A Two-Step Auction in the Presence of Negative Values: An Application to "Farm-Raised" Pre-Cooked Roast Beef

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Uniform auctions are commonly used to elicit willingness to pay for new or novel products, product attributes, or non-market goods. However, most auctions or other contingent-valuation techniques do not allow for negative values, despite the fact that many consumers hold negative values for these products or product attributes. We conducted a WTP auction for a new product along with a within-sample WTA second auction allowing for negative responses. We find that failing to allow for negative values significantly inflates willingness to pay estimates and estimates of expected market share. This paper provides a method of incorporating negative values into auctions and willingness to pay elicitation.

Experimental uniform auctions have become a popular method of eliciting consumer willingness to pay for neoteric goods (Fox et al. 1994, 1995, 1998; Fox, Hayes, and Shogren 2002; Evans et al. 2008; Lusk et al. 2001; Colson, Rousu, and Huffman 2008; Hoffman et al. 1993; Roosen et al. 1998; Shogren et al. 1984, 1999). The popularity of uniform auctions is based on four attractive properties. First, uniform auction mechanisms are demand revealing and incentive compatible; the weakly dominant strategy of the respondent is to reveal their true willingness to pay for the product in question (Lusk 2003). Second, the market-clearing price is determined endogenously. Third, the rules describing pricing and allocation of the product in question are easy to explain. Fourth, because uniform auctions are non-hypothetical, problems associated with hypothetical bias are avoided.

Researchers, however, have recognized that some participants in experiments (and, indeed, consumers in general) may have negative values for the product being evaluated. For example, some consumers may perceive "irradiated" meat to be safer than "non-irradiated" meat and be willing to pay a positive premium to consume it. Other consumers may view "irradiated" meat in a negative light and demand a payment to consume it. Concern about negative values is not limited to neoteric goods, but is a concern in environmental studies as well, especially those using contingent-valuation methods. The concern relates to respondents who express zero value for an environmental good but actually hold a negative value, thus inflating willingness to pay (WTP) estimates and leading to poor policy prescriptions (Hanemann 1994; Diamond and Hausman 1994; Macmillan, Duff, and Elston 2001; Clinch and Murphy 2001). As with environmental goods, auctions for neoteric goods where those with negative values bid zero also artificially inflates WTP values and distorts derived demand functions.

Despite the recognition of potential negative values, many auction experiments are designed presuming people with negative values will bid zero (or are indifferent) (see, e.g., Fox, Hayes, and Shogren 2002). By contrast, Buhr et al. (1993) parsed potential respondents to an auction involving hormone-treated pork into two groups—one preferring hormone-treated meat and one preferring no growth hormones—and conducted two independent auctions. While explicitly accounting for potential negative values, the weakness of this approach is that it *a priori* segments respondents outside of the auction environment. As such, respondents self-select into different auctions by a dichotomous-choice question that is hypothetical resulting in potential hypothetical bias. Dickinson and Bailey (2002) took a different approach by simply allowing respondents to express negative values within a single auction. This approach represents an improvement in that it allows respondents "within sample" to express negative values, but, as the authors note, the mechanism may allow for respondents to "game" the experiment by enticing

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respondents to bid negative values in order to extract payments from the monitor.[1]

We follow a process similar to Parkhurst, Shogren, and Dickinson (2004) that allows respondents to express negative values in an induced value WTP experiment. In contrast to Parkhurst et al., we then propose a second step where respondents who expressed a zero or negative value participated in a willingness to accept (WTA) auction. The purpose of this test is to examine a two-step auction that is more consistent with the needs of applied auctions for neoteric or environmental goods. We find that the two-step auction generally improved demand revelation over both a truncated (non-negative value only) and negative-value WTP auction. Next, we use the two-step procedure in an auction for a neoteric product. Respondents expressed a willingness to pay for the neoteric good in a traditional auction format. Respondents expressing a zero willingness to pay effectively revealed themselves as having no value or a negative value for the neoteric good; that is, they revealed their preference in a non-hypothetical setting consistent with Dickinson and Bailey (2002). These respondents then participated in a second willingness to accept auction, thus revealing their negative value for the neoteric good in a manner consistent with Buhr et al. (1993). Results show that inclusion of the negative-value results significantly lower willingness to pay for the neoteric good, and thus suggest a different estimate of market share for the product.

Induced-Value Experiment

Before using a new procedure, we much first establish its validity in accurately eliciting demand (or WTP). This test is accomplished by examining the "demand revelation" properties. That is, if the economic auction is effective, it should induce respondents to reveal their value for a good by bidding their maximum WTP for a good. To avoid mixing private values with experimental stimuli, we use a generic good and provide "values" for that good; next we observe bidding behavior.

[1] It should be noted that Dickinson and Bailey did not observe large negative bids, suggesting that respondents did not strategically "game" the experiment. Furthermore, negative bids occurred in less than five percent of the bids, and the absolute magnitude of the negative bids relative to positive bids also appears to be small.

Undergraduate students were recruited using standard procedures and a $5 participation fee. Respondents were only told that they would be participating in an economic experiment. A total of 40 respondents were recruited—20 for each of two treatments. Respondents were told that they would be participating in a Vickrey uniform 4th price WTP auction (instructions are available from the author upon request). Vickery auctions are sealed-bid auctions, but rather than the "highest bidder" winning the auction, the nth-highest bidder (in this case, the fourth-highest bidder; a 2nd price auction is the most common for small samples) sets the price. In a 4th price auction the three highest bidders then pay the 4th highest price. The traditional 2nd (or any number) auction is known to be accurate in the aggregate (Vickery 1961), but this auction form does not engage off-margin bidders (that is, people whose values are far below the market price). A random nth price auction (Shogren et al. 2001) remedies this situation but is significantly more complicated for the monitor. Because there was a limited supply of the farm-raised product, an nth price auction was not possible. However, a 4th price auction was used to more actively engage off-margin bidders compared with a 2nd price auction because more respondents had the potential to "win" the auction and purchase the product.

Each respondent was provided an induced value ranging from −$4.20 to $4.20, with 13 of the 20 induced values being positive and seven being negative. Respondents were told they could bid any value and were provided with examples of the implications of both positive and negative bids with both positive and negative induced values. Respondents were then asked to place a bid based on their induced value. The optimal strategy is to bid one's induced value.

Bids were collected and ranked from highest to lowest, with the fourth-highest price setting the market price. Winning bidders were compensated and excused. All non-winning bidders with positive values were paid for their participation and excused. Finally, bidders with a zero or negative bid were asked to stay to participate in a second auction.

Those respondents who bid zero or a negative value then participated in a second auction, where they possessed the same induced value, but were participating in a WTA auction. Respondents were told that they would be participating in a Vickrey-

style 2nd price auction. These respondents were asked to place a bid based on their induced value (the optimal strategy in this case is to bid −1*induced value). Bids were collected and ranked from lowest to highest, with the second lowest bid setting the market price. The winning bidder was compensated and all others were paid their participation fee and the auction ended.

Data were analyzed for demand revelation properties using three perspectives of the data. First, the raw data from the WTP auction (including negative bids) were examined. Bids were regressed against induced values—Bid = $\alpha + \beta$IV—with the null hypothesis for demand revelation being $\alpha = 0$ and $\beta = 1$. That is, if the respondent is perfectly revealing their underlying "value" for the good (or, IV), their bid should perfectly reflect that value. Thus the relationship between bids and induced values should form a 45-degree line from the origin.

Second, for observations where the bid was negative, the actual bid was replaced with a zero (hereinafter called truncated). The truncated data mimics what would be observed in an applied auction where negative values were present but expressed as zero bids. A second regression identical to that above was conducted to examine demand revelation in the truncated auction. Finally, for those observations where a negative or zero bid was observed in the WTP auction, the bids from the second round WTA auction were used to replace the original bids.

Table 1 shows the results of the regressions on the induced values.[2] The first column shows the results for the WTP auction with the original data. The Wald test statistic (14.81) suggests rejection (at the one-percent level) of the null hypothesis of truthful demand revelation (that is, a joint test of $\alpha = 0$ and $\beta = 1$). Likewise, the results from the truncated auction regression (second column) suggest rejection of truthful demand revelation at the one-percent level. However, we fail to reject truthful revelation for the two-step auction (third column) at the one-percent level, but can reject at the five-percent level.

We compared the demand revelation properties of each different view of the data using an F-test (Table 1). In all cases the null hypothesis of equal explanatory power is rejected. Most importantly,

[2] The results are based on a data set where all bids that were more than 400 percent of their induced value were eliminated.

Table 1. Regression Results for Induced-Value Auction.

Variable	Original data	Truncated data	2-Step data
Intercept	0.153	1.064**	−0.126
	(0.303)[a]	(0.198)	(0.306)
Induced value	0.60**	0.252**	0.727**
	(0.105)	(0.068)	(0.105)
Wald test for $\alpha = 1$ $\beta = 1$	14.81**	14.95**	6.93*
F-tests			
Original vs. truncated	13.97**		
Original vs. 2-step	7.52**		
Truncated vs. 2-step	24.49**		

[a] Numbers in parentheses are standard errors.
*Denotes statistical significance at the 0.05 level.
**Denotes statistical significance at the 0.01 level.

the two-step auction exhibited significantly better demand revelation properties than did *both* the truncated and full WTP auctions. Thus it can be concluded that the two-step procedure does improve demand revelation in the presence of negative values in this uniform auction.

Given these results, we used a two-step auction on a neoteric good to examine the potential effects of negative values on predictions of market share and consumer surplus in the face of potential negative values.[3] That auction is outlined below.

Product Background

The product used in this experiment is a pre-cooked "farm-raised" roast beef product developed in a food-science department at a major university. "Farm-raised" in this context refers to the fact that the beef used to produce the roast beef was finished only on grass and forage, not in commercial feedlots. The cuts of meat were marinated, pre-cooked, sliced and packaged in translucent eight-ounce packages with the normal nutritional information. In addition, the label contains the words "farm-raised." Currently, pre-cooked roast beef products are being offered in stores (primarily by Hormel). These products are marinated and pre-cooked in a similar manner to the farm-raised product. Nutritional information is consistent as is package weight. Thus the primary difference between products is the manner in which the beef is produced.[4]

Experimental Design

A uniform 4th price auction was used to elicit respondent willingness to pay (WTP) for the farm-raised pre-cooked roast beef. A total of 25 respondents were recruited from the student body of a major university by offering $10 for participation in an "economic experiment." Respondents were initially asked to fill out a survey that took approximately 20 minutes so that they felt that they had "earned" their initial endowment. Next, respondents were each provided with a Snickers candy bar and told they would participate in a 4th price auction to trade their Snickers bar for a Butterfinger bar.[5] Two hypothetical rounds of the auction for the candy bar were conducted to "train" respondents in the auction mechanism and decision rules to determine the winner. The candy bar auction was conducted as hypothetical so that there would be no alterations to initial endowments (that is, everyone went into the beef experiment with the same amount of show-up fee remaining) for the beef experiment. At the same time, we wished to avoid potential demand reduction effects where those winning the candy bar auction would not feel "saturated" and not actively participate in the beef experiment. Respondents were allowed to ask questions about the auction mechanism after participating in the candy bar exercise.

Next, respondents were told that they would be participating in a non-hypothetical 4th price auction for the pre-cooked roast beef. Each respondent was provided with a Hormel pre-cooked roast beef product and told that they would be bidding to exchange their pre-cooked product for a "farm-raised" product. The farm-raised roast beef product was described and samples were passed among the respondents so that they could examine the product, nutritional information, etc. Respondents were also informed that the Hormel product was derived from their normal commercial beef supply, which is finished in commercial feedlots. The auction mechanism was described again and respondents were allowed to seek any additional information about the mechanism. Respondents were told to place a bid that could be any "non-negative value." One round of bidding was conducted. The top four bidders and fourth-highest price were then identified and winning bidders paid the monitor and exchanged the products.

Those bidders who bid zero (or expressed zero WTP) were asked to stay and all other respondents were dismissed from the experiment. The remaining respondents were told that they were going to participate in a second auction. This auction was a

[3] Use of an environmental good was considered. However, to be able to easily deliver a good in a non-hypothetical context, a private good was chosen. While the policy implications in the context of a private good are not as relevant, it does illustrate the effects on consumer surplus when negative values are present. While not as important in a policy context, the results from the private-good experiment do have implications for predicting market share.

[4] There may be some "brand" affiliation by respondents, leading to potential status quo bias. However, this would exist in the market as well, so results should be consistent with what would be observed in an actual market setting.

[5] Instructions for this and the beef experiment are available from the authors upon request.

willingness to accept auction; that is, respondents were bidding a positive amount of money they would require to be paid to trade their product for the farm raised product.[6] In this case, however, the auction was a 2nd price auction—the lowest bidder would receive the second-lowest bid price for the exchange.[7] The results of the second auction are used to represent the negative values that these individual actually hold for the product.[8]

[6] Parkhurst, Shogren, and Dickinson (2004) observed bias bids when incorporating negative values in the 2nd price auction. We frame all bids as positive values to avoid this bias.

[7] Ordinarily, we would prefer to use the same auction mechanism as in the first experiment. However, because a smaller number of people bid zero in the first auction, a 4th price auction was not possible.

[8] We are assuming that there is no WTP/WTA disparity. Because the divergence between WTP and WTA is related to the ambiguity or riskiness of the product, we do not expect this divergence to be large. As the results show, there is at least one individual who was indifferent (bid zero in both auctions), suggesting that the WTP/WTA divergence is probably not large.

Results

Descriptive statistics of sample characteristics are shown in Table 2. About 76 percent of the sample had previously purchased a pre-cooked roast beef product. Price and visual appearance were the two most important attributes cited by the respondents in their beef-purchase decisions, while label information and special characteristics were least important. There was diversity in the sample between males (56 percent) and females (44 percent); however, the sample was composed primarily of Caucasians (88 percent).

Auction results are shown in Table 3. The "Truncated" column shows the descending rank-order results of the 4th price auction. As can be seen, the average WTP for the "farm-raised" roast beef is $0.42 above the price of the existing product. However, 32 percent of the sample expressed a $0 WTP in this auction, suggesting that a large portion of the sample potentially held negative values for the product.[9]

[9] This finding is supported by the relative unimportance of either origin or special characteristics in beef-purchase decisions expressed by the respondents in Table 2.

Table 2. Descriptive Statistics of Sample Characteristics.

Variable	Mean or proportion	Standard deviation
Purchase		
Have you purchased pre-cooked roast beef before?	0.76	0.436
Factors important in beef purchase decisions (1 = very important; 5 = not important)		
Price	1.92	0.909
Visual appearance	1.80	1.224
Convenience	2.76	1.012
Label information	3.36	1.150
Origin	2.88	1.236
Special characteristics (e.g., no hormones, etc.)	3.88	1.236
Servings of beef per week	4.32	2.926
Gender (1 = male; 0 = female)	0.56	0.506
Age	24.32	4.670

Table 3. Results for Truncated and Willingness to Accept Auctions and Combined Negative Values.

Bidder	Truncated	Bidder	Negative value
19	$2.00	19	$2.00
16	$1.50	16	$1.50
1	$1.00	1	$1.00
6	$1.00	6	$1.00
7	$1.00	7	$1.00
25	$0.75	25	$0.75
4	$0.50	4	$0.50
11	$0.50	11	$0.50
15	$0.50	15	$0.50
21	$0.50	21	$0.50
3	$0.25	3	$0.25
12	$0.25	12	$0.25
23	$0.25	23	$0.25
20	$0.20	20	$0.20
22	$0.10	22	$0.10
24	$0.10	24	$0.10
9	$0.05	9	$0.05
2	$0.00	18	$0.00
5	$0.00	14	−$0.25
8	$0.00	10	−$0.75
10	$0.00	2	−$2.00
13	$0.00	13	−$2.00
14	$0.00	5	−$2.50
17	$0.00	8	−$5.00
18	$0.00	17	−$5.00
Mean	$0.42		−$0.28
STD	$0.53		$1.76

WTA	
Bidder	WTA
18	$0.00
14	$0.25
10	$0.75
2	$2.00
13	$2.00
5	$2.50
8	$5.00
17	$5.00

Those expressing $0 WTP participated in a WTA auction where respondents were asked to bid the lowest amount of money it would take to get them to consume the product (WTA in Table 2). As can be seen, these bids ranged from $0 to $5. These were then inserted in place of the $0 bid as a negative value. If the negative values significantly influence the WTP for the product, the average WTP when negative values were included should be less than the average WTP in the truncated auction. A Kolmogrov goodness-of-fit test is used to test the hypothesis that the distribution from the Negative value and truncated samples are identical. We reject the hypothesis at the five-percent significance level. The distributions underlying the two samples are significantly different. Therefore a t-test for compar-

ing means from dependent samples was calculated. The t-statistic for this comparison (assuming unequal variances) is 2.12, suggesting that the mean WTP in the negative-value auction is significantly less than the truncated WTP at the 0.03 level of significance. Thus we conclude that inclusion of the negative values significantly reduces mean WTP for the farm-raised pre-cooked roast beef.

This result has obvious implications for predictions of market share. Market share at any price is calculated as the percentage of respondents who have WTP equal to or greater than that price. Market-share functions for both the truncated (WTP) and negative-value auctions (WTPN) are shown in Figure 1. At any price equal to or less than $0, the truncated auction predicts that everyone is indifferent, and therefore likely to consume the product. However, we see that inclusion of negative values predicts a lower percentage of people consuming the product at all prices greater than −$5. For example, if we assume that the farm-raised product is priced at the same level as the existing product (price of $0 in the figure), the truncated auction predicts 100 percent of the people would consume it. However, inclusion of the negative values suggests that only 72 percent of the respondents would consume the farm-raised product, meaning that the WTP auction alone results in an overestimation of market share.

To further illustrate the potential policy implications of failure to include negative values, we estimated demand functions for the new product: one for the truncated auction and one with the inclusion of negative values. Bids were rank-ordered from highest to lowest. A demand of one unit was entered for the highest bid, with one additional unit added to the next lowest bid, and so on, until a total demand of 25 units was reached for the lowest bid. The bids were then regressed against quantities, resulting in a demand function of $q = f(p)$. Consumer surplus was then calculated as

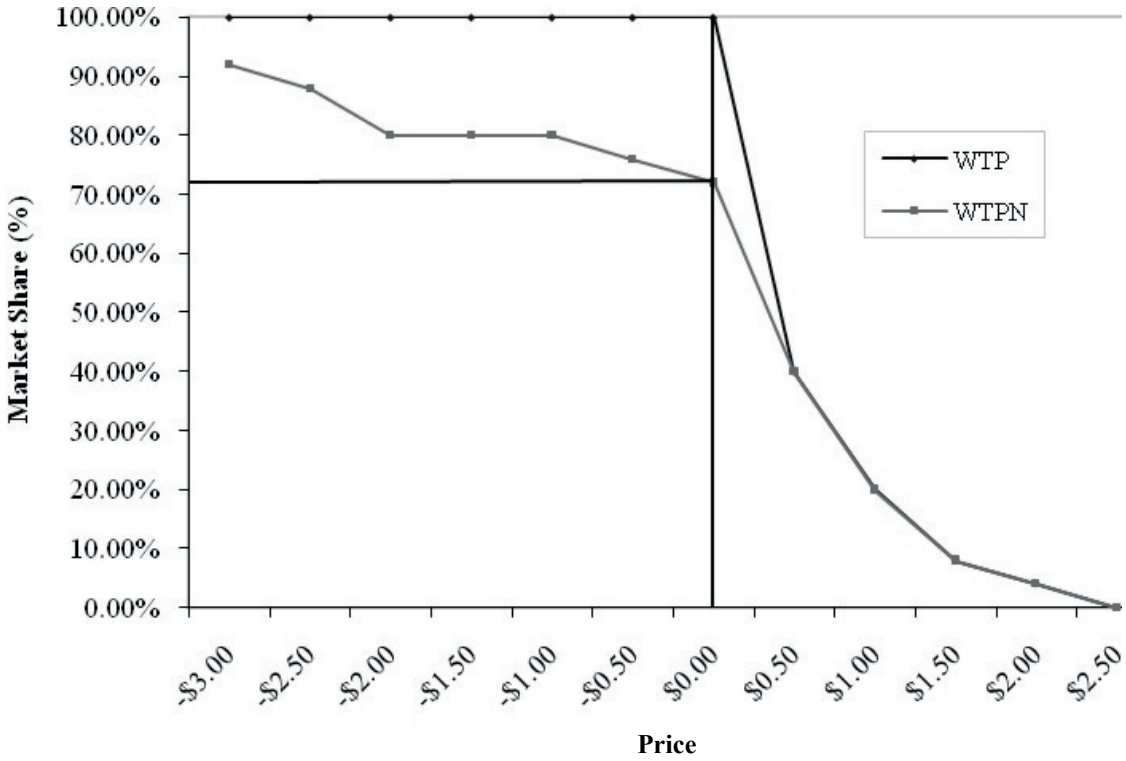

Figure 1. Market Share Predictions for Farm Raised Pre-Cooked Roast Beef Using Truncated (WTP) and Negative-Value Auctions (WTPN).

$$(1)\quad CS = \int_{p=-5}^{p=0} f(p)dp\,.$$

The consumer surplus is estimated over the range of p = −$5 to $0 because −$5 is the lowest price observed and we wish to compare consumer surplus up to the point where prices of the two products is the same.

Because the demand function is censored at 1 and 25, a double-limit Tobit model was used for estimation. The results Tobit model are shown in Table 4. As expected, the quantity demanded is inversely related to the WTP value (price). The Tobit model indicates that consumer surplus with the truncated auction is $367, compared with $137 for the negative-value auction. Thus failure to include negative values in this case would result in an overestimation of consumer surplus by two times.

Conclusion

This analysis used a two-step procedure to incorporate negative values into the elicitation of willingness to pay for a neoteric good. Previous studies have segmented respondents into groups either preferring or not preferring the neoteric good on the basis of a hypothetical dichotomous question (Buhr et al. 1993). Because the question is hypothetical, there is no assurance that the individuals answered truthfully. Other studies have allowed for negative values directly in an auction, but not the potential for strategic behavior on the part of the respondents (Dickinson and Bailey 2002). We combine these methods by using an auction mechanism that allows individuals to reveal either indifference or potential negative values by expressing a zero WTP. Those expressing a zero WTP were then engaged in a WTA auction. The results of the WTA auction were included as negative values for the respondents providing a zero WTP in the first auction.

The results are consistent with expectation in that inclusion of the negative values significantly reduces the average WTP from the auction. In addition, use of the negative values results in a different prediction of product acceptance or market share. Ultimately, failure to account for negative values can result in an overestimation of the potential demand for the product. One could argue that those who express a negative value would not purchase the product anyway. This presumption is likely correct, but these results suggest that a simple expression of zero WTP does not necessarily imply indifference. Thus lumping together those with true indifference (or a true zero WTP) with those with a negative value results in an impression that more people will purchase the product at no price difference than is actually the case. The confounding of these two different groups, therefore, leads to incorrect pricing decisions.

Table 4. Tobit Regression Results.

	WTP	WTPN
Constant	23.008	13.253
	(1.729)*	(0.579)*
Price	−20.133	−5.668
	(2.930)*	(0.555)*
Sigma	5.529	2.748
	(1.079)*	(0.416)*
Adj. R^2	0.72	

Numbers in parentheses are standard errors.
* Statistically significant at the 1-percent significance level.

More broadly, however, the results of this study and previous studies highlight the importance of negative values in policy analysis. In our example, it is obvious that the consumer-surplus estimate using the truncated auction results in a larger consumer surplus than when using the negative-value auction. Because individuals may have a negative value for a product or policy, implementation of that policy, without accounting for the opposition towards the policy, would result in less-than-expected welfare gains. Therefore it is critical methods that incorporate negative values are used in research that elicits WTP estimates.

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