How Auctioneers Set Ex-Ante and Ex-Post Reserve Prices in English Auctions

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Abstract

We compare two commonly used procurement English auction formats - the ex-ante reserve price and the ex-post reserve price, with symmetric and independently distributed private costs. Both formats are indirect implementations of Myerson's optimal mechanism. Both formats yield the same ex post payoffs when auctioneers optimally choose reserve prices. However, the optimal reserve prices follow two counter-intuitive prescriptions: optimal ex-ante reserve prices do not vary with the number of bidders, and optimal ex-post reserve prices are invariant to the realized auction prices. Anticipated regret(Davis et al., 2011) and subjective posterior probability judgement (Shachat and Tan, 2015) are two different approaches to rationalize observed auctioneers' choices that violate the two counter-intuitive prescriptions respectively. We generalized the latter model to one of Subjective Conditional Probabilities (SCP) which predicts optimal ex-ante reserve prices decreasing in the number of bidders and also predicts optimal ex-post reserve prices increasing in the realized auction prices. In our first experiment, in which costs follow a uniform distribution, we find two possible explanations to the experimental results. First, the auctioneers use the SCP model for both formats. Second, they use format-specific models. In our second experiment with a left-skewed cost distribution, we finally find that the SCP provides a unified behavioral model of how auctioneer set reserve prices in the two formats.

JEL classifications: C34; C92; D03; D44

Keywords: Procurement; English auction; ex-ante reserve price; ex-post reserve price; anticipated regret; subjective conditional probability

1 Introduction

Auctions are often used in procurement, particularly when a primary concern is price. In practice, there are two commonly used English auction formats. In one the procurer sets an ex-ante reserve price. For example, Kawai and Nakabayashi (2014) reported that between 2003 and 2006 Japanese public construction projects spent more than 42 billion US dollars via this format. In the second format, rather than setting an ex-ante reserve price, the procurer optionally negotiates with the auction winner for a price concession. The ultimate offer by the procurer is effectively an ex-post reserve price. Shachat and Tan (2015), for example, reported that in 2012 the Hunan Province (China) procurement center made over 9,000 orthopedic related purchases using this format.

Both formats offer promise and peril. On one hand, the auctioneer maximizes his expected benefit by optimally choosing reserve prices in either format. Why? Both formats are indirect implementations of Myerson's optimal mechanism (Myerson, 1981; Riley and Samuelson, 1981; Bulow and Klemperer, 1996). On the other hand, optimal reserve prices follow some counter-intuitive behaviors. In laboratory studies, human subjects generally deviate from these prescriptions.

The first counter-intuitive prescription is that optimal reserve prices in English auctions, with symmetric and independently distributed private values or costs, do not vary with the number of bidders. Davis et al. (2011) experimentally tested whether subjects follow this prescription in forward auctions, those for selling an object. Subjects' reserve prices were increasing, rather than constant, in the number of bidders.

In English procurement auctions with ex-post bargaining, an auctioneer's optimal strategy is to make the winner a take-it-or-leave-it offer if the auction price is too high. This optimal offer, the ex-post reserve price, is counter-intuitively invariant to the auction price (Bulow and Klemperer, 1996). Shachat and Tan (2015) reported laboratory experiments on this setting and found subjects on average correctly choose when to bargain, but their ex-post reserve prices are increasing, rather than constant, in auction prices.

Davis et al. (2011) and Shachat and Tan (2015) use different behavioral approaches to rationalize their participants' choices. The former incorporates anticipated regret into the auctioneer's expected utility function. The auctioneer's regret in this case reflects potential ex-post gains that an ex-ante reserve price does not capture. The latter model takes into account the auctioneer's subjective distortion of the Bayesian posterior of the auction winner's cost. This distortion shifts probability density inward from the outer ranges of the support. Both behavioural models are parsimonious as each is characterized by just two parameters.

We generalize this subjective posterior probability model to subjective conditional probabilities (SCP hereafter). This SCP model predicts, under certain ranges of parameter values, decreasing ex-ante reserve prices in English procurement auctions as the number of bidders increases. And it is equivalent to Shachat and Tan's subjective posterior probability model in ex-post reserve price formats. Thus preserving a predicted positive relationship between auction and ex-post reserve prices.

We report on direct experimental comparisons of these two English procurement auction formats. We employ human participants as the auctioneers and use computerized bidders. These robot bidders follow their weakly dominant strategies of exiting at their realized costs in both formats, and also accept any ex-post reserve price that at least matches its realized cost.

Our two experiments incorporate three treatment variables: the auction format, the number of bidders, and the distribution of sellers' costs. The first treatment variable follows a between-subject design. We call the ex-ante format the *EA* treatment and the ex-post format the *EP* treatment. The second treatment variable follows a within-subject design. Each subject participates in auctions with one, two, and three bidders. The third treatment variable delineates our two experiments. In the first experiment the distribution of costs follows a uniform distribution, the U treatment. In the second experiment, costs follow a heavily left-skewed distribution, the S treatment.

In our first experiment, we find auctioneer's average surplus per auction is similar in both formats, ex-ante reserve prices are decreasing in the number of bidders, and ex-post reserve prices are increasing in auction prices. We present structural maximum likelihood estimates for both the SCP and anticipated regret models. For the EA-U data, the two models' performances are on par with each other as they have similar likelihood values and their respective parameter values are in line with previous studies. For the EP-U data, consistent with Shachat and Tan (2015), the SCP model validates well but the estimated anticipate regret parameters reflect nonsensical positive utility for ex-post losses. Two possible explanations accommodate these results. First, the participants use the SCP model for both formats. Second, participants use format-specific models - anticipated regret in the EA format and SCP in the EP format. Our second experiment allows us to discriminate between these two hypotheses.

In the second experiment, assuming participants use the models' parameter values estimated from the first experiment, auctioneers who follow the SCP model earn the same in both formats. However, if they follow the format-specific models, they will earn less in the EA format. We find that actual subjects' earnings are similar in the EA-S and EP-S formats, favoring the hypothesis that subjects follow the SCP model in both formats. We re-estimate the SCP model parameters and find they generate a similar pattern of subjective conditional probability distortions. However, the parameter estimates statistically differ between the uniform and left-skewed distributions of costs environments.

From these two experiments we find the SCP potentially provides a unified behavioural model of how auctioneer set reserve prices in the two formats. However, the lack of external validity of the estimated SCP model parameters leaves room for future improvements. From a managerial perspective our study shows that the choice of English auction format is not a linchpin to creating value from the use of reserve prices, rather there is an issue of subjective human judgements that systematically leave potential benefits unrealized. Managers would be better served by addressing these judgement issues rather than searching for the optimal auction format.

2 Theoretical models of reserve prices

2.1 The standard case

We review the standard theoretical results for optimal ex-ante and ex-post reserve prices. Consider an auctioneer desiring an indivisible object. His valuation of the object, denoted v, is a random variable with the absolutely continuous distribution H and associated density h whose supports are the interval $[\underline{v}, \overline{v}]$. There are n potential sellers, indexed by i, each of whom can provide the object at a cost of c_i. Each seller's cost is an independent draw from the interval $[0, \overline{c}]$, with $\overline{c} < \overline{v}$, according to the distribution function F. The density function for F is denoted f. We order the sellers from lowest to highest realized cost; i.e. c_1 is the lowest realized cost, c_2 is the second lowest realized costs, etc.. We denote the distribution and density functions of the i^{th} lowest cost by $F_{(i)}$ and $f_{(i)}$ respectively. We further assume $c_i + \frac{F(c_i)}{f(c_i)}$ is strictly increasing on the support of F. The auctioneer's value and sellers' costs are all private information. Each individual knows their own realized value or cost, and the distributions of others' private information. This information structure is known by all parties.

2.1.1 Ex-post reserve prices

In an ex-post format, the process begins with an auction with a price clock starting at $\bar{c}$ and all sellers in the auction. As the price clock ticks down sellers can exit. The auction closes once $n-1$ sellers have exited, or the clock reaches zero. The remaining seller is the auction winner.[1] The auction price is the last tick of the price clock. The auctioneer then has the option to either accept the auction outcome, or to issue the auction winner a lower take-it-or-leave-it offer, which we call the ex-post reserve price $r_p \in [0, \min\{v, c_2\}]$.[2] If the auctioneer accepts the auction outcome his payoff is his value less the auction price, the auction winner's payoff is the auction price less her realized cost, and all other sellers' payoffs are zero. If the auctioneer chooses the ultimatum bargaining option and the seller accepts, the auctioneer's payoff is his value less r_p, the auction winner's payoff is r_p less her realized cost, and all other sellers' payoffs are zero. If the counter offer of r_p is rejected, there is no trade and all parties' payoffs are zero.

In this format a seller has a weakly dominant strategy to exit the auction at the price equal to her cost, and to accept any take-it-or-leave-it offer that does not generate a loss. Accordingly the seller holding c_1 will win the auction and the auction price will be c_2. The auctioneer's strategy is a function that maps from possible value-auction price pairs to possible counter offers joint with accepting the auction outcome. The auctioneer's payoff function, when sellers follow their weakly dominant strategy, is

$$E[\pi(r_p; v, c_2)] = \max\{v - c_2, (v - r_p)D(r_p|c_2)\}. \tag{1}$$

The conditional probability of purchasing at r_p is $D(r_p|c_2) = \Pr\{c_1 \le r_p | c_1 < c_2\} = F(r_p)/F(c_2)$ via Bayes Rule. The first order condition for an interior maximum of the second argument of (1) implies,

$$r_p^* = v - \frac{F(r_p^*)}{f(r_p^*)}. \tag{2}$$

[1] If there are multiple winners one is selected at random.

[2] For simplicity in upcoming arguments, we rule out reserve prices in which the auctioneer exposes themselves to negative payoff outcomes.

Bulow and Klemperer (1996) show the maximized value of the first argument exceeds the second when $c_2 \leq r_p^*$. In other words, the auctioneer should accept the auction outcome when the auction price is less than the optimal ex-post reserve price; otherwise make the auction winner a take-it-or-leave-it offer at the optimal ex-post reserve price.

2.1.2 Ex-ante reserve prices

In the ex-ante format, the auctioneer chooses a reserve price $r_a \in [0, \min\{v, \overline{c}\}]$. This pre-committed maximum price is announced to all sellers. Each seller then decides whether or not to participate in the auction. The auctioneer conducts an English auction with a price clock starting at r_a. The only action that an auction participating seller can take is to exit as the clock ticks down. The auction closes once $n-1$ sellers have exited. The auction price is the last tick and the remaining seller is the winner.[3] A seller has a weakly dominant strategy to enter the auction when her cost is no more than r_a and to exit when the clock price equals her cost (Vickrey, 1961). Accordingly the auction price is the minimum of either the second lowest realized cost c_2 and the r_a. When no seller's cost is less than r_a there is no auction and all parties receive a payoff of zero. When there is an auction the auctioneer's payoff is v less the auction price, the winning seller's payoff is the auction price minus her cost, and all other sellers' payoffs are zero.

When sellers follow their weakly dominant strategy, the auctioneer's ex ante expected payoff, as a function of r_a, is

$$E[\pi_a(r_a; v)] = (v - r_a)B(r_a) + \int_0^{r_a} (v - y) f_{(2)}(y) dy. \tag{3}$$

The reserve price r_a is the purchase price when it lies between the second lowest and lowest realized costs. The probability of this event is $B(r_a) = \Pr\{c_1 \leq r_a < c_2\} = nF(r_a)(1 - F(r_a))^{n-1}$. The second lowest realized cost is the purchase price when it is exceeded by the reserve price, $r_a > c_2$. This occurs with probability, $F_{(2)}(r_a) = 1 - nF(r_a)\big(1 - F(r_a)\big)^{n-1} - \big(1 - F(r_a)\big)^n$. Note, the density function of the second lowest realized cost is $f_{(2)}(y) = n(n-1)F(y)f(y)[1 - F(y)]^{n-2}$. The auctioneer's optimal ex-ante reserve price r_a^*, derived from the first order condition of Equation (3),

[3] Again, in the case of multiple winners, one is chosen randomly. All winners have the same probability of being selected.

is

$$r_a^* = v - \frac{F(r_a^*)}{f(r_a^*)}. \tag{4}$$

We highlight three counter-intuitive properties of the optimal reserve prices. First, inspection of Equations (4) and (2) reveals that the optimal ex-ante and ex-post reserve prices are the same. Clearly, the ex-post format provides the auctioneer more information. However, this does not change the optimal action, just the valuation of the maximized expectation for different realized values of c_2. Second, both the optimal ex-ante and ex-post reserve prices are invariant to the number of bidders. Third, the optimal ex-post reserve price is independent of the observable auction price.

2.2 Optimal reserve prices with subjective conditional probabilities

We derive the implications on optimal reserve prices when the auctioneer's judgement of conditional probabilities are distorted. Our approach generalizes the distorted Bayesian posterior model of Shachat and Tan (2015). We assume an auctioneer's subjective conditional probability judgement of an event is formed by transforming the true conditional probability, x, via Equation (5). This function has five potential shapes based on the values of two parameters μ and λ.[4]

$$\psi(x) = e^{-\mu(-\ln(x))^{\lambda}}, \mu > 0, \lambda > 0, x \in [0, 1]. \tag{5}$$

2.2.1 Ex-post reserve prices

We first consider how subjective conditional probabilities impact optimal reserve prices in the ex-post auction format and how optimal reserve prices respond to changes in the auction price. The auctioneer's subjective expected utility from making the take-it-or-leave-it offer r_p is

$$E[\pi_p(r_p; v, c_2)] = \max\{v - c_2, (v - r_p)\psi\big(D(r_p|c_2)\big)\}.$$

The auctioneer's optimal strategy (Shachat and Tan, 2015) is,

Proposition 1.

[4]This function is also used in Prelec (1998) as the probability weighting function, with an inverted S-shape, component of Prospect Theory. In Shachat and Tan (2015) and this study, it is usually the case the transformation function takes on an S-shape.

(i) The optimal ultimatum offer is $r_p^* = v - \frac{\Phi(r_p^*)}{\Phi'(r_p^*)}$*, where* $\Phi(r_p^*) = \psi\left(\frac{F(r_p^*)}{F(c_2)}\right)$*, and*

(ii) Accept the auction outcome if $r_p^* \geq c_2$*.*

Subjective conditional probabilities result in optimal ex-post reserve prices which generally vary with respect to the realized auction price. The following proposition, for proof see Proposition 2 of Shachat and Tan (2015), conveys the relevant comparative static result.

Proposition 2. *If* $\lambda > 1$*, then* $\frac{\partial r_p^*}{\partial c_2} > 0$*.*

2.2.2 Ex-ante reserve price format

In the ex-ante format the auctioneer receives no information regarding the lowest realized cost. Consequently, the lens of Shachat and Tan (2015) yields the same optimal reserve price as the standard model. We extend the transformed judgement notion from Bayesian updating to the more general case of conditional probability. The auctioneer's key conditional judgement is the likelihood of a reserve price exceeding the lowest cost conditional on not exceeding the second lowest cost. Restating the probability of a reserve price setting the purchase price highlights this:

$$B(r_a) = \Pr\{c_1 \leq r_a < c_2\} = \Pr\{c_1 \leq r_a | c_2 > r_a\} \Pr\{c_2 > r_a\}.$$

For convenience let $G(r_a) = \Pr\{c_1 \leq r_a | c_2 > r_a\}$, or more explicitly, $G(r_a) = \frac{nF(r_a)}{(n-1)F(r_a)+1}$. If the auctioneer transforms the conditional probability of the auction price setting the purchase price by Equation (5), then the auctioneer's corresponding subjective belief becomes,

$$Z(r_a) = \psi(G(r_a))\big(1 - F_{(2)}(r_a)\big).$$

The auctioneer's expected utility from choosing r_a is

$$E[\pi_a(r_a; v)] = (v - r_a)Z(r_a) + \int_0^{r_a} (v - y) f_{(2)}(y) dy. \tag{6}$$

Proposition 3 characterizes the auctioneer's optimal ex-ante reserve price.

Proposition 3.

The optimal ex-ante reserve price for auctioneers with subjective conditional probability judgement *is*

$$r_a^* = v - \frac{Z(r_a^*)}{\widetilde{Z}(r_a^*)}, \tag{7}$$

where $\widetilde{Z}(r_a) = Z'(r_a) + f_{(2)}(r_a)$.

Proof: Provided in the appendix.

How do subjective conditional probabilities impact optimal reserve prices as the number of bidders varies? Under subjective conditional probabilities, the optimal ex-ante reserve price is no longer invariant to the number of bidders. Note that $\widetilde{Z}(r_a)$ and $Z(r_a)$ are functions of the number of bidders n. When the conditional probability is not distorted it has $\frac{Z(r)}{\widetilde{Z}(r_a)} = \frac{F(r_a)}{f(r_a)}$ and the standard model is recovered. Proposition 4 characterizes the comparative static on how the optimal ex-ante reserve price relates to the number of bidders. We will relate this proposition to the parameters λ and μ when we discuss hypotheses in the next section.

Proposition 4.

(i) If $\frac{\partial \widetilde{Z}(r_a^*)}{\partial n} Z(r_a^*) = \frac{\partial Z(r_a^*)}{\partial n} \widetilde{Z}(r_a^*)$, *then* $\frac{\partial r_a^*}{\partial n} = 0$. *This occurs when the auctioneer does not distort the conditional probability of* $G(r_a)$.

(ii) If $\frac{\partial \widetilde{Z}(r_a^*)}{\partial n} Z(r_a^*) < \frac{\partial Z(r_a^*)}{\partial n} \widetilde{Z}(r_a^*)$, *then* $\frac{\partial r_a^*}{\partial n} < 0$.

(iii) If $\frac{\partial \widetilde{Z}(r_a^*)}{\partial n} Z(r_a^*) > \frac{\partial Z(r_a^*)}{\partial n} \widetilde{Z}(r_a^*)$, *then* $\frac{\partial r_a^*}{\partial n} > 0$.

Proof: Provided in the appendix.

2.3 Optimal reserve prices when an auctioneer has anticipated regret

An auctioneer with anticipated regrets experiences disutility when all uncertainties associated with his decisions are resolved with inefficient ex-post outcomes, and he incorporates these potential disutilities into his ex-ante calculations of expected utility. An auctioneer experiences *win regret* after a purchase and realizes a lower reserve price would have increased his ex-post payoff. Note in the ex-post format, when an auctioneer accepts the auction outcome no further uncertainties resolve and his win regret is zero. We assume that an expected amount of win regret x generates a proportional disutility, $w(x) = \delta_w \cdot x$, with $\delta_w \geq 0$. We measure x as the auctioneer's purchase price less the revised expectation of the winner's cost, c_1, whose distribution function is $\frac{F(x)}{F(\min\{c_2, r\})}$.

Explicitly,

$$x = \begin{cases} r - k(r), & \text{for } r \leq c_2 \text{ and } r \geq c_1 \\ c_2 - k(c_2), & \text{for } r > c_2 \end{cases}, \text{ where } k(y) = \int_0^y \nu \, \frac{f(\nu)}{F(y)} \, d\nu.$$

An auctioneer experiences *loss regret* when he fails to purchase the object which he could have done so profitably given the realized auction outcome. We assume that an expected amount of loss regret x generates a proportional ex-ante disutility, $l(x) = \delta_l \cdot x$, with $\delta_l \geq 0$. The auctioneer experiences loss regret in the ex-post format when setting aside an auction outcome yielding a certain positive payoff, and then his ultimatum offer is rejected. The loss regret is calculated,

$$x = \begin{cases} 0, & \text{for } v - c_2 \leq 0 \text{ and } r_p \leq c_1 \\ v - c_2, & \text{for } v - c_2 > 0 \text{ and } r_p \leq c_1 \end{cases}.$$

When the auctioneer experiences a loss regret in the ex-ante auction format, we assume it is proportional to the difference between his value and reserve price. In this case the loss regret is calculated as $x = v - r_a$.[5]

We summarize this associated utility valuations for potential auction outcomes and the associated probabilities in Table 1. The last three rows correspond to the three possible auction outcome events: purchasing at the auction price c_2, purchasing at the auctioneer's reserve price, and failing to purchase. The second and third columns provide the utility and probability respectively for the ex-post format. The fourth and fifth column provide the same for the ex-ante format.

2.3.1 Ex-post reserve prices

We first examine the impact of anticipated regret on the optimal reserve price and its response to varying auction prices in the ex-post format. The auctioneer's expected utility function is

$$E[\pi_p(r_p; v, c_2)] = \max\big\{v - c_2, -l(c_2)\mathbb{1}_{\{v-c_2>0\}}(1 - D(r_p|c_2)) + (v - r_p - w(r_p))D(r_p|c_2)\big\}.$$

The optimal ex-post reserve price is characterized by the following proposition.

[5] We are following specification of loss regret provided by Davis et al. (2011), although we recognize an alternative valid calculation is to let $x = v - E[c_1|c_1 \geq r_a]$.

Table 1: Auctioneer's anticipated regret utilities and associated probabilities for alternative outcomes by auction format.

	Ex-post format		Ex-ante format	
Event	Utility	Probability	Utility	Probability
$r \geq c_2$, purchase price $= c_2$	$v - c_2$	1	$v - c_2 - w(c_2)$	$F_{(2)}(r_a)$
$c_1 \geq r < c_2$, purchase price $= r$	$v - r_p - w(r_p)$	$D(r_p \vert c_2)$	$v - r_a - w(r_a)$	$B(r_a)$
$r < c_1$, no purchase	$-l(c_2) \times \mathbb{1}_{\{v-c_2>0\}}$	$1 - D(r_p \vert c_2)$	$-l(r_a)$	$1 - F_{(2)}(r_a) - B(r_a)$

In this table, relevant probabilities are $F_{(2)}(r_a) = \Pr\{c_2 < r_a\}$, $B(r_a) = \Pr\{c_1 < r_a < c_2\}$, $1 - F_{(2)}(r_a) - B(r_a) = \Pr\{c_1 > r_a\}$, and $D(r_p|c_2) = \Pr\{c_1 \leq r_p | c_1 < c_2\}$. $\mathbb{1}_{\{A\}}$ is the indicator function that equals 1 when A is true and equals zero otherwise.

Proposition 5. *The optimal ex-post reserve price for an anticipated regret auctioneer is*

$$r_p^* = \frac{1}{1+\delta_w}\left(V(r_p^*) + \delta_l \max\{0, v - c_2\} + \delta_w M(r_p^*)\right), \tag{8}$$

where $\delta_l \geq 0$ *and* $\delta_w \geq 0$, $V(r_p^*) = v - \frac{F(r_p^*)}{f(r_p^*)}$ *and* $M(r_p^*) = k(r_p^*) - \frac{F(r_p^*)}{f(r_p^*)}(1 - k'(r_p^*))$.

Proof: Provided in the appendix.

With respect to varying auction prices c_2, we find that optimal ex-post reserve price r_p^*, depends only upon the coefficient of loss regret. Further, we find there is a negative relationship between the auction price and the auctioneer's optimal ex-post reserve.

Proposition 6. *If* $\delta_l > 0$ *and* $v - c_2 > 0$, *then* $\frac{\partial r_p^*}{\partial c_2} < 0$.

Proof: Provided in the appendix.

There is some intuition for this comparative static result. At higher auction prices the potential loss regret from setting aside the auction outcome is smaller. This leads to more aggressive ex-post auction bargaining.

2.3.2 Ex-ante reserve prices

We revisit the analysis of Davis et al. (2011), allowing for v to be a random variable, regarding the optimal ex-ante reserve price for an auctioneer with anticipated regret, and the comparative static of this reserve price with respect to the number of bidders. The auctioneer's expected utility for reserve price r_a is,

$$E[\pi_a(r_a;v)] = -l(r_a)(1 - F_{(2)}(r_a) - B(r_a)) + (v - r_a - w(r_a))B(r_a) + \int_0^{r_a} (v - y - w(y))f_{(2)}(y)dy.$$

The auctioneer's optimal action in this case is given in the following proposition.

Proposition 7. *The optimal ex-ante reserve price for an auctioneer with anticipated regrets is*

$$r_a^* = \frac{1}{1+\delta_l+\delta_w}\left(V(r_a^*) + \delta_l L(r_a^*, n) + \delta_w M(r_a^*)\right),$$

where $\delta_l \geq 0$, $\delta_w \geq 0$, $V(r_a^*) = v - \frac{F(r_a^*)}{f(r_a^*)}$, $L(r_a^*, n) = v + \frac{1-F(r_a^*)}{f(r_a^*)}\frac{1}{n}$ *and* $M(r_a^*) = k(r_a^*) - \frac{F(r_a^*)}{f(r_a^*)}(1 - k'(r_a^*))$.

Proof: Provided in the appendix.

The impact of varying the number of bidders on the optimal ex-ante reserve price is given in the following proposition.

Proposition 8. *If* $\delta_l > 0$, *then* $\frac{\partial r_a^*}{\partial n} < 0$.

Proof: Provided in the appendix.

3 Experimental design and hypotheses

3.1 Experimental design

Our experimental treatment design had two factors. The first factor was the English auction format, which we implemented between-subjects. The second factor was the number of bidders, which we implemented within-subject. All subjects assumed the role of the auctioneer. An auctioneer took part in a sequence of 90 procurement auctions. In each auction, the auctioneer's value v was an independent random draw from a Uniform distribution over the range 50 to 150. The auctioneer knew (1) the bidders were computerized and programmed to follow their respective weakly dominant strategy in each format[6] and (2) each seller's cost was an independent draw from

[6] We adopted computerized sellers as Davis et al. (2011). Shachat and Tan (2015) used human sellers in their ex-post format study and found human subjects overwhelmingly exit the auction at cost and almost always accept any ultimatum offer that does not generate a loss.

a Uniform distribution over the range 0 to 100. Note, we created paired sequences of values and costs by randomly drawing the value and costs for the 90 auctions for one subject participating in the ex-post format, and then using the same sequence for a subject participating in the ex-ante format.

All auctioneers face a varying number of bidders across auctions. The number of bidders in an auction was either 1, 2, or 3. An auctioneer's sequence of auctions was broken into three block of 30 auctions; one block for each of the three levels of bidders. As we will discuss shortly, we conducted four sessions for each auction format, and each session's block sequence of n uniquely followed one of four orders: $\{1, 2, 3\}$, $\{2, 1, 3\}$, $\{2, 3, 1\}$ and $\{3, 2, 1\}$. This was done to control for order effects.

The two experimental English auction format treatments were Ex-post reserve price (EP-U) and Ex-ante reserve price (EA-U). In an auction, the computer software[7] first informed a subject of her current value and the number of bidders. In the EP-U treatment, the software presented n cards, one for each bidder, sorted left-to-right by descending cost. When $n = 2$ or 3, the left most $n - 1$ cards displayed the corresponding seller's bid, and the right most card displayed "W" to indicate the auction winner. The auctioneer was informed of the auction price, which matched the number on the second farthest right card. In the case of $n = 1$, the auctioneer saw a single card with a "W" and was informed the auction price was 100. Next the auctioneer decided to either accept the auction price or make a take-it-or-leave-it offer, r_p, to the winning seller. The winning seller accepted r_p if it exceeded his cost, otherwise he rejected it and there was no purchase.[8]

In the EA-U treatment, an auction started with the auctioneer learning her value and the number of bidders. Then she is prompted to select a reserve price, r_a. Next the software presented n-cards in similar fashion to the EP-U treatment. However, if a seller's cost exceeded r_a, his card displayed "D". If all cards displayed "D," there was no purchase. Otherwise the auctioneer purchased at price equal to the lower of r_a and c_2.

We recruited 16 subjects for each session, conducted four sessions for both formats, giving us a total of 128 subjects. The subjects were undergraduate and graduate students at a large prestigious university in Southern China and recruited via the subject pool management software ORSEE (Greiner, 2004). Subjects could only participate in one session. An experimental session

[7] All experiments were computerized with a program developed using zTree (Fischbacher, 2007).
[8] We provide full instructions for both treatments in an appendix.

lasted no more than two hours. We paid subjects their accumulated earnings from their 90 auctions, with an exchange rate of 60 experimental currency units to 1 Chinese RMB. We also paid subjects a 5 RMB show-up fee. Overall subjects earned approximately 60 RMB on average from their participation.

3.2 Hypotheses

Our hypotheses are developed around three alternative models of auctioneer expected utility: risk neutrality, SCP, and anticipated regret. Our hypotheses concern the equality of reserve prices across auction formats, the comparative statics of reserve prices with respect to the number of bidders in the ex-ante format and with respect to the level of realized auction prices in the ex-post format. We develop the specific nature of the hypotheses are developed using the value and cost respectively adopted Uniform distributions.

In the standard model, optimal ex-ante and ex-post reserve prices are the same. Thus for any realized value and set of costs, the same allocation and price results in the two formats. With the adopted distributions for value and costs the optimal reserve price, according to Equations (4) and (2), the optimal reserve price in both formats $r^*(v) = v - F(r^*(v))/f(r^*(v)) = v/2$ in both ex-ante and ex-post cases.[9] Hypothesis 1 summarizes these predictions.

Hypothesis 1. ***Risk neutral benchmark****: (a) Selected reserve prices, actual purchase prices, and the auctioneers' average earnings are the same in the two formats. (b) Reserve prices are invariant to the number of bidders in both formats. (c) Reserve prices are invariant to the realized auction price in the ex-post format.*

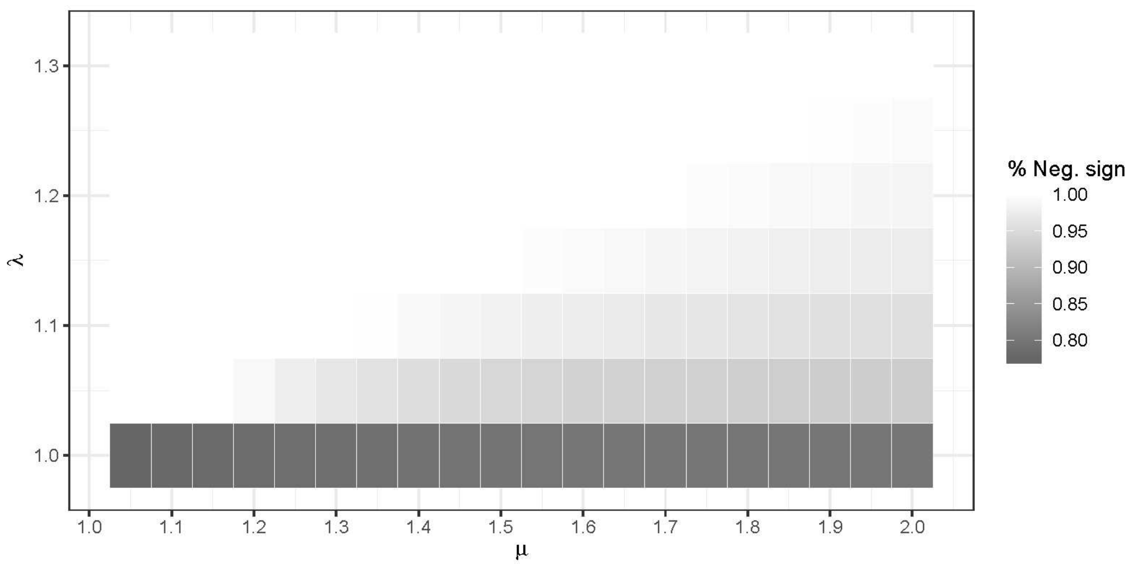
In the SCP model the two comparative statics results of interest depend upon the specific distributions of value and costs, and the value of the SCP transformation parameters λ and μ. Shachat and Tan (2015) found the estimated values of λ and μ for most subjects both exceed 1. This implies an S-shaped transformation function of ψ, which redistributes probability density away from the ends of the support towards the interior. For the ex-post format, Proposition 1 shows when $\mu > 1$ and $\lambda > 1$ that ex-post reserve prices increase with auction prices.

[9]Note that if the auctioneer is risk averse that both the optimal ex-ante reserve price (Hu, 2011) and ex-post Shachat and Tan (2015) are increasing in the degree of risk aversion, but invariance to the number of bidders and realized auction price remain.

For the ex-ante format, Proposition 4 gives a condition in which optimal reserve prices are decreasing in n. Under our uniform distributions for value and costs the sign of the $\partial r_a^*(v)/\partial n$ is ambiguous with respect to absolute bounds on λ and μ. We develop a numerical characterization of the (μ, λ) pairs for which $\partial r_a^*(v)/\partial n < 0$.

We consider the sign of the $\partial r_a^*/\partial n$ for the range of $(\mu, \lambda) = [1.05, 2] \times [1, 1.3]$ with a grid size of 0.05. For each grid point, we evaluate the sign of $\partial r_a^*/\partial n$ for each integer value of $v = 50, 51, \ldots, 150$ and for each number of bidders of $n = 1, 2, \ldots, 10$. We then calculate the percentage of cases in which this sign is negative. We report these percentages in the heat map of Figure 1. The figure reveals that as long as μ does not greatly exceed λ, then the relationship between the optimal ex-ante reserve prices and the number of bidders is certainly negative.

Figure 1: The percentage of cases that $\partial r_a^*(v)/\partial n < 0$ for alternative (μ, λ) pairs



Hence, when the parameters of μ and λ are sufficient larger than 1, we can obtain Hypothesis 2 based on the subjective conditional probability model.

Hypothesis 2. ***Subjective conditional probability****: (a) If $\lambda > 1$ and $\mu > 1$, then ex-post reserve prices are strictly increasing in realized auction prices. (b) Additionally if μ does not greatly exceed λ, then ex-ante reserve prices are strictly decreasing in the number of bidders.*

In the anticipated regret model, Proposition 7 indicates when auctioneers have anticipated regret their ex-ante reserve prices vary with the number of bidders. In the uniform-distributed cost environment, winning regret reduces to $w(r) = \frac{\delta_w r}{2}$ and losing regret to $l(r) = \delta_l(v - r)$. The optimal ex-ante reserve price is $r_a^*(v) = \frac{100\delta_l + (\delta_l+1)vn}{\delta_l(n+1)+(2+\delta_w)n}$. This implies the optimal ex-ante reserve price r_a^* is decreasing in n, when $\frac{1+\delta_w}{1+\delta_l} > \frac{1}{2}$. Corresponding optimal ex-post reserve prices, derived from the Proposition 8, are $r_p^*(v) = \frac{v+\delta_l \max\{0, v-c_2\}}{2+\delta_w}$. Proposition 6 demonstrates that when $\delta_l > 0$ and $v - c_2 > 0$, $\frac{\partial r_p^*}{\partial c_2} < 0$.

Hypothesis 3. ***Anticipated regret****: (a) The auctioneers' ex-ante reserve prices are negatively related to the number of bidders, and (b) their ex-post reserve prices are negatively related to the auction price.*

To summarize, the SCP and anticipated regret models predict specific deviations from the standard model in terms of the counter intuitive predictions of reserve prices that are invariant to the number of bidders and, in the ex-post format, the realized auction prices. The SCP and anticipated regret models disagree on the direction by which ex-post reserve prices vary with respect to realized auction prices.

4 Experimental results

4.1 Comparison: auctioneers' earnings, reserve prices and procurement outcomes

We start our analysis comparing basic performance and choice measures between auction formats. First, auctioneers' average payoffs per auction are 39.64 and 39.88 in the EP-U and EA-U treatments respectively. The difference between these payoffs is not statistically different from zero according to a t-test (p-value=0.70). However, both of these measures are significantly lower that the risk neutral benchmark of 42.01 (both p-values<0.01). Table 2 provides more similar comparisons when the number of bidders varies. At every level of n, the differences between the average auctioneer payoffs in the two formats are not statistically from zero; the p-values are 0.31, 0.79 and 0.97 for the numbers of bidders 1, 2 and 3 respectively. However all levels are significantly less than the risk neutral benchmark for all three levels of n (all p-values < 0.01.)

Table 2: Auctioneers' average auction payoffs in EA-U and EP-U treatments

	$n = 1$	$n = 2$	$n = 3$
EP-U	24.55	41.04	53.35
	(5.06)	(4.90)	(5.76)
EA-U	25.14	41.15	53.36
	(5.20)	(4.93)	(5.86)
Risk neutral	27.11	43.59	55.32
benchmark (RN)	(4.62)	(4.63)	(4.98)
	t-test statistics (p-value)		
H_0: EA-U= EP-U	0.31	0.79	0.97
H_0: EA-U=RN	<0.01	<0.01	<0.01

Note, standard deviations are in parentheses and each subject is an independent observation.

Table 3: Auctioneers' purchase rate and purchase price in EA-U and EP-U treatments

	$n = 1$	$n = 2$	$n = 3$
Purchase Rate			
EP-U	0.59	0.75	0.85
	(0.09)	(0.08)	(0.09)
EA-U	0.60	0.76	0.84
	(0.10)	(0.09)	(0.10)
Risk neutral	0.50	0.72	0.85
benchmark	(0.09)	(0.07)	(0.06)
Purchase Price			
EP-U	65.00	49.63	40.17
	(9.42)	(5.37)	(4.09)
EA-U	63.53	48.40	38.21
	(9.06)	(7.05)	(6.34)
Risk neutral	54.35	45.76	38.89
benchmark	(3.58)	(3.79)	(2.50)

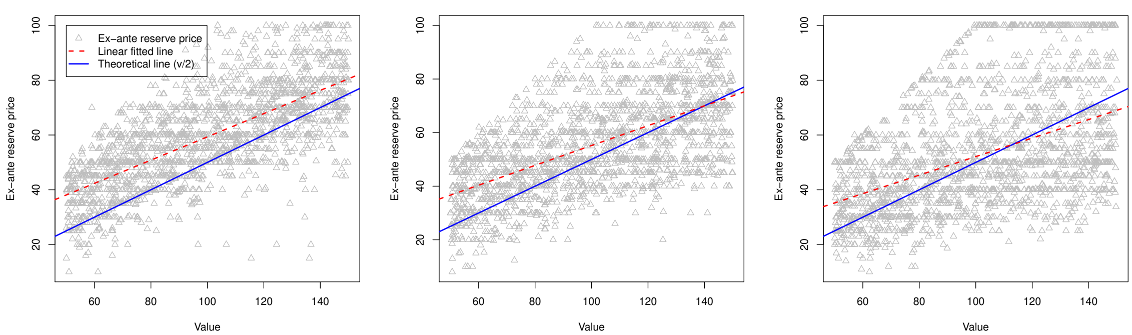
Note, standard deviations are in parentheses and each subject is an independent observation.

Next, we examine the auctioneers' reserve prices across treatments. Figure 2 displays scatter plots of ex-ante and ex-post reserve prices versus value, overlaid with a line for the optimal reserve price of the risk neutral benchmark, $r^* = v/2$, and a regression fitted line. The first row of Figure 2 presents the scatter plots for the EA-U treatment. Reserve prices do not align with the risk neutral benchmark, but the differences between the fitted line and the risk neutral benchmark grow less stark as the number of bidders increases. By Wilcoxon signed rank tests, the differences between the ex-ante reserve prices and risk neutral optimal reserve prices are significantly different from zero (p-values are <0.01, <0.01 and <0.01 when n =1, 2 and 3, respectively).

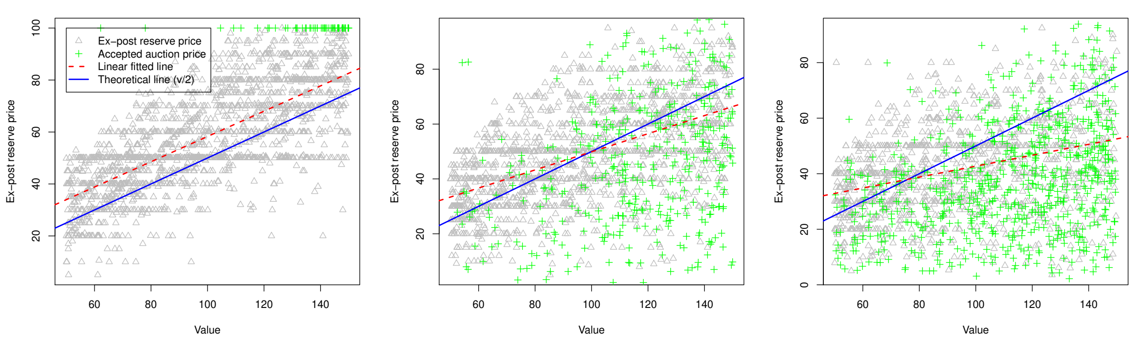
The second row of Figure 2 presents the scatter plots for the EP-U treatment. Recall that ex-post reserve prices are right-censored at realized auction prices. We observe censoring, i.e. accepted auction outcomes, of 2.86%, 20.00%, and 38.54% for $n = 1, 2,$ and 3 respectively. The fitted lines for the EP-U treatment are derived from linear regressions of observable ex-post reserve prices (shown by grey triangles) on values.[10] The differences between the observable ex-post reserve prices and the optimal risk neutral reserve prices are all significant (p-values are <0.01, =0.01 and <0.01 when n =1, 2 and 3, respectively.)

Figure 2: Reserve prices in treatments

(a) EA-U (n=1) (b) EA-U (n=2) (c) EA-U (n=3)



(d) EP-U (n=1) (e) EP-U (n=2) (f) EP-U (n=3)



In the two treatments, the values and costs are fully paired, allowing us to compare the non-censored ex-post reserve prices with matched ex-ante reserve prices. The p-values derived from

[10]We report more appropriate Tobit regressions below.

Wilcoxon signed rank test are 0.02, <0.01 and <0.01 for $n = 1, 2,$ and 3 respectively. Thus the difference between ex-ante and ex-post reserve prices is significant at the level of 5%. Disaggregating by the number of bidders, the average observed ex-post reserve prices of 57.47, 48.59 and 41.42, which are lower than average of their respectively matched ex-ante reserve prices are 58.48, 52.78 and 48.93 for $n = 1, 2,$ and 3.

Based on these results above, we reject the first two parts and confirm the last part of Hypothesis 1*(a)* to obtain Result 1.

Result 1. *Ex-ante reserve prices are significantly different from ex-post reserve prices, and they all deviate from the optimal reserve price. The auctioneers' average profits are not significant different in EA-U and EP-U treatments, but they are lower than the theoretical expected profit.*

4.2 Do auctioneers' values solely determine the reserve prices?

We next evaluate, via reduced form regressions, hypotheses regarding the relationship between reserve prices and factors such value, the number of bidders and realized auction prices. Table 4 shows linear model estimates for reserve prices in the two treatments. Relevant standard errors are clustered by subject. Models (1) and (2) are Tobit regression models for the EP-U treatment, realized ex-post reserve prices are right-censored by realized auction prices. Model (1) only includes a constant and the factors value, v, and auction price, c_2. The risk neutral benchmark predicts that the constant and auction price coefficients are 0 and the coefficient for v is 0.5. However, estimated constant is significantly positive, the estimated price coefficient is 0.30, and the estimated value coefficient is 0.39. The significant and positive price coefficient is evidence in favor of the SCP model over the risk neutral and anticipated regret models.

Table 4: Estimates of linear models in EP-U and EA-U treatments

Variable	EP-U treatment		EA-U treatment	
	Model(1)	Model(2)	Model(3)	Model(4)
Intercept	-9.25***	7.17***	17.94***	16.89***
	(1.58)	(2.20)	(1.74)	(2.04)
$\mathbb{1}_{\{n=2\}}$	-	-15.45***	-	1.25
		(2.36)		(1.68)
$\mathbb{1}_{\{n=3\}}$	-	-11.11**	-	1.40
		(2.65)		(2.20)
Value	0.39***	0.52***	0.38***	0.42***
	(0.02)	(0.02)	(0.02)	(0.02)
Value$\cdot\mathbb{1}_{\{n=2\}}$	-	-0.17***	-	-0.05***
		(0.02)		(0.02)
Value$\cdot\mathbb{1}_{\{n=3\}}$	-	-0.25***	-	-0.09***
		(0.03)		(0.03)
Auction price	0.30***	-	-	-
	(0.03)			
Auction price$\cdot\mathbb{1}_{\{n=2\}}$	-	0.35***	-	-
		(0.03)		
Auction price$\cdot\mathbb{1}_{\{n=3\}}$	-	0.44***	-	-
		(0.03)		
Log(scale)	2.63***	2.58***	-	-
	(0.04)	(0.04)		
R^2	-	-	0.33	0.35
F test(p-value)	-	-	-	<.001
$Log(L)$	-19220	-19040	-	-
LR test (p-value)	-	<0.001	-	-

** Coefficient is significant at the 5% level;
*** Coefficient is significant at the 1% level.

Model (2) takes into account the number of bidders in terms of constant and interaction terms with value and realized auction price. Note there is no estimate for the auction price coefficient in 1-bidder auctions, because the auction price is always 100 in these cases. We reject the Model (1) in favor of Model (2) by a Likelihood Ratio test with a p-value < 0.001. The estimated coefficients of Model (2) suggests that when $n = 1$ the risk neutral benchmark is a good approximation.[11] However as n increases, the auctioneers' ex-post reserve prices grow more sensitive to realized auction prices and less sensitive to values. These countervailing effects do not allow us to sign the direction of change in r_p in response to changes in n. Regardless, this is evidence against our

[11] Although a Likelihood Ratio test rejects the joint hypothesis that the constant is zero and the coefficient on $v = 0.50$.

specification of our SCP model as these interaction terms should all be zero.

For the EA-U treatment, Models (3) and (4) presents OLS estimations for ex-ante reserve prices. Model (3) only considers the intercept and value, while Model (4) additionally takes into account the number of bidders. An F-test rejects the Model (3) in favor of Model (4). Strong evidence that the number of bidders influences ex-ante reserve prices, and the negative values of the estimated coefficients for the interaction of the number of bidders and value are indicative of auctioneers who more aggressively set reserve prices based when there are more bidders. This is consistent with both the SCP and anticipated regret models, but contradicts the risk neutral benchmark. We summarize the conclusions of these reduced form analyses.

Result 2. *Reserve prices do not solely depend on auctioneers' values. When the number of bidders increases, ex-ante reserve prices are decrease. Ex-post reserve prices are not independent from realized auction prices or the number of bidders. Hence we reject Hypotheses 1*(b) *and* (c)*.*

4.3 Structural estimates of the SCP and Anticipated Regret models

Table 5 presents the maximum likelihood estimates of the SCP model parameters for each auction format and then pooled. We first note that for all models, the estimated values of μ and λ are all greater than 1, suggesting that S-shaped transformation functions, $\psi(p)$ prevails in both EP-U and EA-U treatments. With respect to EP-U treatment, Model (5) is an estimate of our base SCP formulation. Model (6) extends by allowing the parameters of ψ to depend on the number of bidder in the most general way by letting $\mu_n = \mu + \mu \cdot \mathbb{1}_{\{n=2\}} + \mu \cdot \mathbb{1}_{\{n=3\}}$ and $\lambda_n = \lambda + \lambda \cdot \mathbb{1}_{\{n=2\}} + \lambda \cdot \mathbb{1}_{\{n=3\}}$. A Likelihood Ratio test rejects Model (6) in favor of Model (5) (p-value=0.63). This is strong evidence in favor of the SCP model as it demonstrates an ability to explain the comparative statics of the $\partial r_p^* / \partial n$ without having λ and μ depend on n. Furthermore, recall that in our reduced form regression Model (2) we found n significantly impacts the marginal effects of value and realized auction prices on ex-post reserve prices.

Table 5: Maximum Likelihood estimates of the SCP model for Experiment 1

Variable	EP-U treatment		EA-U treatment		Pooled
	Model(5)	Model(6)	Model(7)	Model(8)	Model(9)
μ	1.45***	1.45***	1.57***	1.47***	1.50***
	(<.001)	(0.02)	(<0.01)	(<0.01)	(<0.01)
λ	1.25***	1.23***	1.42***	1.55***	1.35***
	(<.001)	(0.03)	(<0.01)	(<0.01)	(<0.01)
$\mu \cdot \mathbb{1}_{\{n=2\}}$	-	-0.07**	-	0.35***	-
		(0.03)		(<0.01)	
$\mu \cdot \mathbb{1}_{\{n=3\}}$	-	0.10***	-	0.17***	-
		(0.03)		(<0.01)	
$\lambda \cdot \mathbb{1}_{\{n=2\}}$	-	0.02	-	0.03***	-
		(0.03)		(<0.01)	
$\lambda \cdot \mathbb{1}_{\{n=3\}}$	-	0.02***	-	0.01***	-
		(<.001)		(<.001)	
ln(scale)	12.71	12.32	15.33	15.27	14.27
	(0.15)	(0.12)	(0.15)	(0.15)	(0.10)
ln(*Likelihood*)	-19063.6	-19062.3	-23898.8	-23874.93	-43067.9
LR-test *p*-value	-	0.63	-	<0.01	<0.01

* Coefficient is significant at the 10% level, ** 5% level and *** 1% level.

We consider the same specifications for the EA-U treatment in Models (7) and (8). The estimated values of μ are similar for EP-U and EA-U; However, the estimated values of λ are larger for EA-U. Further in this case, we can't conclude that λ and μ are jointly unaffected by the number of bidders. A Likelihood Ratio test rejects Model (7) in favor of Model (8). The estimates of Model (8) suggests these differences arise from large differences in the estimations of μ for each of the level of bidders; however the estimated values are not monotonic in n and thus difficult to interpret. We summarize these findings in our next result.

Result 3. *In EA-U treatment, ex-ante reserve prices are negatively correlated to the number of bidders, and, in EP-U treatment, ex-post reserve prices are positively correlated to the auction price. These two correlations are consistent with the subjective conditional probability model in which auctioneers have an S-shaped transformed function.*

There are Two key attributes for a structural model like our SCP: we recover similar values for the underlying parameters across distinct tasks, and that the values of the parameters do not depend upon other environmental factors. With respect to the latter, this holds true for the EP-U estimates but not so for the EA-U estimates. To evaluate the former criteria we estimate Model (9) with estimates λ and μ pooling the data from the two treatments. Then we conduct a Likelihood Ratio test that rejects Model (9) in favor of having format separate models, (5) and (7). We find this aspect of the SCP's performance concerning, which we address in the next section.

We next consider the structural estimates of the anticipated regret model. Table 6 presents the results of maximum likelihood estimates of the anticipated regret model parameters for each auction format. For the EP-U treatment, the estimates of δ_l and δ_w are both negative, as Shachat and Tan (2015) also found, indicating that regret generates utility rather than disutility. This is largely driven, at less with respect to loss regret, by auctioneers select ex-post reserve prices that are increasing in realized auction prices rather than decreasing. Thus, we confirm that the anticipated regret model is an inappropriate behavioral model for the ex-post format.

Table 6: The estimates of anticipated regret model

Variable	EP-U treatment	EA-U treatment
Lossing regret (δ_l)	-0.59***	2.25***
	(0.01)	(0.56)
Winning regret (δ_w)	-0.46***	2.70***
	(0.01)	(0.70)
$\ln \sigma$	13.23***	15.46***
	(0.14)	(0.16)
$\ln(L)$	-19043.1	-23946.3

*** Coefficient is significant at the 1% level.

However, the anticipated regret performs well for the EA-U treatment. In EA-U treatment, the estimates of δ_l and δ_w are 2.25 and 2.7 respectively. This suggests that the anticipated regret model has some degree of robustness for explaining ex-ante reserve price setting. Our estimates are similar to those of Davis et al. (2011) in a quite different environment. For example, in our experiment the auctioneers' values vary across while in Davis et al.'s study the auctioneers' values are constant. Overall, the first half of Hypothesis 3 is confirmed but the second half has to be reject, which comes to Result 4.

Result 4. *Anticipated regret model predicts the right direction for EA-U treatment in which auctioneers' ex-ante reserve prices are decreased by the number of bidders. But it predicts an opposite direction for EP-U treatment in which auctioneers' ex-post reserve prices positively correlate to* *auction prices.*

One of our objectives is to identify a single parsimonious behavioural model that can explain how auctioneers set both ex-post and ex-ante reserve prices. We have found more evidence in favor of the SCP model versus the alternatives of risk neutrality and anticipated regret. However, for the SCP model we do find distinct estimates for λ and μ for each format, and that we can't reject that for the EA-U data these parameters depend upon n. Further, in the EA-U treatment, The base models of anticipated regret and SCP yield similar maximized likelihood values, -23946 and -23899 respectively, suggesting both are comparable explanations for behavior in the EA-U treatment. At this point, we can't rule out the possibility that the best explanation is that subjects use the SCP model to set ex-post reserve prices and anticipated regret to set ex-ante reserve prices. Accordingly, we conduct a robustness experiment to provide additional evidence of the single SCP model versus a dual model alternative.

5 Experiment 2: left-skewed cost distribution

5.1 Predictions for a left-skewed cost distribution

We conduct a second experiment to evaluate the hypothesis auctioneers use the SCP model to set both ex-post and ex-ante reserve prices, versus the alternative hypothesis auctioneers use distinct models to set these reserve prices. The alternative more specifically stated: auctioneers set ex-post reserve prices using the SCP model but set ex-ante reserve prices using the anticipated regret model. Further, we use this new data to assess the robustness of structural SCP parameter estimates. This experiment uses identical procedures and sampling as the first, except it substitutes the Uniform distribution of cost for a left-skewed one. Bidders' costs are drawn from the cumulative distribution $F(c) = (c/100)^4$. We call the two treatments in this experiment EA-S and EP-S.

We start by generating, for 64 auctioneers each, a 90-element sequence of values and costs as we did in the first experiment, but this time drawing costs from its new distribution. Second, we predict the auctioneers' ex-ante reserve prices, by using the parameter values of $\delta_w = 2.7$ and $\delta_l = 2.26$, as well as the parameters of $\mu = 1.57$ and $\lambda = 1.42$, the structural parameter estimates reported in Tables 5 and 6. We also predict ex-post reserve prices using the SCP model for $\mu = 1.45$ and $\lambda = 1.25$, again the estimates we reported in Table 5.

Our empirical strategy is two-fold. We first use these simulated reserve prices to generate predictions of the auctioneers' average auction payoffs, and then compare these predictions to the realized earnings. Second, we re-estimate the SCP parameters using the new data and evaluate if they differ from our original ones.

Table 7: Simulated auctioneers' average payoffs for $F(c) = (c/100)^4$

	$n = 1$	$n = 2$	$n = 3$
Panel A: Predictions			
EP-SCP	$14.09^{\dagger\dagger\dagger}$	$20.82^{\dagger\dagger}$	25.49
	(2.19)	(3.08)	(3.50)
EA-Regret	$10.20^{\dagger\dagger\dagger}$	$12.01^{\dagger\dagger\dagger}$	$15.28^{\dagger\dagger\dagger}$
	(2.69)	(2.62)	(3.32)
EA-SCP	13.89	20.61	25.59
	(2.30)	(3.14)	(3.46)
Risk neutral	14.54	21.08	25.74
benchmark (RN-S)	(2.35)	(3.11)	(3.43)
Panel B: Experimental results			
EP-S	13.45	19.17	24.21
	(2.43)	(3.01)	(3.91)
EA-S	12.85	19.21	24.20
	(2.52)	(3.73)	(3.73)
Results of t-tests (p-value) for treatment effects			
H_0: EA-S=EP-S	<0.01	0.88	0.97
H_0: EA-S=RN-S	<0.01	<0.01	<0.01
Difference between observed and predicted auctioneer payoffs			
EA-S - EA-Regret	2.65^{***}	7.20^{***}	8.93^{***}
EA-S - EA-SCP	-1.04^{***}	-1.40^{***}	-1.40^{***}
EP-S - EP-SCP	-0.64^{***}	-1.65^{***}	-1.28^{***}

††† Prediction is significantly different from EA-SCP at the 1% level, †† 5% and † 10%
*** Difference is significantly different from zero at the 1% level.

Panel A of Table 7 reports the predicted average auctioneers' payoffs under alternative models and formats. Further, it also demonstrates that the experiment should generate significant treatment effects under differing behavioural hypotheses. The anticipated regret model predicts statistical significantly lower auctioneers' payoffs in the ex-ante format, for each level of n, relative to the SCP model. The SCP model predicts similar auctioneer payoff levels in both auction formats, although the predicted payoffs significantly differ for $n = 1$ and 2.

These predictions underlie a test of the hypothesis of the SCP model for both formats versus the alternative of the anticipated regret and SCP models respectively for the ex-ante and ex-post formats. If we observe auctioneers earn less in the EA-S treatment relative to the EP-S treatment, this favors the alternative of format conditional models. However, if we observe similar auctioneer earnings in the two treatments this favors the conjecture of the auctioneers following the SCP model in both formats. Hypothesis 4 summarizes this.

Hypothesis 4. *In the left-skewed cost environment, the format-specific models hypothesis predicts that auctioneers in the EA-S treatment earn less than in the EP-S treatment. The SCP model hypothesis predicts auctioneers' profits do not differ economically between the EA-S and EP-S treatments.*

5.2 Experimental results in the left-skewed distribution treatments

Panel B of Table 7 summarizes auctioneers' average earnings in the new experiment. Auctioneers' average earnings in the EP-S treatment are sightly higher than in the EA-S treatment when $n = 1$ (p-value < 0.01) but virtually identical for $n = 2$ or 3. However, for both treatments the auctioneers' average earnings are demonstrably lower than the RN-S predictions (all p-values < 0.01.). We view this as evidence in favour of the SCP model for both formats hypothesis.

Result 5. *The auctioneers' average earnings in the EA-S and EP-S treatments do not differ economically. These differences are not statistically significant when $n > 1$. The SCP model's predictions perform better than those of the anticipated regret model.*

While the qualitative nature of the SCP hypothesis holds, we see in the last two rows of Panel B in Table 7 the SCP model's predicted earnings exceed the actual ones. This raises questions regarding the external validity of the SCP parameter estimates we obtained under the Uniform cost distribution.

We re-estimate the parameter values of μ and λ for the left-skewed cost treatments and report them in Table 8. First, we note the estimated parameters of (μ, λ) for the EP-U treatment move from (1.45, 1.25) to (1.31, 1.15) in the EP-S treatment; and, the estimated parameters for the EA-U treatment move from (1.57, 1.42) to (1.41, 1.65) in the EA-S treatment. Likelihood ratio tests reject that these parameters values within format are the same. Second, we reject that the parameters values of (μ, λ) are the same for the EP-S and EA-S treatments. This is evidenced by the Likelihood ratio test reported for model (14) - the last column of Table 8. Finally we reject, via a Likelihood ratio test, that our estimates of (μ, λ) are invariant to the number of bidders in the EP-S treatment; but we only weakly reject parameter invariance with respect to the number of bidders in the EA-S treatment. While our estimates of (μ, λ) qualitatively still reflect the S-shaped character of the conditional probability transformation function, the lack of consistency of the shape parameter estimates across alternative cost distributions falls short of our aspirations.

Table 8: The estimates of the SCP model - left-skewed cost distribution

Variable	EP-S treatment		EA-S treatment		Pooled[c]
	Model(10)[a]	Model(11)	Model(12)[b]	Model(13)	Model(14)
μ	1.31***	1.22***	1.41***	1.55***	1.20***
	(<0.01)	(0.03)	(<0.01)	(<0.01)	(<0.01)
λ	1.15***	1.21***	1.65***	1.84***	1.35***
	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)
$\mu \times \mathbb{1}_{\{n=2\}}$	-	0.08**	-	-0.26***	-
		(0.03)		(<0.01)	
$\mu \times \mathbb{1}_{\{n=3\}}$	-	0.54***	-	0.28***	-
		(<0.01)		(<0.01)	
$\lambda \times \mathbb{1}_{\{n=2\}}$	-	-0.05***	-	-0.26***	-
		(<0.01)		(<0.01)	
$\lambda \times \mathbb{1}_{\{n=3\}}$	-	-0.16***	-	0.14***	-
		(<0.01)		(<0.01)	
Log(scale)	8.58***	8.55***	8.27***	8.34***	8.64***
	(0.10)	(0.09)	(0.08)	(0.08)	(0.06)
Log(L)	-16742.75	-16721.53	-20345.07	-20341.22	-37437.53
LR test(p-value)	-	<0.01	-	=0.10	<0.01

[a] *Log*(L) of pooled model (EP-U & EP-S) is -36173.55 and estimated (μ, λ) is (1.35, 1.15).
[b] *Log*(L) of pooled model (EA-U & EA-S) is -45347.69 and estimated (μ, λ) is (1.61, 1.51).
[c] EP-S and EA-S treatments.
[*] Coefficient is significant at the 10% level, [**] 5% level and [***] 1% level.

6 Conclusion

We provide direct experimental comparison between the ex-ante and ex-post reserve price formats of the English auction. The first experiment addresses two counter-intuitive prescriptions: first, the optimal ex-ante reserve price is invariant to the number of bidders; second, the optimal ex-post reserve price is independent of auction prices. The experimental results show that ex-ante reserve prices decrease with the number of bidders and ex-post reserve prices increase with auction prices. The anticipated regret (Davis et al., 2011) effectively explains the first finding but provides an inaccurate prediction of the second. Although the SCP model successfully explains the two findings, it does not dominate the anticipated regret explanation for ex-ante reserve prices. Hence, it is not clear whether auctioneers use format-specific models or the unified SCP model across auction formats.

The second experiment is designed to assess these two explanations, by redrawing costs from a left-skewed distribution. The experimental result shows the unified SCP model has a better performance of predicting auctioneers' behavior in this experiment. In addition, although the specific values of (μ, λ) pair are varied over treatments, the S-shaped transformed function always hold according to the SCP structural model estimation.

In practice, correcting this subjective judgement bias is a challenging but potentially highly desired task. Providing a decision support tool is a natural intervention, One would reasonably believe confronting decision makers with the objective probabilities and consequences over outcomes from potential decision would stem the value loss. However, there is evidence that this type of subjective judgement is difficult to correct with such support tools. Shachat and Tan (2015) reported an experimental treatment in which auctioneers are provided such support tool, and find auctioneers' judgement bias is more severe. The challenge of framing an effective support system to correct this subjective judgement bias remains open.

A Appendix

Proof of Proposition 3

Proof. The first order condition for expected utility maximization of Equation (6) is,

$$-Z(r_a^*) + (v - r_a^*)\widetilde{Z}(r_a^*) = 0.$$

Let $\widetilde{Z}(r_a^*) = Z'(r_a^*) + f_{(2)}(r_a^*)$ and then rewrite the first order condition,

$$r_a^* = v - \frac{Z(r_a^*)}{\widetilde{Z}(r_a^*)}.$$

To guarantee r_a^* is interior maximum, the second order condition needs to satisfy

$$-Z'(r_a^*) - \widetilde{Z}(r_a^*) + (v - r_a^*)\widetilde{Z}'(r_a^*) < 0.$$

Furthermore, substituting r_a^* for $v - \frac{Z(r_a^*)}{\widetilde{Z}(r_a^*)}$, the second order condition comes to

$$-\frac{Z'(r_a^*)\widetilde{Z}(r_a^*) - Z(r_a^*)\widetilde{Z}'(r_a^*) + \widetilde{Z}(r_a^*)^2}{\widetilde{Z}(r_a^*)} < 0.$$

Since $\widetilde{Z}(r_a^*) > 0$, the negative of the nominator has to be $Z'(r_a^*)\widetilde{Z}(r_a^*) - Z(r_a^*)\widetilde{Z}'(r_a^*) + \widetilde{Z}(r_a^*)^2 > 0$. □

Proof of Proposition 4

Proof. Differentiate r_a^* with respect to n at the optimal solution to obtain

$$\frac{\partial r_a^*}{\partial n} = \frac{-Z'(r_a^*)\widetilde{Z}(r_a^*) + Z(r_a^*)\widetilde{Z}'(r_a^*)}{\widetilde{Z}(r_a^*)^2}\frac{\partial r_a^*}{\partial n} + \frac{-\frac{\partial Z(r_a^*)}{\partial n}\widetilde{Z}(r_a^*) + Z(r_a^*)\frac{\partial \widetilde{Z}(r_a^*)}{\partial n}}{\widetilde{Z}(r_a^*)^2} = 0. \tag{9}$$

Rearranging terms,

$$\frac{\partial r_a^*}{\partial n} = \frac{Z(r_a^*)\frac{\partial \widetilde{Z}(r_a^*)}{\partial n} - \widetilde{Z}(r_a^*)\frac{\partial Z(r_a^*)}{\partial n}}{Z'(r_a^*)\widetilde{Z}(r_a^*) - Z(r_a^*)\widetilde{Z}'(r_a^*) + \widetilde{Z}(r_a^*)^2}. \tag{10}$$

The second order condition implies $Z'(r_a^*)\widetilde{Z}(r_a^*) - Z(r_a^*)\widetilde{Z}'(r_a^*) + \widetilde{Z}(r_a^*)^2 > 0$. Thus the sign of Equation (10) is determinate by the nominator. When the nominator is strictly negative, the partial derivative is strictly less than 0. □

Proof of Proposition 5

Proof. Since $D(r_p|c_2) = \frac{F(r_p)}{F(c_2)}$, if $v - c_2 > 0$, the first order condition for maximizing the second argument of $E[\pi_p(r_p; v, c_2)]$ is,

$$l(c_2)\frac{f(r_p^*)}{F(c_2)} + (-1 - w'(r_p^*))\frac{F(r_p^*)}{F(c_2)} + (v - r_p^* - w(r_p^*))\frac{f(r_p^*)}{F(c_2)} = 0.$$

Substituting $l(c_2) = \delta_l(v - c_2)$ and $w(r_p^*) = \delta_w(r_p^* - k(r_p^*))$ into the first order condition and dividing it by $\frac{F(c_2)}{f(r_p^*)}$ on both sides,

$$\delta_l(v - c_2) + \big(-1 - \delta_w + \delta_w k'(r_p^*)\big)\frac{F(r_p^*)}{f(r_p^*)} + \big(v - (1 + \delta_w)r_p^* + \delta_w k(r_p^*)\big) = 0.$$

Rearranging terms,

$$V(r_p^*) + \delta_l(v - c_2) + \delta_w M(r_a^*) = (1 + \delta_w)r_p^*,$$

where $V(r_p^*) = v - \frac{F(r_p^*)}{f(r_p^*)}$ and $M(r_p^*) = k(r_p^*) - \frac{F(r_p^*)}{f(r_p^*)}(1 - k'(r_p^*))$. Dividing by $1 + \delta_w$,

$$r_p^* = \frac{1}{1 + \delta_w}\bigg(V(r_p^*) + \delta_l(v - c_2) + \delta_w M(r_p^*)\bigg).$$

If $v - c_2 < 0$, since the lose regret has $l(x) = 0$, the second term $\delta_l(v - c_2)$ has to be 0. Generally,

$$r_p^* = \frac{1}{1 + \delta_w}\bigg(V(r_p^*) + \delta_l \max\{0, v - c_2\} + \delta_w M(r_p^*)\bigg).$$

□

Proof of Proposition 6

Proof. To obtain the relationship between r_p^* and c_2, we differentiate Equation (8) with respect to c_2,

$$\frac{\partial r_p^*}{\partial c_2} = \frac{1}{1+\delta_w}\left(V'(r_p^*)\frac{\partial r_p^*}{\partial c_2} - \delta_l + \delta_w M'(r_p^*)\frac{\partial r_p^*}{\partial c_2}\right).$$

Rearranging terms,

$$\frac{\partial r_p^*}{\partial c_2} = \frac{-\delta_l}{1+\delta_w - V'(r_p^*) - M'(r_p^*)}.$$

Since the denominator is the negative of the second order condition, $1+\delta_w - V'(r_p^*) - M'(r_p^*) > 0$. As $\delta_l > 0$, $\frac{\partial r_p^*}{\partial c_2} < 0$. □

Proof of Proposition 7

Proof. The first order condition for maximizing $E[\pi_a(r_a; v)]$ is

$$-l'(r_a^*)(1-F(r_a^*)) + l(r_a^*)nf(r_a^*) + (-1-w'(r_a^*))nF(r_a^*) + (v - r_a^* - w(r_a^*))nf(r_a^*) = 0.$$

Substituting $l(r_a^*) = \delta_l(v-r)$ and $w(r_a^*) = \delta_w(r_a^* - k(r_a^*))$ into the first order condition,

$$\begin{aligned}&\delta_l - \delta_l F(r_a^*) - nF(r_a^*) - \delta_w(1-k'(r_a^*))nF(r_a^*)\\ &\quad + vnF(r_a^*) - r_a^* nf(r_a^*) - \delta_w(r_a^* - k(r_a^*))nf(r_a^*) + \delta_l(v - r_a^*)nf(r_a^*) = 0.\end{aligned}$$

Dividing by $nf(r_a^*)$,

$$v - \frac{F(r_a^*)}{f(r_a^*)} + \delta_l\left(\frac{1-F(r_a^*)}{f(r_a^*)}\frac{1}{n} + v\right) + \delta_w\left(k(r_a^*) - \frac{F(r_a^*)}{f(r_a^*)}(1-k'(r_a^*))\right) = (1+\delta_w+\delta_l)r_a^*.$$

Dividing by $1+\delta_w+\delta_l$ on both sides,

$$r_a^* = \frac{1}{1+\delta_l+\delta_w}\left(V(r_a^*) + \delta_l L(r_a^*, n) + \delta_w M(r_a^*)\ \right),$$

where $\delta_l \geq 0$, $\delta_w \geq 0$, $V(r_a^*) = v - \frac{F(r_a^*)}{f(r_a^*)}$, $L(r_a^*, n) = v + \frac{1-F(r_a^*)}{f(r_a^*)}\frac{1}{n}$ and $M(r_a^*) = k(r_a^*) - \frac{F(r_a^*)}{f(r_a^*)}(1 - k'(r_a^*))$. □

Proof of Proposition 8

Proof. Differentiate r_a^* with respect to n yields,

$$\frac{\partial r_a^*}{\partial n} = \frac{1}{1+\delta_l+\delta_w}\left(V'(r_a^*) + \delta_l\frac{\partial L(r_a^*, n)}{\partial r_a^*} + \delta_w M'(r_a^*)\right)\frac{\partial r_a^*}{\partial n} + \frac{\delta_l}{1+\delta_l+\delta_w}\frac{\partial L(r_a^*, n)}{\partial n}.$$

Rearranging terms,

$$\frac{\partial r_a^*}{\partial n} = \frac{\delta_l \frac{\partial L(r_a^*, n)}{\partial n}}{(1+\delta_l+\delta_w) - \left(V'(r_a^*) + \delta_l\frac{\partial L(r_a^*, n)}{\partial r_a^*} + \delta_w M'(r_a^*)\right)}$$

The denominator is the negative of second order condition. Therefore the denominator is strictly positive. Consider the terms in the nominator. $\frac{\partial L(r_a^*, n)}{\partial n} = -\frac{1-F(r_a^*)}{f(r_a^*)}\frac{1}{n^2} > 0$, where $1 - F(r_a^*) > 0$.

The strict inequality is implied by r_a^* being an interior solution. Hence, the partial derivative of $\frac{\partial r_a^*}{\partial n} < 0$. □

B Instruction translation

B.1 EP-U treatment - N varying from 1 to 3

Preliminary Remark

You are participating in an experiment studying individual decision-making in auctions. Contingent on your decisions in this experiment, you can earn money in excess of your participation fee of 5 RMB. Therefore, it is very important that you read the instructions very carefully.

In the experiment, we request you to switch off your hand phones and other devices; except for the experimental software application do not open other applications on the computer. Please read instruction quietly if there is a lull. Please do not talk with the other subjects in the entire experiment, or look at other computer monitors. If at some point you have a question, please raise your hand and we will address it as soon as possible. If you do not observe these rules, we will have to exclude you from this experiment and all associated payments, and ask you to leave.

Today the experiment will consist of 90 rounds and you will receive earnings from each round. In the experiment, all monetary amounts are donated in experimental currency denoted as \$. Any earnings will be converted to RMB at the exchange rate \$60 = 1 Yuan RMB. All payments will be made privately at the conclusion of the experiment.

You will participate in a procurement auction in each round. In an auction, the buyer may purchase a single unit of a fictitious good from one of the N sellers, the auction winner. Your are the buyer and the computer plays the role of sellers.

How are your earnings calculated?

As a buyer, each round you will have a unit value of the good. These values generated by the computer varies over rounds. We will provide more details later about generating a value. If you purchase a unit, your earnings are

Buyers profit = unit value – purchase price

You are not obligated to purchase a unit, and if you do not make a purchase your earnings for that round are zero. For example, if a buyers unit value is \$131.00 he purchases a unit at the price of \$75.00, then his profit in a round is \$56.00 (\$131.00 - \$75.00). Your earnings in each round will be recorded and be summed up to pay you at the end of the experiment. Notice that, a buyers profit can be negative in a round. Please make a decision seriously.

How do you buy a unit of fictitious good?

You can purchase a unit of fictitious good through procurement auction in each round. As previously stated, todays experiment consists of 90 rounds. Each round is an independent procurement auction. As a buyer, you will engage in the procurement auction to buy a good. In the rounds of 1 - 30, you will be matched with 1 computer seller in each round; in the rounds of 31 60, you will be matched with 2 computer sellers; In the rounds of 61 - 90, you will be with 3 computer sellers.

- ▶ The Auction Stage which computer sellers take part in:

  When an auction begins, the price starting at \$100 will be dynamically reduced at a constant speed. At any point a seller can drop out the auction, but once a seller exits he cannot re-enter the auction. The current price when a seller drops out becomes his drop-out price. The auction is over once all N seller exit. The last seller to exit is the auction winner. The auction price is the price when the $N-1$th seller exit the auction. Notice that, when N=1, there is no $N-1$th seller and therefore the auction price will be the initial price of \$100. In this experiment, a computer seller will exit the auction when the price reaches his own cost.

- ▶ The Decision Stage which you take part in:

  After the auction outcome is presented, you have two options: accept the price or make a counter offer.

  - ✓ If you accept the auction price, you will purchase a unit of the fictitious good at the auction price, and this round will end.
  - ✓ If you make a counter offer (to less than the auction price, with a minimum unit of 0.01). There are two possible results:

    If your counter offer is lower than the auction winners drop-out price, this round ends up without a transaction and your profit in this round is zero.

    If your counter offer is higher than or equal to the winners drop-out price, this round ends up with a transaction. You can purchase a unit of the fictitious good at the price of counter offer.

Note that the auction winners drop-out price is invisible to you.

How are costs and unit values determined?

At the beginning of a period, each sellers cost is randomly selected to be between \$0.00 and \$100.00. Every cost level within this range is equally likely. Similarly, your unit value is randomly selected to be between \$50.00 and \$150.00. Every value level within this range is equally likely. Note that all sellers costs and other buyers unit values have no influence on your unit value. This random determination of costs and unit values is done every period, and the realization of these values is not influenced by past realizations nor they will influence future realizations.

A simple example

Lets consider an example. Suppose computer Seller 1's unit cost is \$25.00 and that computer Seller 2's unit cost is \$67.00. In the auction, computer Seller 2 first drops out the auction at \$67.00 and computer Seller 1 drops out at \$25.00 (invisible to you). Auction ends and Computer Seller 1 becomes to the auction winner. The auction price is equal to computer Seller 2's drop-out price of \$67.00. The buyer, whose value is \$108.00, has two choices: accept the price \$67.00 or send a counter offer lower than \$67.00.

If the buyer accept the auction price of \$67, this round is over and the buyer would receive a profit of \$41.00 (buyer's value - auction price, or \$108.00 - \$67.00).

If the buyer chooses to send a counter offer of \$29.00 to the auction winner (computer Seller 1), which is higher than the winner's drop-out price, the buyer receives a profit of \$79.00 (buyer's value - offer price, or \$108.00 - \$29);

Or, if the buyer sends a counter offer of \$20.00 to the auction winner, which is lower than his drop-out price. The buyer cannot purchase and earn \$0 in this round.

How to use the computer program

After all participants have read the instructions and successfully completed the attached quiz, the experimenter will start the computerized auctions. There will be two phases in each round: an Auction and a bargaining phase.

Figure 3 gives an example of what your computer screen looks like in the Auction phase. The left hand side window shows the price of computer seller exiting chronologically: price and W.

- Shows W, he is the auction winner, and his drop-out price is not visible;
- Show price $XX.XX, he is not the winner, and his drop-out price is XX.XX.

In this screen, you will be informed of your unit value and auction price in this round. You can choose “accept auction price” or “bargain”. To accept the auction price you can simply click the “Accept” button and you will purchase the fictitious good at the auction price.

Figure 3: A screen-shot for the Auction Phase

If you choose Bargain, the next page will display (as shown in Figure 4). You enter your counter offer into the “Your Offer” box and then click button “OK”.

In the review page, you will be informed of the results, including whether you purchased or not, accept the auction price or send a counter offer, the purchase price, and your profit.

Figure 4: A screen-shot for the Bargaining Phase

B.2 EA-U treatment - N varying from 1 to 3

Preliminary Remark

(*The same as in EP-U treatment*)

How are your earnings calculated?

(*The same as in EP-U treatment*)

How do you buy a unit of fictitious good?

(*The same as in EP-U treatment*)

- ▶ The Auction Stage which computer sellers take part in:

  (*The same as in EP-U treatment*)

- ▶ The Decision Stage which you take part in:

  Before the auction begins, you will know the value of the good in current round. You need to decide a reserve price for the auction. The reserve price is the highest price which you would like to pay for the fictitious good in this round. The reserve price is over the range of from 0 to 100 with a minimum unit of 0.01. After the auction stage concludes, the auction price becomes the purchase price if it is lower than your reserve price; or your reserve price becomes the purchase price if your reserve price lower than the auction price and higher than the auction winners drop-out price; or you cannot purchase if your reserve price less than all drop-out prices.

Note that the auction winners drop-out price is invisible to you.

How are costs and unit values determined?

(*The same as in EP-U treatment*)

A simple example

Let's consider an example. Suppose 2 computer sellers participate in an auction, your unit value for a fictitious good is $90 and you set up a reserve price of $X. Computer Seller 1 has a unit cost of $88 and Computer Seller 2 has a unit cost of $66. The following process (your invisible information) will run in the system:

- In the auction, Computer Seller 1 first drops out the auction when the current price is $88;
- Computer Seller 2 drops out the auction when the current price is $66;
- Computer Seller 2 becomes the auction winner, and the auction price is $88.

Based on your reserve price of $X decided before auction, the following circumstances will occur (take three examples) (your visible information):

- ✓ If your reserve price is $X=89, it is higher than the auction price. You will observe that the penultimate seller exiting the auction at the price of $88 and the winner being indicated as W. You will purchase the fictitious good at the auction price of $88 and will yield a profit of $2 in this round (unit value - auction price, or $90 - $88);

✓ If your reserve price is $X=77, it is lower than the auction price but not less than the winners drop-out price. You will learn that one sellers drop-out price is higher than your reserve price, by observing of D (More details provided later). You will also learn that the winners drop-out price is not higher than your reserve price, by observing of W. You will purchase the fictitious good at the price of $77 and will yield a profit of $13 (unit value - reserve price, or $90 - $77).

✓ If your reserve is $X=55, it is less than all drop-out prices of computer sellers. You will know it by observing two D. You will not purchase in this round and your profit will be $0.

How to use the computer program

After all participants have read the instructions and successfully completed the attached quiz, the experimenter will start the computerized auctions. There will be two phases in each round: a phase to setting reserve price and a phase to reviewing auction outcome.

Figure 5 gives a screen-shot of setting up a reserve price before auction. You are informed of your unit value and the number of bidders. You have to decide a reserve price (from 0.00 to 100.00) and type it into the box and then press "confirm".

Figure 5: A screen-shot for the phase to setting reserve price

Figure 6 gives an example of what your computer screen looks like in auction phase. The duration of an auction is 5 seconds. After that, the left hand side window shows the price of computer seller exiting chronologically: D, W or price.

- Shows D, the drop-out price of this computer seller higher than the reserve price;
- Show price $XX.XX, the drop-out price of this computer seller lower than the reserve price but he is not the auction winner. The drop-out price (bid) is XX.XX.

- Shows W, this computer sellers drop-out price less than the reserve price and he is the auction winner. If all cards display D, it means your reserve price less than all drop-out prices. There is no auction winner in the auction and you cannot purchase in that round.

  The right hand side window shows the result of a round, including reserve price, whether purchase or not, purchase price and profit.

Figure 6: A screen-shot for the phase to reviewing auction outcome

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