Fine-Tuning Willingness-To-Pay Estimates in Second Price Auctions

Bachir Kassas[1], Marco A. Palma[2], and David P. Anderson[3],

[1]Research Assistant, Department of Agricultural Economics, TAMU.

[2]Corresponding author. Associate Professor, Department of Agricultural Economics. Texas A&M University. 2124 TAMU, College Station, Texas, 77843. (979) 845-5284. E-mail: mapalma@tamu.edu

[3]Professor and Extension Economist, Department of Agricultural Economics, TAMU.

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Abstract

It is well documented that people overbid in second price auctions (SPAs). Yet, this fact is conveniently ignored when eliciting willingness-to-pay (WTP) for market goods. We propose a simple design that not only tests the external validity of SPA bids, but also suggests a more accurate method of eliciting WTP in SPAs. Following the SPA, participants were offered a randomly chosen price, from the range of retail prices in actual markets, at which they can purchase any amount of the good in an onsite secondary market. The design links overbidding and underbidding behavior to violations of the weak axiom of revealed preferences (WARP). We find robust evidence that the dominance of overbidding over underbidding in SPAs leads to an upward bias in the WTP estimates. While this can compromise market good valuations by inflating the perceived value of products, our design enables utilization of Kotlarski's identity to recover the distribution of the unobserved true valuations.

JEL Classification: D44, C91

Keywords: overbidding, WARP, WTP, Kotlarski's identity, non-parametric estimation

Auctions stand among the oldest and most popular value elicitation mechanisms, with applications dating back to 500 B.C. (Krishna 2002). Across history, several auction formats including English auctions, Dutch auctions, and sealed-bid auctions, have been developed and used to sell items in various social settings. Holding a high importance in almost every society, auctions have long been a topic of interest to game theorists and experimental economists, who devote considerable efforts to the theoretical analysis and practical applications of auction mechanisms.

Second price auctions (SPAs) are perhaps the simplest auction format to understand theoretically. Participants in this auction have a weakly dominant strategy to submit a bid exactly equal to their true valuation regardless of risk preferences, the number of rival bidders, and the distribution of bidder valuations (Kagel and Levin 1993; Cooper and Fang 2008; Georganas et al. 2009). However, despite theoretical assertions of incentive compatibility, and experimental measures taken to ensure truthful reporting, previous investigations of SPAs have documented a recurring phenomenon of overbidding (Kagel, Harstad, and Levin 1987; Kagel and Levin 1993; Rutstrom 1998; Cooper and Fang 2008; Delgado et al. 2008). Yet, this fact is conveniently ignored when eliciting willingness-to-pay (WTP) for market goods. To this end, this study investigates the effect of overbidding on WTP estimates in SPAs and describes a procedure for recovering the distribution of the true underlying valuations based on two different measurements.

Researchers have spent significant efforts trying to understand overbidding in SPAs and have proposed several explanations for this behavior. For instance, it is argued that individuals overbid in SPAs due to an asymmetry in the potential benefits versus costs of overbidding (Kagel, Harstad, and Levin 1987). That is, since the winning bidder pays the second highest bid, there is a higher probability that he will actually get rewarded, rather than punished, for bidding slightly above his valuation. This means that overbidders seldom encounter the situation where they have to pay an amount higher than their valuation for the item and so are encouraged to overbid. Conversely, some researchers have credited overbidding in SPAs to a lack of understanding of the intricacies of the mechanism or the optimal strategy to follow (Kegel, Levin, and Harstad 1995; Georganas et al. 2009; Cooper and Fang 2008). According to Georganas et al. (2009) for example, discovering the dominant strategy in a SPA is cognitively demanding and can easily be missed by the untrained bidder.

The leading alternative explanations of overbidding in SPAs are *"the joy of winning"* and *"the spite"* hypotheses. While the joy of winning attributes overbidding to an added level of satisfaction that is derived from winning the competition (Cox, Smith, and Walker 1992; Cooper and Fang 2008; Delgado et al. 2008), the spite hypothesis perceives overbidding as a deliberate attempt by the overbidder to spitefully lower the surplus of rival bidders in the auction (Cooper and Fang 2008; Nishimura et al. 2011; Bartling and Netzer 2016; Morgan, Steiglitz, and Reis 2003; Andreoni, Yeon-Koo, and Jinwoo 2007). This spiteful mentality, however, is often countered with the reaction to punish spiteful bidders. Nishimura et al. (2011) found that bidders with higher valuations tend to underbid in an attempt to reciprocate the spiteful overbidding and increase the chance of punishing overbidders by having them pay more than their valuation for the item. Although the joy of winning and spite hypotheses present completely different perspectives on overbidding in SPAs, Cooper and Fang (2008) found that they can jointly contribute to this apparent behavior. Specifically, they reported that individuals slightly overbid when they perceive their rivals to have similar valuations (supporting the joy of winning), but overbid more aggressively if they believe their rivals hold much higher valuations (supporting the spite hypothesis).

This study proposes a simple experimental design that not only tests the external validity of SPA bids, but also suggests an alternative, more accurate method of eliciting WTP in SPAs. Specifically, following the SPA, an onsite secondary market was conducted, where each participant was assigned a unique price, randomly selected from the range of local market prices, at which he could purchase any amount of the auctioned good. The participants were split into *time-consistent* and *time-inconsistent* types based on a comparison between their decisions in the secondary market and their bids in the SPA. Moreover, the secondary market was used to update the bids in the SPA and create another measurement of the unobserved true valuations, which in turn was used to non-parametrically recover the underlying distribution of the individuals' true WTP.

The design enabled us to link overbidding behavior with violations of the weak axiom of revealed preferences (WARP). We found that a sizeable portion of the participants refused to purchase the product at a price lower than their bid in the SPA. On the other hand, we also report instances where participants chose to purchase the product at a higher price than what they bid for it. Those findings conform to previous results surrounding the existence of overbidders and underbidders in SPAs, with overbidding as the dominant behavior (Kegel and Levin 1993; Georganas et al. 2009; Garratt, Walker, and Wooders 2012). The adjusted WTP estimate calculated using the subsample of *time-consistent* bidders was significantly lower than the one obtained using the overall sample of participants. The robustness of this result was demonstrated using several Tobit regression specifications, which captured the effect of the presence of *time-inconsistent* bidders on WTP estimates. Furthermore, the recovered distribution of the true underlying valuations differed significantly from the bids reported in the SPA. Thus, conveniently ignoring overbidding in SPAs, as is usually the case when eliciting WTP for market products, can bias WTP estimates and result in misleading policy recommendations by inflating the perceived market value of products.

The rest of the article is organized as follows: Section 2 describes the experimental design and procedures. Section 3 includes a discussion of the methodology and analysis of the results, while section 4 briefly summarizes the main findings and concludes the article.

Experimental Design

The experiment was conducted over 9 sessions, where each session included 21-25 participants for a total of 201 subjects[1]. Internet and local newspaper ads were used to recruit grocery shoppers in the area (nonstudents). The subjects in each session participated in two rounds of a second price sealed bid Vickrey (1961) auction, where they submitted bids for eight different goods. Following the auction rounds, subjects filled out a short demographics survey, after which they participated in an onsite secondary market where they were given the opportunity to purchase a randomly selected good from the auction. Finally, they received their payments and were escorted out of the session. Each subject was paid a $35 compensation for his participation minus the amount of any purchases made during the auction or the secondary market. Table 1 shows the demographic and socioeconomic summary statistics of the participants.

The goods used in the auction were vegetable products: 1) Conventional Green Lettuce; 2) Conventional Red Lettuce; 3) Organic Green Lettuce; 4) Organic Red Lettuce; 5) Hydroponic Green Lettuce; 6) Hydroponic Red Lettuce; 7) Hydroponic Mixed Lettuce; and 8) Spinach.

In the SPA, participants were presented with the eight vegetable products, which were placed on a table in the center of the room where the session took place. Participants were given the liberty of inspecting the different products in any order they wished before they wrote their bid for each product on a piece of paper and waited for the session monitor to collect it. The two rounds of bidding consisted of a baseline round followed by a treatment round, which varied across subjects. Half of the participants received a blind tasting treatment, while the other half received an information treatment[2]. In order to induce incentives, the participants were explained that one product will be randomly chosen as binding from one of the rounds. The participant with the highest bid for this binding product will have to purchase it and pay the second highest bid. The payment amount was deducted from the participant's compensation fee and he was given the lettuce product to take home.

After finishing the two auction rounds, subjects participated in an onsite secondary market, which was used as the time consistency test to check the external validity of their reported bids. In order to maintain a simple design, only one of the eight products was chosen at random and was available for purchase in the secondary market. Subjects were not aware that they will participate in the secondary market until after all bids were submitted in the SPA. Each participant was offered a unique random price, which lied within the range of retail prices for that product, and could purchase any quantity of the product at his assigned price. The randomly chosen product was the hydroponic red lettuce*,* which ranged in retail price from $0.5 to $3.5. The subjects only knew their uniquely assigned price and were not given any information on the assigned prices for other participants. Since they reported two different rounds of bids, the last bid was compared with the price offered in the secondary market, since it represents the individual's current valuation for the product right before participating in the secondary market.

Obviously, the individual should make a purchase when offered a price below his bid and should refuse to purchase when the offered price lies above his bid for the product.

The experimental design included several steps to make sure that participants fully understood how the SPA works. First, subjects were given extensive instructions about the auction mechanism. They also completed two hypothetical practice rounds using stationary products. The market prices were posted and discussed after each practice round to make sure that everyone was familiar with the procedure. Moreover, subjects were required to answer a short knowledge quiz that tested their understanding of how the bids are ordered, the winner is selected, and the market price is determined. Upon completing the knowledge quiz, the answers were provided and discussed thoroughly by the session monitor, after which the participants were allowed the opportunity to ask questions. Finally, it was explicitly explained to the subjects that the optimal strategy in this auction format is to bid one's valuation for the product. Also, general examples were presented concerning how an individual would be worse off if he submitted a bid above or below his valuation.

Results and Discussion

This section includes a descriptive analysis of the main results along with a discussion of the procedure for recovering the distribution of the unobserved true valuations.

Descriptive Analysis

The participants were classified as *time-consistent* or *time-inconsistent* based on whether their behavior in the secondary market complied with their reported WTP in the SPA. A *time-consistent* individual would purchase at least one unit of the good when the offered price in the secondary market is lower than his SPA bid and would not purchase otherwise. On the other hand, a *time-inconsistent* individual is either an overbidder (someone who refuses to purchase when the offered price is lower than his bid) or an underbidder (someone who purchases at least one unit when the offered price is above his bid).

As shown in figure 1, the overruling majority of *time-inconsistent* individuals are overbidders. In fact, 55 out of 82 participants who were offered a price below their bids in the SPA refused to purchase the product. On the other hand, only 5 out of 119 subjects who were offered a price above their bids in the SPA purchased at least one unit of the product. This means that underbidders represent only around 2.5% of the subject pool, compared to 27.4% overbidders. This result is consistent with previous findings surrounding the existence of overbidders and underbidders in SPA, with overbidding as the dominant behavior (Kegel and Levin 1993; Georganas et al. 2009; Garratt, Walker, and Wooders 2012). For instance, Kagel and Levin (1993) reported that around 62% of all bids in their SPA exceeded the bidders' value, while only 8% of the bids were below the bidders' value.

It is important to note that *time-inconsistency* in our design can be viewed as a violation of the weak axiom of revealed preferences (WARP). To illustrate, we will consider the case of an overbidder[3]. Bidding $\$x$ for the product implies that the person is willing to exchange $\$x$ in order to get one unit of the product. More importantly, it also means that the person would choose the product over any amount of money $\$P$, where $P < x$. So given set A, which includes $\$P$ and one unit of the product as alternatives, the individual would choose the product (i.e: $c(A) = l$, where $c(A)$ denotes the choice from set A and l represents one unit of the product). However, when the individual refuses to purchase the product in the secondary market at a price $\$P$ below what he bid for it ($P < x$), he is implying that he would rather take $\$P$ than one unit of the product. This implies that given set B, which contains $\$P$ and one unit of the product as alternatives, he would choose $\$P$ (ie: $c(B) = \$P$, where $c(A)$ denotes the choice from set B). This clearly is a violation of WARP.

Next, we address the effect of the presence of *time-inconsistent* bidders on the average WTP estimate calculated from the SPA. Figure 2 shows the average WTP for the good calculated using the bids from the overall sample of participants as well as the *time-consistent* and *time-inconsistent* subsamples. The average WTP for *time-inconsistent* individuals was around \$2.0, which is substantially higher than the \$1.5 average WTP for the overall sample ($P < 0.001$). This result seems reasonable considering the dominance of overbidding among the subsample of *time-inconsistent* bidders. It means that overbidders are reporting bids that are well above average. In fact, using only those individuals who passed the *time-consistency* test resulted in a significant drop in the average WTP to \$1.24 ($P = 0.015$). Since the bids of *time-inconsistent* individuals do not reflect their true valuations for the product as they violate WARP, this result indicates that failing to account for overbidding in SPAs could lead to a significant upward bias in WTP estimates.

In order to ensure robustness of the results, several Tobit regression specifications were estimated to capture the effect of the presence of *time-inconsistent* bidders on WTP. As shown in table 2, the specification in column 1 was estimated using *time-consistency* as the only explanatory variable. This was specified as an indicator variable of whether the bidder was *time-consistent*. Purchases were controlled for in column 2 using an indicator variable of whether the participant made a purchase in the secondary market. The specification in column 3 controlled for the significance of the participation fee by incorporating the ratio of that fee to the hourly wage of the participant (fee-to-income-ratio), while the specification in column 4 included an indicator variable of whether the subject made any fruit or vegetable purchases during the previous two days. Finally, the specification in column 5 controlled for demographic characteristics including age, gender, household size, and whether the participant was a student.

Consistent with our previous findings, the effect of *time-consistency* on WTP is uniform across all specifications, where the coefficient estimate is highly significant and ranges from -0.8 to -0.9. This implies that the WTP reported by *time-inconsistent* bidders was on average \$0.74 to \$0.83 higher than that of *time-consistent* bidders (marginal effects not shown in the table). More importantly, this result stands as evidence that the presence of *time-inconsistent* bidders, who are predominantly overbidders, causes a significant upward shift in the average WTP. Besides *purchase*, none of the other explanatory variables that were controlled for had a significant impact on willingness-to-pay. This result suggests that overbidding is a general behavior and is not correlated with specific individual characteristics. The effect of *purchase* was positive and significant across all specification and ranged from 0.57 to 0.66, which reasonably implies that individuals who made purchases in the secondary market were the ones who carried higher valuations for the product.

Non-parametric estimation of the Distribution of True Valuations

This section details the procedure for recovering the distribution of the true unobserved valuations. This method is based on two measurements of the true valuation, which were constructed using our experimental design. Let $X_i^*, i = 1, \dots, n,$ be independent and identically distributed (i.i.d.) random variables denoting the true individual valuations. Given two imperfect measurements of X_i^* (X_{1i} and X_{2i}), we can invoke Kotlarski's identity to estimate the characteristic function of X_i^* using the joint characteristic function of the two measurements, after which we can recover the density of X_i^* using inverse Fourier transform.

This procedure is commonly applied in nonlinear measurement error models, which are often referred to as nonlinear errors in variables (EIV) models (Schennach 2000; Tong Li 2002; Li and Vuong 1998; An and Hu 2012). For instance, Li and Vuong (1998) applied Kotlarski's identity to estimate the probability density function (pdf) of a scalar unobserved variable using two identically distributed measurements, while Tong Li (2002) generalized this method to estimating the pdfs of vectors of unobserved variables using measurement variables that need not be identically distributed.

The method adopted in this study is similar to the one used by Li and Vuong (1998) and Tong Li (2002), where estimation of the pdf of the X_i^* is based on the following assumptions:

A1. *There exist at least two measurements for the unobserved variable such that* $X_l = X^* + \varepsilon_l$ for $l = 1,2$.

A2. X^*, ε_1, *and* ε_2 *are mutually independent (i.e.,* $X^* \perp \varepsilon_1 \perp \varepsilon_2$*)*

A3. *The characteristic functions of* X^* *and* ε *are non-vanishing everywhere*

The first two assumptions ensure the existence of two proxies for the latent variable with independent error components, while the third assumption is standard in the deconvolution literature.

Given the above assumptions, estimation of the pdf of X^* is achieved by first estimating the joint characteristic function of X_1 and X_2 with the equation

$$\widehat{\Phi}_{X_1,X_2}(s,t) = \frac{1}{n}\sum_{j=1}^{n} e^{isX_{1j}+itX_{2j}} * \hat{f}_{X_1,X_2}(X_{1j}, X_{2j}), \quad (1)$$

where i is the imaginary unit and $\hat{f}_{X_1,X_2}$ is the estimated joint pdf of X_1 and X_2 given by

$$\hat{f}_{X_1,X_2}(X_{1i}, X_{2i}) = \frac{1}{nh_1h_2} \sum_{j=1}^{n} K\left(\frac{X_{1j}-X_{1i}}{h_1}\right) * K\left(\frac{X_{2j}-X_{2i}}{h_2}\right), \tag{2}$$

where K is any kernel function[4]. Next, the characteristic function of the unobserved variable X^* is estimated by

$$\widehat{\Phi}_{X^*}(T) = exp\left(\int_0^T \frac{\partial\widehat{\Phi}_{X_1,X_2}(0,t)/\partial t}{\widehat{\Phi}_{X_1,X_2}(0,t)} dt\right) \tag{3}$$

after which we can recover the pdf of X^* using inverse Fourier transform as follows

$$\hat{f}_{X^*}(x^*) = \frac{1}{2\pi} \int e^{-iTx^*} \widehat{\Phi}_{X^*}(T) dT \tag{4}$$

The SPA bids were used as the first measurement of the unobserved true valuations X^*, which stands for X_1 in the above model. As for the second measurement, hereafter X_2, it was constructed by adjusting the bids in the SPA based on the decisions in the secondary market. Specifically, the SPA bids were replaced with the price offered in the secondary market for the case of *time-inconsistent* individuals and remained unchanged for *time-consistent* individuals[5]. Histograms and summary statistics of those two variables are presented in figure 3 and table 3 respectively. The two measurements seem to be follow a chi squared distribution, however, X_1 is more skewed to the right and has a higher mean, median, and maximum than X_2. This is clearly a result of the significant overbidding in the SPA and its dominance over underbidding in the subsample of *time-inconsistent* individuals.

Figure 4 shows the recovered pdf of X^* based on the above mentioned method. While the estimated density of the unobservable true valuations also resembles a chi squared distribution, it is shifted leftwards compared with the bids reported under the SPA. This stands as clear evidence that the substantial overbidding in the SPA results in a significant upward bias in the WTP estimates, thus compromising the accuracy of the data. Interestingly, the estimated pdf of X^* is closer to the adjusted bid (X_2) than the reported bid (X_1), which implies that even in the absence of sophisticated econometrics methods to recover the distribution of the true valuations, our simple design holds the advantage of allowing for a valuable adjustment in the reported bids which improves the reliability of the WTP estimates and provides producers a more conservative and realistic perspective concerning the market value of their products.

Conclusion

Despite their incentive compatibility and theoretical simplicity, second price auctions (SPAs) are among the auction formats on which past research has reported robust evidence of overbidding. While the presence of underbidders in SPAs has also been documented, they are often overshadowed by the predominance of overbidders. Although several explanations have been proposed to explain the tendency of bidders to deviate from the weakly dominant strategy of bidding their valuations for the auctioned product, little has been done to quantify its effect on willingness-to-pay (WTP) estimates of market goods, let alone present a potential remedy for this apparent anomaly.

Using a simple experimental design, we were able to provide another perspective to understand deviations from the optimal strategy in SPAs, measure the impact of this behavior on WTP estimates, and offer a detailed procedure for enhancing the accuracy of the analysis by recovering the distribution of the unobserved true individual valuations. First, our results conform to previous findings from induced value auctions concerning the dominance of overbidding over underbidding in SPAs. Moreover, using the proposed design draws a clear relationship between deviations from the optimal strategy in SPAs and violations of the weak axiom of revealed preferences (WARP). Our findings demonstrate the prevalence of overbidding in SPAs as it persisted in spite of the fact that the optimal bidding strategy was explicitly explained to the subjects. This implies that a lack of understanding of the auction mechanism, alone, cannot fully account for the overbidding behavior that is consistently reported in the literature.

We find robust evidence that, if not accounted for, the presence of *time-inconsistent* bidders in the SPA, who are predominantly overbidders, significantly decreases the reliability of the results as it inflates the WTP estimates. This could mislead agents into becoming overly optimistic about the market value of their products. Using our simple design provides a viable solution to this problem by allowing for the recovery of the distribution of the unobserved true valuations, which greatly enhances the accuracy of the analysis.

Footnotes

1. The 9 sessions were identical in that each included the second price auction and secondary market. The experiment was divided into 9 sessions due to space limitations and in order to have more control over the subject pool.

2. Although the vegetable products are commonplace, the treatment was designed to familiarize participants with all the products on the table. The effects of the blind tasting and information treatments were not analyzed here, since they are not related to the main focus of the article.

3. Similar logic can be applied to link underbidding behavior to a violation of WARP.

4. A Gaussian kernel function was used in estimating the joint pdf. Moreover, a trimming parameter T_n was applied following An and Hu (2012) in order to construct well defined non-parametric estimates. In this regard, trimming parameters are commonly used in the literature (Carroll et al. 1995; Horowitz and Markatou 1996).

5. Intuitively, a *time-consistent* individual has proven, through his decisions in the secondary market, that his reported bid in the SPA is consistent with his true valuation; however, *time-inconsistent* individuals have shown that their reported bids in the SPA actually deviate from their true WTP and so the price in the secondary market was used to refine their reported bids.

Tables and Figures

Table 1. Demographic and Behavioral Characteristics of Shoppers

Variable	Category	Sample		
		Mean	Std. Dev.	Percent
Age (years)		40.93	19.28	
Household Size (Individual)		2.54	1.50	
Education	High School Diploma or less			6.74
	Bachelor's Degree or at least some college			58.43
	Graduate Courses or more			34.83
Race	Caucasian			72.83
	Hispanic			12.14
	Other			15.03
Gender	Female			57.59
	Male			42.41
Marital Status	Married			43.72
	Not Married			56.28
Annual Household Income ($)		57,462	37,612	
Primary Shopper	Primary Shopper			84.08
	Secondary Shopper			15.92
Fresh Vegetables on Hand (% of full stock)		35.51	25.30	

Table 2. Tobit Regressions of the Effect of Time-Consistency on Willingness to Pay

	[1]	[2]	[3]	[4]	[5]
Variable	Parameter	Parameter	Parameter	Parameter	Parameter
Constant	2.027 ***	1.973 ***	2.094 ***	2.094 ***	1.909 ***
	(0.115)	(0.111)	(0.142)	(0.201)	(0.366)
Time-Consistent	-0.817 ***	-0.889 ***	-0.876 ***	-0.868 ***	-0.801 ***
	(0.137)	(0.133)	(0.136)	(0.135)	(0.147)
Purchase	-	0.656 ***	0.588 ***	0.577 ***	0.568 ***
		(0.167)	(0.174)	(0.174)	(0.181)
Fee-to-Income-Ratio	-	-	-0.054	-0.062	-0.061
			(0.041)	(0.041)	(0.053)
Last Fruit Purchase Within 2 Days	-	-	-	-0.167	-0.134
				(0.160)	(0.172)
Age	-	-	-	-	0.001
					(0.005)
Student	-	-	-	-	0.118
					(0.180)
Female	-	-	-	-	-0.002
					(0.137)
Household Size	-	-	-	-	0.054
					(0.046)
Sigma	0.889 ***	0.855 ***	0.856 ***	0.853 ***	0.848 ***
	(0.046)	(0.045)	(0.045)	(0.045)	(0.048)
Observations	201	201	197	197	174
Log Likelihood	-260.707	-253.256	-248.259	-247.716	-217.647

Notes: Subjects were free to bid any value for the products including negative values. The data includes a total of 12 negative bids that were censored at zero. Considering the significance of sigma, a Tobit regression generates significantly different estimates compared to an OLS regression.

Table 3. Summary Statistics for the Two Measurement Variables

Variable	Min	Max	Median	Mean	Std. Dev.
X_1	0	4.99	1.4	1.48	0.92
X_2	0	3.75	1.19	1.29	0.77

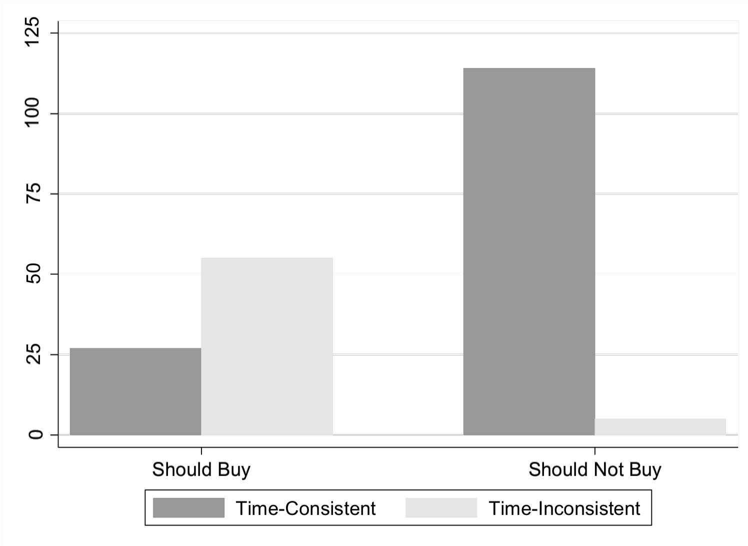

Figure 1. Distribution of time-consistent and time-inconsistent bidders

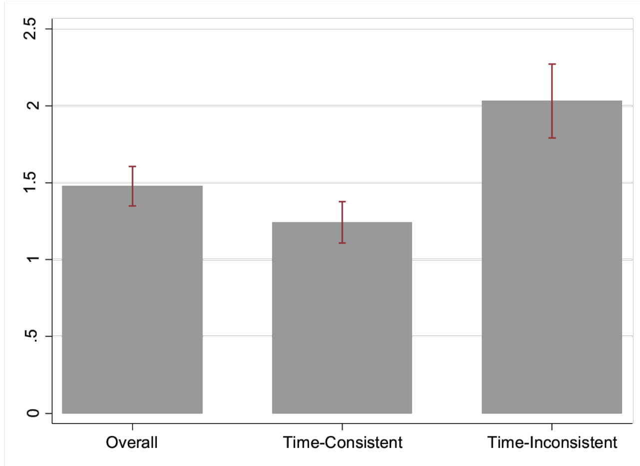

Figure 2. Willingness-to-pay for time-consistent and time-inconsistent individuals

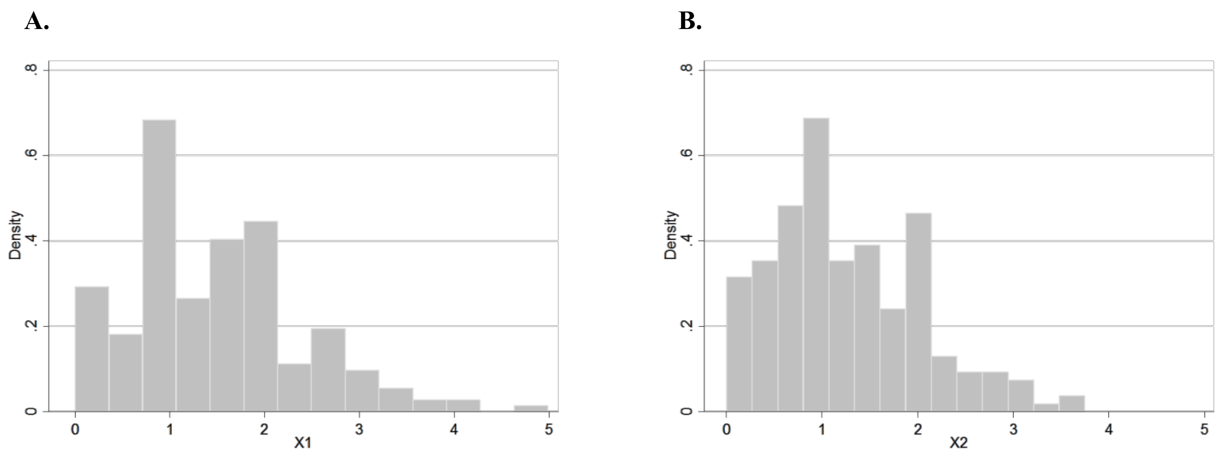

Figure 3. Histograms for the two measurement variables. (A) Histogram for reported SPA bids. (B) Histogram for adjusted SPA bids based on decisions in secondary market.

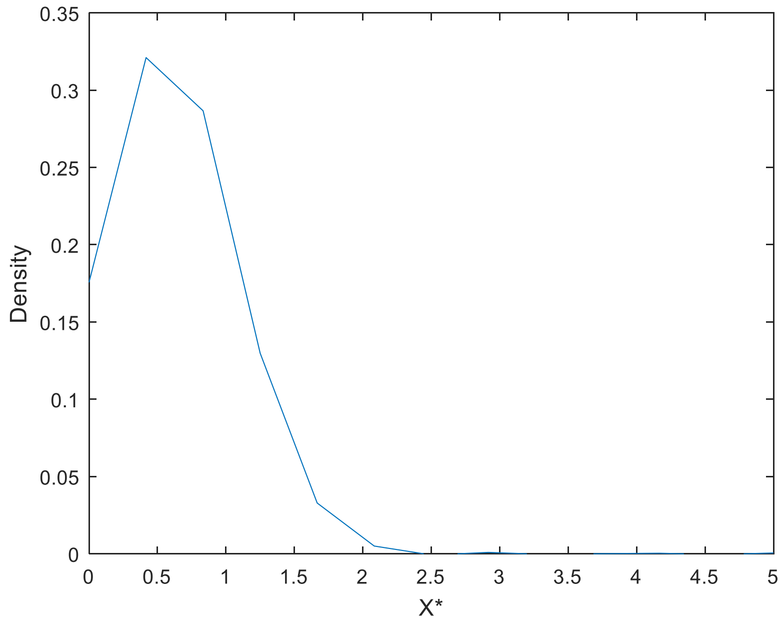

Figure 4. Recovered density function of the unobservable true valuations

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