

# **Interpreting Bids From a Vickrey Auction when There Are Public Good Attributes**

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## **Abstract**

This paper provides a model that allows for interpreting bids in a Vickrey auction when the good has public good attributes. It also examines information obtained from a Vickrey auction, which collected consumer's willingness-to-pay for pork products that had embedded environmental attributes, and applies the new interpretation to the bids.

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## Introduction

Since the early 1990's, a floodgate of research has opened up using experimental economics, specifically Vickrey auctions, to obtain consumers' willingness-to-pay for attributes related to products. Auctions have been used to elicit values for food safety attributes in selected food products (Fox, 1994; Fox et al., 1995; Fox et al., 1996; Hayes et al. 1996; Roosen et al. 1998), quality differences in food products (Melton et al. 1996a, 1996b; Umberger et al., 2001), and packaging of food products (Hoffman et al. 1993; Menkhaus et al. 1992). Fox et al. went one step further and used experimental techniques to calibrate contingent values from a CVM study (1998).

While there are four primary auctions that have been used in the market to value goods—the first price auction, the second price (Vickrey) auction, the Dutch auction, and the ascending auction—the Vickrey auction or a variant of it is one of the more widely used auctions in the research arena for examining people's willingness-to-pay for an attribute.<sup>2</sup> The reason researchers prefer using the Vickrey auction is that it has a mechanism that provides for truthfully revealing demand preferences.

There are two objectives of this paper. The first objective is to provide a model that allows for the interpretation of bids in a Vickrey auction when the good has embedded environmental attributes. The second objective is to examine bid data from an experiment that has collected consumers' willingness-to-pay for pork products with embedded environmental attributes. Specifically, bids will be examined from a multiple round Vickrey auction to investigate whether consumers' have a willingness-to-pay for environmental attributes related to production air quality, surface water, and ground water.

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<sup>2</sup> One offshoot of the Vickrey auction is the random n<sup>th</sup> price auction. For more information regarding this auction method, see Shogren et al (2001).

## **Truthful Revelation Property of the Second-Price Sealed-Bid Auction**

In 1961, William Vickrey laid the foundations for the study of auctions (1961). He investigated the four auctions mentioned above under what is now considered the benchmark model for studying auctions. In his paper he investigated these four auctions under six basic assumptions. One basic assumption Vickrey used for studying auctions was that the bidders in the auction are risk neutral. Another assumption Vickrey made was that the bidders were symmetric. Bidders are said to be symmetric when they draw their valuations from the same probability distribution. Symmetry also requires that bidders who draw the same valuation give identical bids. A third assumption made by Vickrey is that there is no collusion among the bidders. The fourth assumption is that payment is a function of the bids alone. This implies that there are no reservation values of the auctioneer or initial payments to the auctioneer to enter the auction.<sup>3</sup> No initial payment implies that anyone can participate in the auction without paying a fee to the auctioneer. An implicit fifth assumption Vickrey made was that bidders have expected utility maximizing behavior.<sup>4</sup> The sixth assumption in Vickrey's investigation is that the independent-private-values assumption applies. Under this assumption, each bidder is assumed to know her exact valuation of the good she is bidding on, while not knowing anyone else's valuation. Also, the bidder perceives the value of any other bidder as a random draw from some probability distribution where the value of other bidder's is statistically independent from her.<sup>5</sup>

Before consumer behavior can be understood in a second-price sealed-bid auction where the product has embedded environmental attributes, a major characteristic of the auction must be

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<sup>3</sup> A reserve price is the minimum price set by the auctioneer at which she will sell the item being auctioned. If the highest bidder's bid is below the reserve price, the item being auctioned will not be sold.

<sup>4</sup> This specific assumption was not given in Vickrey's 1961 paper explicitly. Karni and Safra (1986, 1989) demonstrated that Vickrey needed to assume that the bidders are expected utility maximizing agents to make some of his arguments.

<sup>5</sup> There is actually a seventh assumption that Vickrey had to make regarding the auction. He implicitly assumed that the good being auctioned did not have public good attributes.

discussed. A characteristic of the single-unit second-price sealed-bid auction is that it requires the top bidder to purchase the object being bid upon at the second highest bid price. This feature of the auction ensures that each participant will bid his/her true willingness to pay for the product being auctioned, i.e., each participant's true valuation (Vickrey 1961). The reason this holds true is because in a game theoretic setting it is the bidder's weakly dominant strategy to bid his/her true value.<sup>6</sup> This true valuation can be defined as the maximum income that the bidder would be willing to give up to obtain the product. The bidder's utility in this situation is equal to the bidder's utility when she has her full amount of income and no product.

To see why the second-price sealed-bid auction gives the true willingness-to-pay for an object, the following standard argument from the literature is presented (Vickrey 1961; McAfee and McMillan 1987, Karni and Safra 1989). Suppose there are  $N$  bidders where bidder  $i$ ,  $i = 1, 2, \dots, N$ , gives a bid of  $b_i$  for an object and has a true valuation of  $v_i$  for that object. It is also assumed that the benchmark model set of assumption explained above holds true for each bidder—the bidders are risk neutral expected utility maximizers, there is no collusion among the bidders, the independent-private-values assumption holds, the bidders are symmetric, and the bidders payment is a function of their bids alone. Let  $W$  be the maximum bid of all other bidders excluding bidder  $i$ . Without loss of generality, assume that if bidder  $i$  does not purchase the object her utility level is 0. Also assume that if she does purchase the good her utility is equal to her true valuation minus the second highest bid. Hence, if her true valuation is greater than the second highest bid she obtains a positive utility from purchasing the good.

There are two general scenarios that must be investigated. The first scenario is when bidder  $i$  bids higher than her true valuation, i.e.,  $b_i > v_i$ . In this first scenario, suppose that  $W \geq$

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<sup>6</sup> A weakly dominant strategy is a strategy such that no other strategy is strictly better than it is. In this case, some strategies may be equally good, but not necessarily for all cases.

$b_i$ . This would imply that bidder  $i$  receives 0 utility whether she bids her true valuation or not because she is not the highest bidder. Now suppose that  $W \leq v_i < b_i$ . In this case bidder  $i$  obtains utility level  $v_i - W$ , which she would have obtained by bidding her true valuation  $v_i$ . Suppose that the maximum bid from all other participants is greater than the true valuation of bidder  $i$  but less than the bid given by bidder  $i$ , i.e.,  $v_i < W < b_i$ . This would imply that the utility of bidder  $i$  is equal to  $v_i - W$ , which is obviously a negative number. In this situation, it would have been better for bidder  $i$  to bid her true valuation  $v_i$  and obtain a utility level of 0. Hence, it has been shown that bidder  $i$  would have done no worse by bidding her true valuation and in some cases would have been better off.

The second scenario that needs to be investigated is when bidder  $i$  bids less than her true valuation, i.e.,  $b_i < v_i$ . In this situation, when bidder  $i$  bids greater than or equal to the maximum of the other bidders, i.e.,  $b_i \geq W$ , she receives a utility level of  $v_i - W$ , which is a positive level. Bidder  $i$ , in this case, would have received the same utility level if she bids her true valuation. If the true valuation of bidder  $i$  is less than or equal to the maximum bid of all the other individuals, i.e.,  $W \geq v_i$ , then she received 0 utility. In this case, she could receive the same utility level by bidding her true valuation because she will never be the highest bidder. Finally, if the bid of bidder  $i$  is strictly less than the maximum bid of the other individuals, which is strictly less than the true valuation of bidder  $i$ , i.e.,  $v_i \geq W > b_i$ , then bidder  $i$  foregoes a positive utility level by under bidding. In this case it would have been in the best interest of bidder  $i$  to bid her true valuation. Hence, it has been shown under this second scenario that bidder  $i$  would have done no worse by bidding her true valuation and in some cases would have been better off.

Two major implications of the Vickrey auction can be drawn from the above discussion. The first implication is that the second-price sealed-bid auction has the property of optimizing

individuals revealing their true preferences in a noncooperative game theoretic setting. The second implication is that this auction mechanism divorces the bidders from strategic interaction, i.e., the bidders do not base their bids on what they believe the other bidders are doing. This can be seen from the fact that probabilities were not utilized in the argument above.<sup>7</sup> These implications will be important when looking at willingness-to-pay for environmental attributes and consumer behavior.

### **Interpreting the Bids from a Second-Price Auction when the Item Has Embedded Environmental Attributes**

It was demonstrated above that the dominant strategy in a second-price sealed-bid auction is to bid one's true value for the item being auctioned. This result is very robust unless the bidder is not an expected utility maximizer or if collusion exists among the bidders. One of the implicit assumptions that was made to prove the dominant strategy in the second-price auction is that the item being auctioned is a purely private good with no public good attributes. When examining items with embedded environmental attributes, this implicit assumption does not hold. These items have a public good aspect to them. From the public goods literature, it is known that when public good attributes exist, there is a possibility of free-riding by consumers.<sup>8</sup> This motivates the question as to how to interpret the bids from a second-price auction when some of the goods have embedded environmental attributes. To understand how to interpret bids in an auction when the item has embedded environmental attributes, an understanding of a bidder's valuation is necessary.

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<sup>7</sup> Implicitly, the bidder increases her probability of being the highest bidder by increasing her bid, but this does not increase her gains (utility) compared to bidding her true valuation. The assumption that relates to probability structures in the benchmark model of assumptions is used to prove revenue equivalence among the four auctions. This assumption is not necessary when establishing the dominant strategy of the second-price auction.

<sup>8</sup> For a discussion of the free-rider problem see Cornes and Sandler (1986).

It shall be assumed that there are  $I$  bidders in a second-price sealed-bid auction bidding on one item which has embedded environmental attributes. Bidder  $i$ 's,  $i = 1, 2, \dots, I$ , true valuation of the product being auctioned is  $v_i$ . Bidder  $i$ 's true valuation  $v_i$  is assumed to be the sum of three disjoint values, i.e.,  $v_i = v_{i1} + v_{i2} + v_{i3}$ .  $v_{i1}$  is defined to be the maximum amount of money bidder  $i$  is willing to give up to obtain the physical attributes embodied in the product being auctioned. For example, in the case of a pork chop, this value is derived from such physical attributes as tenderness, color, type of cut, marbling, etc. The second value,  $v_{i2}$ , is defined as the true value the bidder receives from being the one that contributes to the public good, i.e., it is the maximum amount of money the bidder is willing to give up to provide to the public good no matter what other bidders do. This value could be derived from altruism or warm-glow altruism.<sup>9</sup> Altruism is where people give to a public good and receive utility from the consequences of their giving. Warm-glow altruism is where people receive satisfaction from the process of giving to the public good with no regard to the consequences of giving (Kotchen et al. 2000). For this value to exist, the bidder must be the one who obtains the item from the auction, i.e., she has to be the one that is giving to the public good.  $v_{i3}$  can be viewed as the value one receives from the public good being provided by some other person. It is the maximum amount of money the bidder is willing to give to the public good, which does not overlap with  $v_{i2}$ , assuming that no other person is contributing to the public good. If other bidders are contributing to the public good, this value is going to be conditional on the other bidder's contribution. This value exists for each bidder no matter who provided the public good. Hence, this is a value where free-riding can occur. The distinction made between  $v_{i2}$  and  $v_{i3}$  is that  $v_{i2}$  is only realized if the bidder is the highest bidder, whereas,  $v_{i3}$  is realized no matter who is the highest bidder.

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<sup>9</sup> Altruism and warm-glow altruism have been studied by Andreoni (1988, 1990).

To interpret the bids from a second-price auction when the item has embedded environmental attributes, the same type of reasoning used to prove the pure private good case can be used, i.e., Vickrey's argument can be adapted to this situation. First of all, it shall be assumed that the assumptions of the benchmark model hold.<sup>10</sup> In the pure private good case, it was assumed without loss of generality that the utility of the bidder was 0 if she did not purchase the object. This is no longer the case with an item that has embedded environmental attributes. Even if bidder  $i$  does not purchase the good, she still obtains  $v_{i3}$ . This is because no matter who provides the public good, bidder  $i$  receives utility from the public good characteristic of the product being auctioned. Hence, as long as bidder  $i$  believes that someone will purchase the good with embedded environmental attributes, it will never be in the interest of bidder  $i$  to incorporate  $v_{i3}$  into her bid function.<sup>11</sup> This implies that in a second-price auction it is not a dominant strategy for the bidder to reveal her true valuation of the item. To show this rigorously, a stronger statement will be proven. Under the assumptions of the benchmark model, when the item has embedded environmental attributes and the bidder has some free-riding tendencies, the dominant strategy for each bidder is for her to bid a value equal to  $v_{i12} = v_{i1} + v_{i2}$ .

Define  $W$  as the maximum bid given by all bidders excluding bidder  $i$ . If bidder  $i$  is the highest bidder, then  $W$  is the second highest bid. Bidder  $i$  is assumed to have a true valuation of the product of  $v_i$ , where  $v_i = v_{i1} + v_{i2} + v_{i3}$ . Define  $V_i$  as the difference between bidder  $i$ 's true valuation,  $v_i$ , and  $W$ . There are two scenarios, one with four cases and the other with three, that need to be examined to show that bidding  $v_{i12}$  is the dominant strategy.

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<sup>10</sup> Note that the assumption of bidders' being risk neutral can be weakened to risk averse.

<sup>11</sup> In auction setting, this belief is not unrealistic. Since the item being auctioned has already been produced, the environmental characteristics have already been provided. This being the case, bidder  $i$  can view  $v_{i3}$  as an initial endowment of utility which she does not have to pay for.



The first scenario is when bidder  $i$  bids higher than  $v_{i12}$ , i.e.,  $b_i > v_{i12}$ . In this first scenario, suppose that  $W \geq b_i$ . This would imply that bidder  $i$  receives a utility level of  $v_{i3}$  whether she bids  $v_{i12}$  or not because she is not the highest bidder. Suppose that the maximum bid from all other participants is greater than the true valuation of bidder  $i$  but less than the bid given by bidder  $i$ , i.e.,  $v_i < W < b_i$ . This would imply that the utility of bidder  $i$  is equal to  $V_i = v_i - W$ , which is obviously a negative number. In this situation, it would have been better for bidder  $i$  to bid  $v_{i12}$  and obtain a utility level of  $v_{i3}$ . Under this situation, if the bidder bid her true valuation  $v_i$ , she would have obtained a positive utility of  $v_{i3}$ . Now suppose that  $v_{i12} < W \leq v_i < b_i$ . In this case bidder  $i$  obtains utility level  $V_i = v_i - W$ . Since  $W$  is less than bidder  $i$ 's true valuation  $v_i$ , then  $V_i \geq 0$ . While  $V_i$  is nonnegative in this case, this does not imply that bidding one's true valuation is a dominant strategy. Since  $W$  is greater than  $v_{i1} + v_{i2}$ , then the bidder would have done better off by bidding  $v_{i12}$ . By bidding  $v_{i12}$ , bidder  $i$  would have received utility level  $v_{i3}$ . In this case,  $V_i = v_i - W \leq v_{i3}$ . The final case in scenario one assumes that  $W \leq v_{i12} < v_i < b_i$ . While bidding  $b_i$  in this case gives the bidder a utility level greater than  $v_{i3}$ , the bidder could have done just as well by bidding  $v_{i12}$ . Hence, it has already been shown that it is not the bidder's dominant strategy to bid her true valuation. It has also been shown for scenario one that bidder  $i$  can do no better than bidding  $v_{i12}$ .

The second scenario that needs to be investigated is when bidder  $i$  bids less than  $v_{i12}$ , i.e.,  $b_i < v_{i12}$ . In this situation, there are only three cases that need to be examined. In case one, assume that  $W \geq v_{i12} > b_i$ . Under this first case, bidder  $i$  could have received the same utility  $v_{i3}$  if she bid  $v_{i12}$ . Suppose that for case two,  $v_{i12} \geq W > b_i$ . By bidding below  $v_{i12}$ , bidder  $i$  obtains utility  $v_{i3}$ . Bidder  $i$  could have been better off had she bid  $v_{i12}$ , because  $V_i$  would have been equal to  $v_i - W \geq v_i - v_{i12} \geq v_{i3}$ . In this case, bidder  $i$  foregoes a greater utility level by under

bidding. Finally for case three, suppose that  $v_{i12} \geq b_i \geq W$ . In this case, it would make no difference whether bidder  $i$  bid  $b_i$  or  $v_{i12}$ . Under each bid she would obtain the utility  $V_i = v_i - W$ . Hence, it has been shown under this second scenario that bidder  $i$  would have done no worse by bidding  $v_{i12}$  and in some cases would have been better off.

Coupling the results in scenario two with scenario one's results, it has been shown that bidding  $v_{i12} = v_{i1} + v_{i2}$  is a dominant strategy for bidder  $i$ . The intuition behind this result is the following. Since  $v_{i3}$  represents the value of the public good, which the bidder gets even if she is not the highest bidder, it is not in her best interest to incorporate it into her bidding strategy. The term  $v_{i12}$  represents the value to the bidder only if she obtains the item being auctioned. Hence, if the bidder wants to maximize her probability of obtaining the largest surplus from the auction procedure, she should bid  $v_{i12}$ . It should be noted that if a person is a perfect free-rider with no altruistic tendencies and the product being auctioned has embedded environmental attributes, then the bid received in this auction would be equal to the bid received in a second-price auction when the item has no embedded environmental attributes.

It has been shown that in a second-price sealed-bid auction, only the private value  $v_{i12}$ , which is less than  $v_i$  when free-riding exists, is submitted as the bid. When environmental attributes exist or any other type of spillover effect, the second-price auction does not get at a bidder's true valuation.

## **Study Design and Data**

Data collection consisted of two main parts: surveys and auction experiments. There were two surveys conducted during each experimental session. The first survey was conducted before the auction and collected personal information and information on participants' perception about industry issues. Some of the specific information collected was age, gender, household income,

and education. The second survey was conducted immediately following the auction.<sup>12</sup> This survey dealt with participant knowledge about pork production and contained questions pertaining to methods of obtaining environmental attributes in products. These questions were related to issues such as methods of manure storage and application and livestock production facilities.

The auction method used was a second-priced sealed-bid auction segmented into five bidding rounds. To familiarize the participants with the second price auction, we first used a preliminary auction using candy bars. This allowed the participants to become familiar with the second price auction. After this first auction was completed, a multiple trial second price auction with the pork products was conducted. In the first three rounds, participants bid only on the physical attributes of the product having no other information except for the previous round's bids. This allowed participants to become familiar with the auction process and obtain feedback on price information. In the fourth round, the participants were informed of the specific environmental attributes associated with the respective products. This release of information allowed for determining what the effect of releasing environmental information had on participants' bids. In the fifth round, the implications of the environmental attributes were further explained and the participants were allowed to bid a final time. Following Fox et al. (1995, 1996), wealth effects were controlled by randomly choosing at the end of the experiment both one round and one product from that selected round to be the product sold.<sup>13</sup>

The products used to elicit bids were two-pound packages of uniformly cut, boneless, 1¼ inch pork loin chops. These packages were developed to look as uniform as possible. The first

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<sup>12</sup> Since this survey had questions related to the environment, which could have led to a bias in a participant's opinion affecting his/her bid, it was given after the experiment to minimize any bias.

<sup>13</sup> Wealth effects are when participants change their bids because they won an earlier trial (Fox et al., 1995). See Davis and Holt for a discussion of wealth effects in experimental markets.

three rounds of bidding allowed for identifying if the packages provided were perceived as similar. Thus, in round four, participants were only bidding on the environmental attribute information provided. Bid responses would reflect the value of the environmental attribute. The participants were allowed simultaneously to bid on ten different packages of pork chops each having different environmental attributes. The packages of pork chops were arranged in a row, and placed on ice in one of three white coolers. Each of the ten packages were labeled as Package  $i$ , where  $i = 1, \dots, 10$ . For each experiment, after the third round each participant was told that one package was a “typical package” with no particular environmental attributes. In this same round, the other nine packages were assigned varying levels of environmental attributes dealing with ground water, surface water, and odor. Odor reduction was at two levels: a 30-40 percent reduction, and an 80-90 percent reduction over the “typical” product. Ground water and surface water impacts were also available at two levels: a 15-25 percent reduction and a 40-50 percent reduction over the “typical” product. Packages were provided with single attributes (only air, ground water, or surface water), double attributes, or all three attributes embedded. The double and triple attribute pork packages were all at the high reduction levels.

Experiments were conducted in six different areas of the United States: Ames, Iowa; Iowa Falls, Iowa; Manhattan, Kansas; Raleigh, North Carolina; Burlington, Vermont; and Corvallis, Oregon. Three experiments were conducted at each site. At each site, each experiment lasted about two hours. The first experiment was conducted at 9:00 a.m., the second at 11:30 a.m., and the third at 2:00 p.m. To control for bias in package labeling, corresponding package number were switched with the assigned environmental attribute for each of the different time slots. A random sample of individuals from the area being studied was used to obtain participants for the study. This sample was obtained by a random computer generated

sample drawn from telephone numbers in the respective local telephone directory. Each participant was paid forty dollars for participating in the experiment.

## Results

Of the 333 participants in the study, results from 329 were usable.<sup>14</sup> Information provided in Table 1 shows the distribution of participants by study region. The experiments were conducted during the summer 1997 through summer 1998 time periods. The number of participants ranged from sixty for the Corvallis, Oregon and Manhattan, Kansas locations to twenty-seven for Burlington, Vermont. In Iowa, the Ames location had forty-nine participants while the Iowa Falls location had fifty-eight participants. Two experiments were conducted in the Raleigh, North Carolina area.

**Table 1: Number of Participants by Area**

Experiment Area	Number of Participants
All areas	329
Ames, IA	49
Manhattan, KS	60
Raleigh, NC (6/28/97)	31
Burlington, VT	27
Iowa Falls, IA	58
Corvallis, OR	60
Raleigh, NC (6/27/98)	44

Table 2 provides a summary of the average bids for each product during each round. It also provides the t-statistic related to the hypothesis test that the average bid from the current round is equal to the average bid in the previous round for the same product. For round one, the highest average bid for the group of pork chops was \$3.47 for the package of pork chop which was later identified with the low-level odor reduction attribute (thirty to forty percent odor reduction). The lowest average bid in round one was \$3.21 for the package aligned with low-

<sup>14</sup> Four participants were omitted because they did not finish the experiment and surveys. One person had to leave during the study because she was ill. The other three did not complete the survey for unknown reasons.

level ground water improvement (fifteen to twenty-five percent reduction in the impact to ground water). When testing the hypothesis that these two means are equal, a sample t-statistic of 1.60 is calculated. This implies that the null hypothesis cannot be rejected at the five-percent level of significance. Thus statistically, they are not significantly different.

**Table 2: Average Bid for Each Product by Bid Round (All Participants)**

<b>Pork Chop Environmental Attributes (Level of Improvement over Typical)</b>	<b>Average Bids(\$)</b>				
	<b>No Environmental Information</b>			<b>Environmental Information</b>	
	<b>Round 1</b>	<b>Round 2</b>	<b>Round 3</b>	<b>Round 4</b>	<b>Round 5</b>
No Particular Environmental Attributes (Typical)	3.35	3.91 (3.32)	4.13 (1.28)	3.61 (-2.96)	3.57 (-0.22)
Odor 30-40%	3.47	4.01 (3.37)	4.26 (1.57)	3.87 (-2.41)	3.90 (0.16)
Odor 80-90%	3.22	3.81 (3.49)	4.05 (1.45)	3.92 (-0.77)	3.91 (-0.04)
Ground water 15-25%	3.21	3.72 (3.00)	3.91 (1.13)	3.85 (-0.33)	3.86 (0.03)
Ground water 40-50%	3.25	3.84 (3.61)	4.03 (1.18)	3.94 (-0.50)	4.00 (0.36)
Surface Water 15-25%	3.43	4.00 (3.27)	4.15 (0.87)	3.99 (-0.93)	4.05 (0.34)
Surface Water 40-50%	3.26	3.82 (3.38)	4.06 (1.43)	4.10 (0.23)	4.12 (0.14)
Odor 80-90%/Ground Water 40-50%	3.43	4.10 (3.94)	4.25 (0.88)	4.56 (1.77)	4.68 (0.65)
Odor 80-90%/Surface Water 40-50%	3.45	4.08 (3.53)	4.17 (0.52)	4.58 (2.22)	4.66 (0.37)
Odor 80-90%/Ground Water 40-50%/Surface Water 40-50%	3.46	4.06 (3.28)	4.19 (0.67)	5.13 (5.00)	5.17 (0.23)

Note: The number in parenthesis is the t-statistic for the test of whether the average bid in the current round is equal to the average bid in the previous round.

Examining the average bids in round two compared to round one, it appears that all the average bids by product increased. Testing the hypothesis that the average bids in round two are equal to the average bids for the same product in round one, it is discovered that at the five-percent significance level that the bids in round two are not equal to the bids in round one. With a second-price sealed-bid auction, the expectation is that these average bids from round one to round two would be equal if participants were truly revealing their preferences. Two explanations can be offered for these bids not being equal. One is that the participants were still in the process of discovering their preferences and responding to the market information. Another is that

participants did not fully understand the intuition behind the second price auction. This type of bid increase has been seen in previous studies (Fox et al. 1994; Fox et al. 1995).

In round three, there were further increases in the aggregate bids of all the bids, but not by as much as from round one to round two. The question arises whether the bids from round three are statistically equal to the bids for round two. Another way of posing this is to ask whether the bids seem to converge. One way to define convergence is to test whether the average bid in a current round is not statistically different from the average bid in a previous round. If this type of convergence occurs, this could be evidence that the intuition of the second-price sealed-bid auction holds, i.e., participants truthfully reveal their preferences. If participants were truthfully revealing their preferences, little change in bids should be seen when no substantial new information has been released. Hence, from round two to round three, little change should be noticed between the two means. Table 2 shows that all the average bids for the products in round three are not statistically different at the five-percent significance level to the average respective bids in round two. Hence, at the aggregate level, it appears that bids are converging by the definition provided.

While convergence in the bids seems to be evident after the third round is completed when aggregating all the participants together, it is more appropriate to evaluate each respective study location for convergence. Drawing inferences about bid convergence at the national level may be misleading because the set of pork chops are not exactly the same for all the locations. A set of fresh pork chops was bought for each location on the day of the study to assure quality. Hence, a particular package of chops could have different visual characteristics and perceived desirability across each location. These differences could cause variations between regions that could lead a

particular package of chops to converge at the aggregate level even though it does not converge within each specific location.

Table 3 shows the percent of products by region that converged by round three. It also provides the number of the corresponding products that converged. When looking at each study site separately, convergence in the third round on the local level seems to support the aggregate data. At the five-percent level of significance, testing for difference in means from round two to round three for each package of pork chops shows that all test sites had a product convergence of eighty percent or greater. There were only two locations that did not have complete convergence—Manhattan, Kansas and Corvallis, Oregon. This result coupled with the aggregate data provide further evidence for the initial findings of Coppinger et al. (1980) and Cox et al. (1985) that participants eventually discover their preferences and the Vickrey auction with multiple trials does obtain true willingness-to-pay.

**Table 3: Number of Products That Had Bids Converge by Round Three by Area**

<b>Experiment Area</b>	<b>Percent of Products Converging</b>	<b>Products That Converged by Product Number</b>
All areas	100	1, 2, 3, 4, 5, 6, 7, 8, 9, 10
Ames, IA	100	1, 2, 3, 4, 5, 6, 7, 8, 9, 10
Manhattan, KS	80	2, 3, 4, 5, 7, 8, 9, 10
Raleigh, NC (6/28/97)	100	1, 2, 3, 4, 5, 6, 7, 8, 9, 10
Burlington, VT	100	1, 2, 3, 4, 5, 6, 7, 8, 9, 10
Iowa Falls, IA	100	1, 2, 3, 4, 5, 6, 7, 8, 9, 10
Corvallis, OR	90	2, 3, 4, 5, 6, 7, 8, 9, 10
Raleigh, NC (6/27/98)	100	1, 2, 3, 4, 5, 6, 7, 8, 9, 10

Prior to the participants bidding in the fourth round, they were provided information on the environmental attributes embodied within the respective packages of pork. Following release of the information, each participant was allowed to bid on each package with the new information. With this release of information, there was a substantial change in some of the bids. The average bid levels are provided in Table 2 in the round four column.



Figure 1 shows the average bids in each round for the low-level environmental attribute products with the typical product as the basis. This figure shows that all the packages with a low-level of environmental attributes increased between rounds one through three. In round four, all of these products decreased in value substantially. In comparison to the previous rounds, the bid changes from round four to round five were small.

**Figure 1: Average Bids by Round for the Packages with Single Low-Level Embedded Environmental Attributes in Comparison to the Typical Package with No Particular Environmental Attributes**

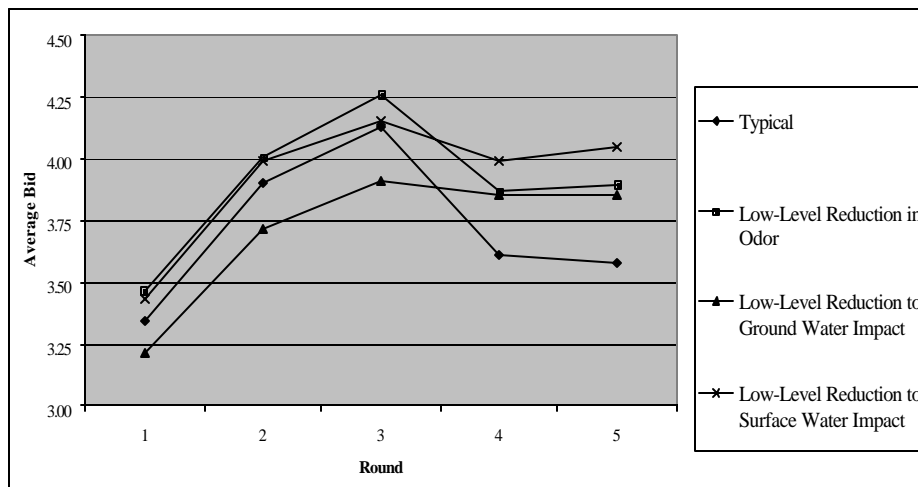
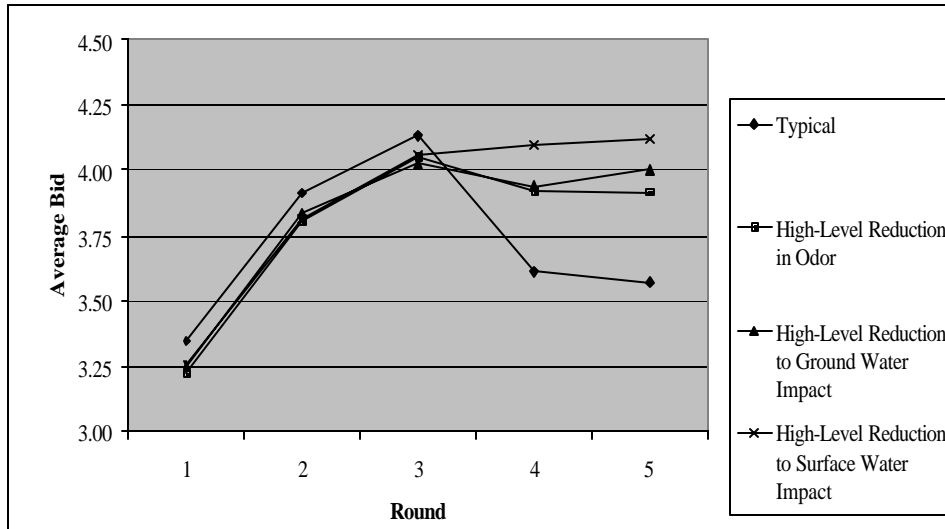


Figure 2 shows the average bids in each round for the single high-level environmental attribute products again with the typical product with no particular environmental attributes as the basis. Similar to Figure 1, all the packages in this group increased substantially between rounds one and three. In round four, the packages with embedded environmental attributes related to odor and ground water decreased in value, while the package with the surface water increased. Again, in round five, there were few adjustments in the bids compared to round four.

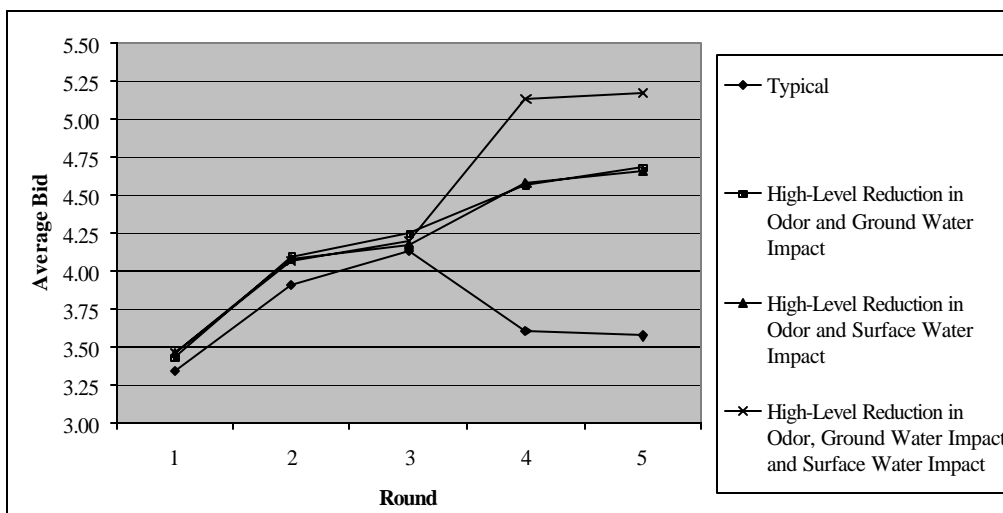
Figure 3 shows the average bids for the products with the highest levels of embedded environmental attributes—those packages with the double and triple high-level environmental attributes. As in the previous two figures, there was a steady increase in bids between rounds one

and three. It is clear from this figure that all the multi-attribute products experienced a substantial increase in bid levels from round three to round four. Again, in round five, there was very little change compared to the previous round.

**Figure 2: Average Bids by Round for the Packages with Single High-Level Embedded Environmental Attributes in Comparison to the Typical Package with No Particular Environmental Attributes**



**Figure 3: Average Bids by Round for the Packages with Double and Triple High-Level Embedded Environmental Attributes in Comparison to the Typical Package with No Particular Environmental Attributes**



## Discussion

To summarize Figure 1 through Figure 3, there were increases in bids for the first three rounds. By the fourth round, releasing environmental information caused a positive and substantial increase in the bids for the high-level multi-attributes products, two of which had significant increases at the five-percent level, had mixed results on the bids of single high-level attribute packages, and negative effects to bids of single low-level attribute packages. In round five, there were no large changes in the bids from round four.

In the bids given above in Table 2, it was seen that many of the products decreased in value when information regarding the embedded environmental attributes was released. Even though some of the bids decreased when the environmental information was released, a clear ranking can be seen from the bids. The products with the highest levels and quantities received the highest premium levels, while those that had single high-level attributes were valued more than the low-level attributes. All the products with embedded environmental attributes were ranked above the product with no particular environmental attributes.

The model given above for second-price auctions with products that have embedded public good attributes can explain this ranking of products based on quantity and level of environmental attributes using the idea of warm-glow value. It was seen that the products were not viewed as significantly different in value for the third round when only visual attributes were being valued. This implies that the ranking that occurs in round four may be indicative of the warm-glow the participants receive from purchasing the product assuming they were perfect free-riders. As the model demonstrated, the bids cannot be interpreted as the participant's true-willingness-to-pay, only the value of the visual attributes and the warm-glow attributes.

## Summary and Conclusions

In this paper a model was presented that allows for interpreting bids from a second-price auction where the products have embedded environmental attributes. Normally in a second-price auction, it is the bidders' dominant strategy to bid their true valuation for the good being auctioned. It was shown that when public good attributes exist within a product being auctioned and the participant's have the desire to free ride, then it is no longer appropriate to define the bid as the participant's true willingness-to-pay. Using the public good literature, this paper showed one way that the bids can be interpreted from a second-price auction. It was shown that in a second-price sealed-bid auction, only the private value  $v_{i12}$  is the dominant strategy bid for each bidder, where  $v_{i12} = v_{i1} + v_{i2}$ . The term  $v_{i1}$  was defined as the maximum amount of money bidder  $i$  is willing to give up to obtain the physical attributes embodied in the product, whereas,  $v_{i2}$  was defined as the true value the bidder receives from being the one that contributes to the public good, i.e., it is the maximum amount of money the bidder is willing to give up to provide to the public good no matter what other bidders do. This value was related to what the public good literature calls warm-glow altruism. For this value to exist, the bidder must be the one who obtains the item from the auction.

The finding of this paper has a major implication on interpreting the bids from past, current, and future research using second-price auctions to evaluate consumer's WTP for a product that has public good attributes, e.g., organics, biotech that has environmental or other public good attributes, or pesticide reduction or elimination in production of products. Any study that uses a second-price auction to value products that have embedded public good attributes may not get the participant's true valuation of the product. Rather, what you get from this auction is a lower limit of the participant's true valuation.

While this paper has given an interpretation to the bids received in a second-price auction when the products being auctioned have embedded public good attributes, there are many research questions that need to be answered regarding using auctions as a means of valuing goods that have embedded public good attributes. Some of these questions include: 1) Is one auction type better than others to get at bidder's true valuation of products when embedded public good attributes exist? 2) How much free-riding occurs by the participant's when using an auction to value embedded public good attributes? 3) What type of bidding behavior is expected in other auction methods when the good being evaluated has embedded public good attributes? 4) Is an auction an appropriate tool to value a good when it has embedded environmental attributes? These are just a few of the questions that need to be answered to obtain a full understanding of what limitation the second-price auction has of valuing goods that have public good attributes.

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