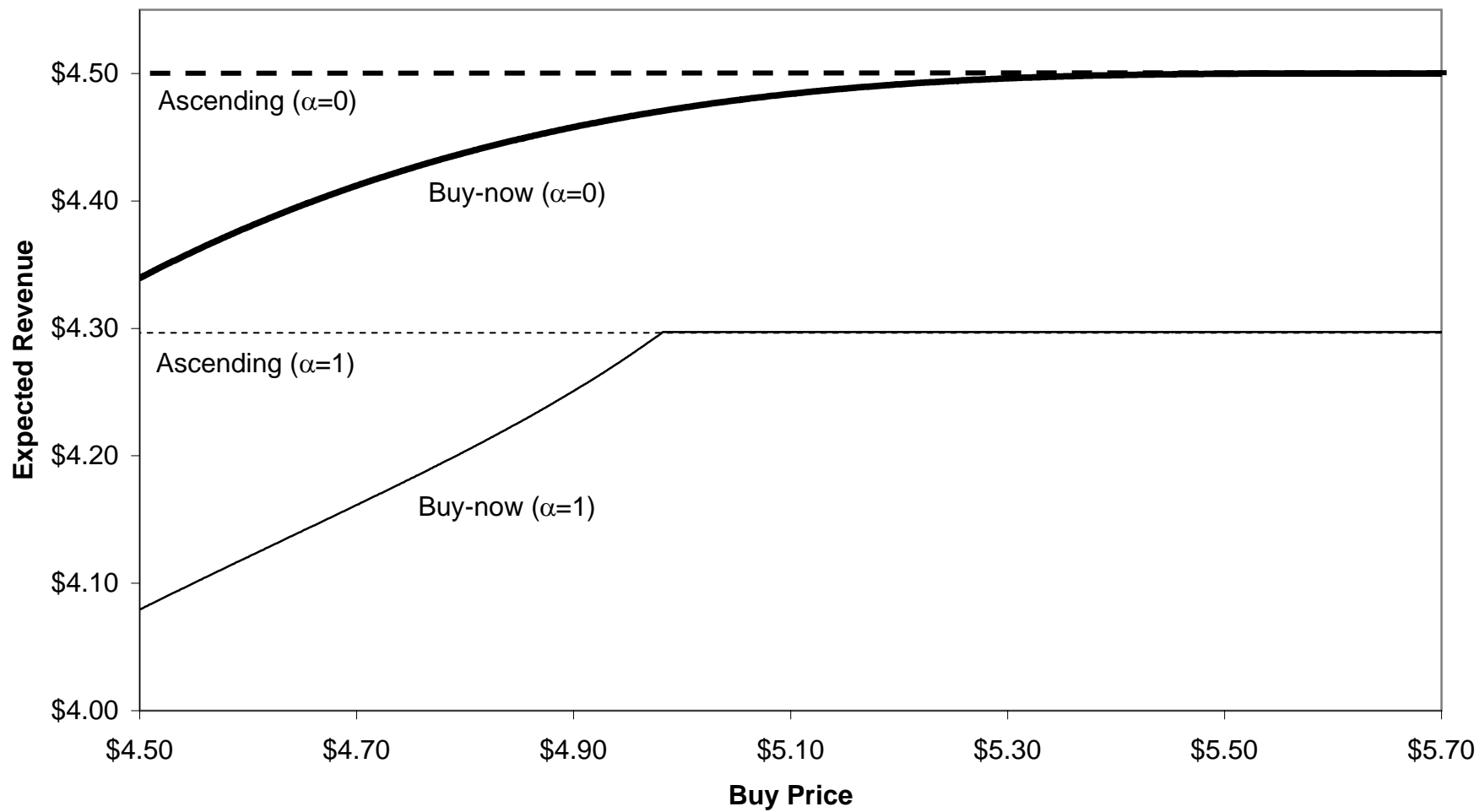


Figure 4
c.d.f. of Seller Revenue in Private Value Auctions
With and Without a Buy Price of \$8.10

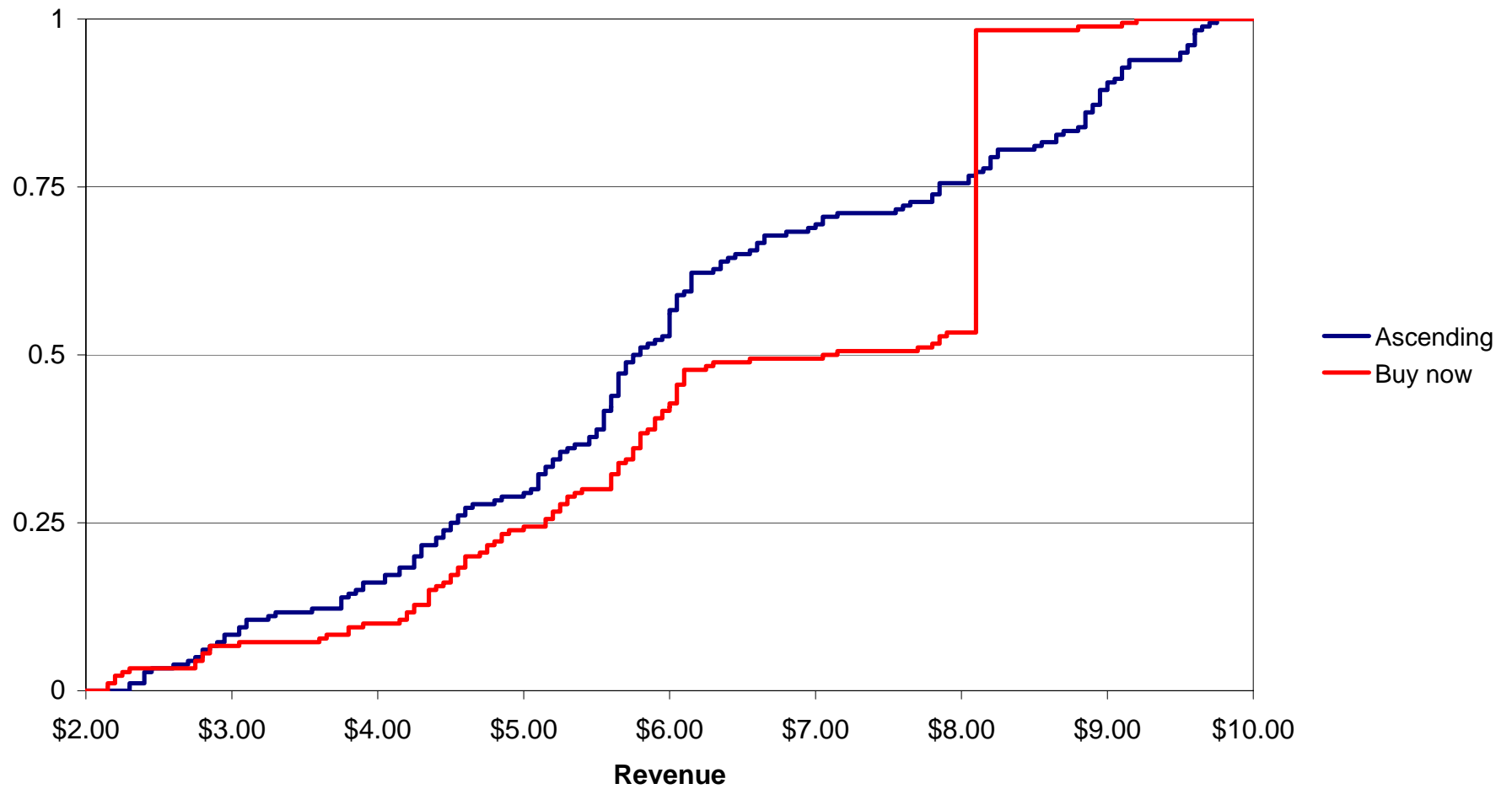


Figure 5
c.d.f. of Seller Revenue in Common-Value Auctions
With and Without a Buy Price of \$5.60

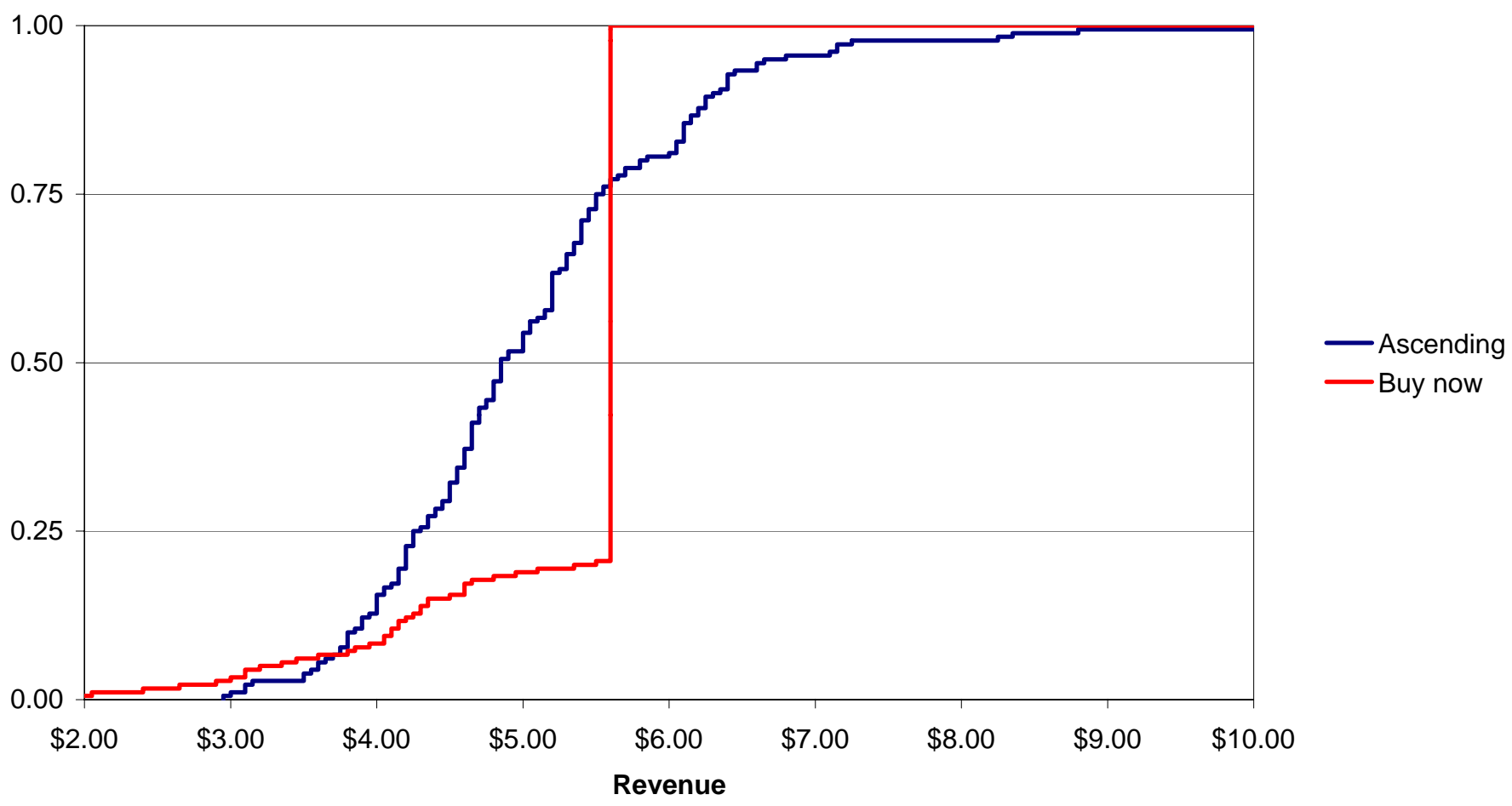


Figure 6
Dropout prices in Ascending Common-Value Auctions

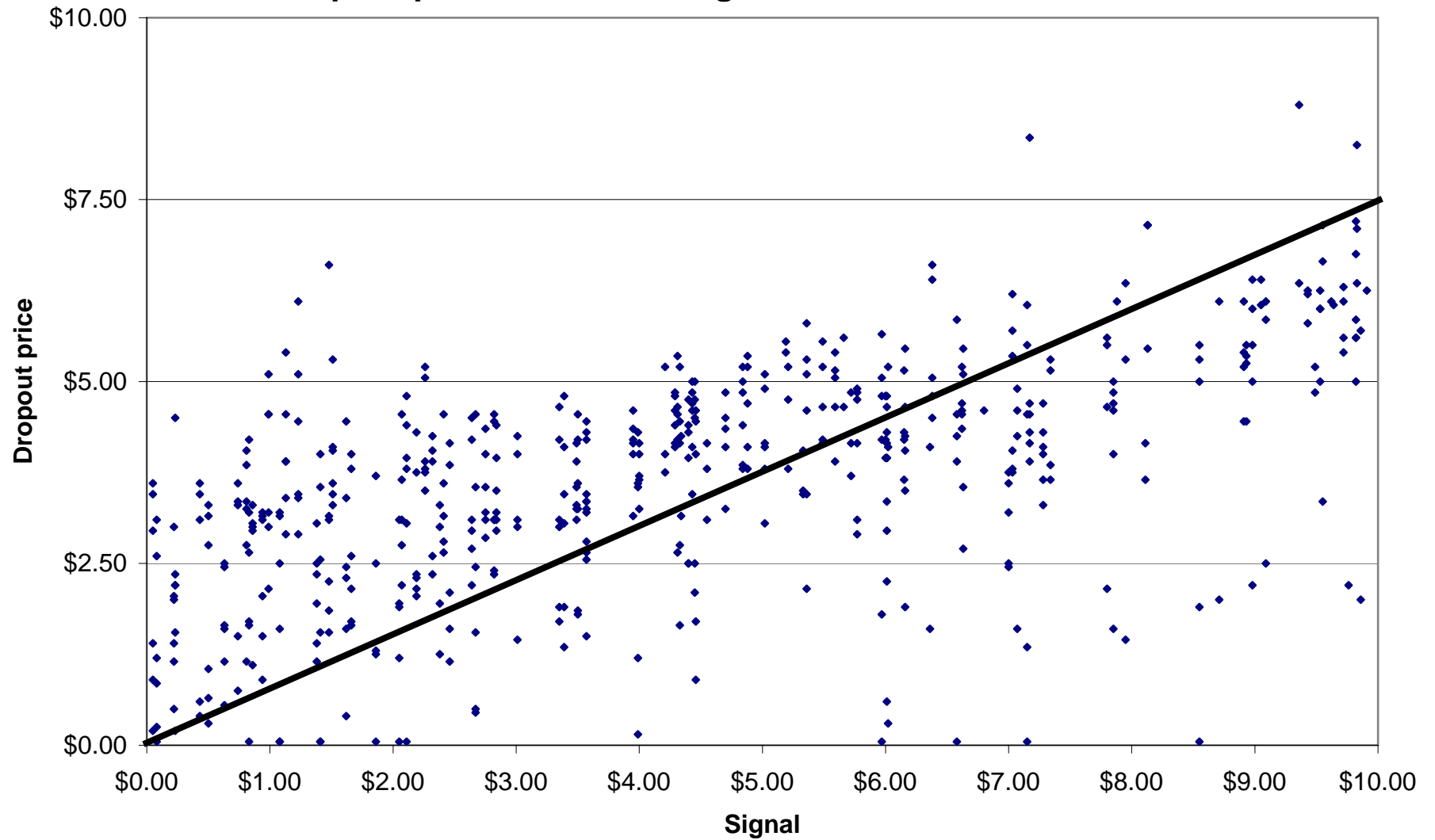


Figure 7
c.d.f. of Seller Revenue in Common-Value BIN Auctions
Observed vs. Predicted EV+

