Demand Curve Effects in Experimental Auctions: The Effect of Quantity Already Owned

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Introduction

Experimental auctions have become an increasingly common mechanism for eliciting consumers' willingness to pay (WTP). In part, the increased prominence of experimental auctions derives from their theoretically demand revealing properties. That is, unlike a hypothetical survey, participants have a dominant strategy to truthfully reveal their preferences through their bids. Comparisons between value estimates from experimental auctions have shown this is indeed the case (e.g., see Fox et al. 1998 and List 2001).

While experimental auctions are demand revealing in theory, there has been much attention in the literature focusing on the “proper” design of auctions. There has been discussion regarding whether participants should bid on products in repeated rounds with posted prices (e.g., List and Shogren 1999 and Rousu and Corrigan 2006b), the effect of endowing participants with products (e.g., Corrigan and Rousu 2006a), and the impact of laboratory versus market environments (e.g., Lusk and Fox 2003).

Across studies, one area where most experimental auction methods are consistent is in dealing with potential substitution or negatively sloped demand-curve effects. These effects occur when participants' bids are affected through the potential of obtaining multiple units of a product during the auction. Researchers usually prevent this possibility by having only one round of bidding (on one unit of a commodity) in the auction serve as the "binding" round where participants can win products (e.g., Dickinson and Bailey 2002 and Alfnes and Rickertsen 2003).

While researchers are careful to control for demand curve effects within an auction, previous studies do not control for demand curve effects from outside the auction. As previously mentioned, a demand-revealing auction theoretically elicits a consumers' reservation price for a product. If bidders may at most win a single unit of the product, then their bids reflect their reservation price for a single unit. But, the fact that bidding is on only a single unit does not yield the researcher any information as to whether consumers are in fact bidding on their 1st or nth (n>1) unit of the product. This arises because it is possible that they currently posses the product through a previous purchase unrelated to the auction. Hence, to the researcher it is unknown whether bids reflect reservation prices for the 1st or nth unit of the product.

Omitting inventories presents problems in the standard design and analysis of experimental auction data.[1] First, if bids by otherwise equivalent individuals with and without inventories are the same, experimental auctions may not properly access willingness to pay or demand. Namely, it would raise the question of whether consumers fully consider their monetary and non-monetary endowments in the somewhat “artificial” market environment of the experimental auction. Conversely, if consumers with and without units of the product do in fact bid differently as theory dictates, this can present a problem for previous studies in that bids are compared from individuals at different points on their demand curves. In addition, if a researcher does not know where an individual bidding in an auction is on his demand curve, it is not possible to distinguish preferences from demand curve effects. For example, an individual who submits a small bid for a product could either have low preferences for the product or high preferences for the product, but with quantity already owned. As illustrated in the next section, this

[1] Please note that while this paper in particular considers the impact of quantity owned in the context of experimental auctions, the implications extend beyond auctions. Other mechanisms commonly used to elicit preferences or valuations (e.g. stated choice experiments) will potentially be affected by the same issue.

has implications for the interpretation and application of auction data, particularly when considering non-durable commodities that are purchased on a repeated basis.

In this article, we examine the impact of outside inventories on bids in a random nth-price auction with fresh broccoli, tomatoes, and potatoes as commodities. After completing the rounds of bidding, participants were asked if they currently have any of the auctioned products at home. Since the auctioned vegetables have a short shelf-life, we propose that individuals with inventory would have lower bids conditional on properly controlling for other confounding factors. Regression analysis indicates that there is a significant "quantity owned effect". This result has important implications for the design of experimental auctions where the target is elicitation and analysis of willingness to pay.

The paper is outlined as follows. The next section provides a simple model of bidding when outside inventories are held. Section 3 describes the auction procedures. Section 4 summarizes bids by individuals with and without quantity owned. Section 5 presents estimates of a fixed-effects regression model. Finally, the paper is concluded.

Model of Auction Bids

To illustrate how product inventories can affect consumers' bids in an experimental auction we present a simple model of product demand and bidding behavior. Consider a representative consumer with a per unit of time monetary budget of Y (e.g., a weekly food budget) to be allocated over a choice set of $N + 1$ goods denoted by $\{z, \boldsymbol{x}\}$ where z is a scalar and $\boldsymbol{x}$ is a vector of N goods. Let market prices for the goods be denoted w and $\boldsymbol{p}$ respectively. At the time of the auction, the consumer may potentially hold inventories of some of the products in their resource set (i.e. products that have been purchased but not consumed/depleted during the time period). For simplicity of exposition, we consider an individual who potentially holds inventories only of good z and denote the quantity already owned as $\bar{z}$ (where $\bar{z} \geq 0$). We assume that there is no resale market for these inventories (or equivalently that the transaction cost for resale is sufficiently high). As well, we assume that a unit of a similar good that is purchased in an experimental auction is a perfect substitute for a corresponding unit in inventory. Given the choice set of goods, market prices, product inventory, and resource constraints, the representative consumer solves a utility maximization problem whose dual representation is the following expenditure minimization problem:

(1) $$e(w, \boldsymbol{p}, U) = \min wz + \boldsymbol{px}, \; s.t. \; U(z + \bar{z}, \boldsymbol{x}) \geq U, \; z, \boldsymbol{x} \geq 0.$$

Immediately from the optimization specification we see that if the consumer holds inventories ($\bar{z} > 0$), the expenditure minimization problem departs slightly from the classic textbook representation. Here, z represents the net demand for the good (i.e. the quantity of additional units the consumer would purchase, $\bar{z}$ is the quantity already owned, and the sum $z + \bar{z}$ is total demand (i.e., the aggregate quantity that would be consumed over an appropriate time interval). For each commodity optimization yields compensated demand functions, $z + \bar{z} = h(w, \boldsymbol{p}, U)$ and $\boldsymbol{x} = \boldsymbol{h}(w, \boldsymbol{p}, U)$, and inverse compensated demand functions (or "WTP curves"), $w = \pi(z + \bar{z}, \boldsymbol{p}, U)$ and $\boldsymbol{p} = \boldsymbol{\pi}(\boldsymbol{x}, w, U)$. The expression $\pi(z + \bar{z}, \boldsymbol{p}, U)$ represents the price the consumer is willing to pay for the $(z + \bar{z})$'th unit.

Now, appealing to the compensating variation measure, we are able to express the consumer's WTP for an additional unit of good z. Assuming that the consumer engages in a fully demand revealing incentive compatible auction, they should submit a bid equal to the maximum amount of money such that they would be indifferent between winning the auction or not. This amount is simply equal to the area under the inverse compensated demand function arising from the change in quantity. Assuming that the consumer is bidding on a single unit of commodity z, their auction bid is

(2) $$Bid_z = \int_0^1 \pi(z + \bar{z}, \boldsymbol{p}, U)dz.$$

The bid expression shows that product inventories can have an impact on bid levels. Specifically, as would be expected, given that π is a non-increasing function in quantity, it follows that the bid level is non-increasing in inventory $\bar{z}$. Hence, we would expect bids by an individual with inventory who is otherwise identical to an individual without inventory to be smaller.

While from the preceding model it is clear that units held in inventory can decrease a consumer's bid-price in an auction, from a researcher's perspective the question remains: is this a concern? The answer depends upon the target of the inquiry and the nature of the goods being considered. For durable goods that are infrequently replaced, consumers' bid-prices conditional on inventories represents their willingness to pay for an additional unit in both the near and more distant future. This is likely the target value a researcher studying these types of goods is seeking, and hence, assuming bidders do in fact consider their inventories when bidding, should receive appropriate bid data.

However, for studies involving non-durable goods that degrade and are characterized by repeated replenishment (e.g., food items that spoil), bids will reflect current conditions, not the near future where inventories are consumed and potentially replaced (e.g., after the refrigerator is depleted and the consumer returns to the supermarket). Using bids without considering the impact of inventories prohibits appropriate analysis of arguably the primary target of such studies, behavior in the next purchase scenario when inventory is depleted.[2]

Furthermore, inventories present a problem when comparing bids across individuals. Since those individuals with higher preferences for the auction commodity are the most likely to be purchasers of the product in the outside market, they are also more likely to be holding inventories at the time of the experiment. For individuals with lower preferences, the converse is likely. Hence, there is a greater likelihood that bids by those individuals who have high preferences are pushed downwards due to them being most probable to be holding inventories. Therefore, potentially resulting in high preference individuals appearing to the researcher as low preference individuals. This would be most problematic for products with relatively inelastic demand curves. Again, while this may not be a problem for durable goods, when considering products such as perishable food items this could lead to bid and welfare analysis that does not appropriately characterize "next period" demand.

Auction Design

The bidding data used in this study is part of a larger project to assess consumers' willingness to pay for genetically modified (GM) and GM Free foods. Participants in the study were solicited from the general public by the Iowa State University Center for Survey Statistics and Methods. Potential participants were invited to participate in a

[2] It could be argued that the potential impact of inventories on bids is more significant in laboratory experiments compared to field experiments given the likelihood of consumers holding smaller or no inventories when arriving to shop at the field experiment location.

university study for $45 in compensation, but were not told beforehand the nature of the project. Willing participants were given their choice between four different session starting times and provided with directions to the site of the experiments. The steps of each experimental session are as follows.

After participants completed a brief questionnaire and consent forms, the session leader provided instructions and examples about the random *n*th-price auction (Shogren et al. 1994) which was used in the study. Participants were further trained on the mechanism by engaging in a two-round practice auction. After the training period, participants were randomly assigned one of five different information treatments containing perspectives on genetic modification. The information treatments included combinations of pro-biotech, anti-biotech, and third-party perspectives on genetic modification. A no information treatment was also included as a control.

After participants finished reading their respective information treatments, the session monitor led the participants through a multi-round random *n*th-price auction. Bids were collected by the session monitor after each round and not posted until all bidding rounds were completed and the single binding round was announced. In each round three separate products were placed up for sale: broccoli (1 lb.), beefsteak tomatoes (1 lb.), and russet potatoes (5 lb.). For the purposes of this study, we are utilizing bidding data on GM Free labeled products and Plain labeled products ("Plain label" denotes a product that bore a label only detailing the product name and weight with no descriptor of genetic modification).

After completion of the bidding rounds participants were asked to complete an exit questionnaire. Among the included questions, three key responses are utilized in this study. For each commodity (broccoli, tomatoes, and potatoes) participants were asked if they (1) currently have any of the vegetable at home, (2) regularly purchase the vegetable, and (3) regularly eat the vegetable. After finishing the exit questionnaire, winners of the auction proceeded to a separate room to purchase their products and non-winners were free to leave.

Bid Summary

In this section, a summary of the auction participants' bids is provided. Table 1 shows the proportion of individuals who indicated that they (1) had the product at home at the time of the auction, (2) regularly eat the food product, and (3) regularly purchase the food product.[3] More than half of the sample regularly eats and purchases each of the three commodities. As well, slightly more than half of the sample at the time of the auction had fresh broccoli and tomatoes at home, and nearly 90% of the auction participants had fresh potatoes in inventory.

Table 1. Summary Statistics for Current Inventory and Habit Variables

Variable	Variable Definition	Broccoli	Tomato	Potato
Purchase	1 if regularly purchase product	0.60	0.58	0.77
Eat	1 if regularly eat product	0.61	0.65	0.81
Have	1 if currently have product at home	0.60	0.58	0.89

Table 2 summarizes average bids for Plain label and GM Free food products, broken-down by responses to whether bidders have the product currently at home, eat and purchase regularly. A null hypothesis of no significant difference in bid prices across responses was tested (an unpaired t-test). Individuals who currently have the commodity

[3] As would be expected, the correlation between regularly eat and regularly purchase is nearly one.

at home have a lower average bid price for some, but not all of the Plain label and GM Free commodities. For none of the food products is the mean difference in bids by those with and without inventory statistically different. This result, when viewed in isolation, fails to confirm the expectation that individuals with quantity owned would bid less than individuals without quantity owned.

Table 2. Mean Bids for Food Products

		Have			Eat			Purchase		
Product	**Label**	**Yes**	**No**	**Diff**	**Yes**	**No**	**Diff**	**Yes**	**No**	**Diff**
Broccoli	Plain	1.21	1.28	-0.07	1.42	0.95	0.47**	1.43	0.95	0.48**
Tomato	Plain	1.42	1.12	0.30	1.67	0.59	1.08**	1.72	0.71	1.01**
Potato	Plain	2.05	1.94	0.11	2.04	1.98	0.07	2.07	1.91	0.16
Broccoli	GMF	1.41	1.49	-0.07	1.57	1.24	0.33	1.59	1.23	0.36*
Tomato	GMF	1.52	1.29	0.23	1.77	0.78	0.99**	1.82	0.88	0.93**
Potato	GMF	2.17	2.50	-0.33	2.14	2.50	-0.36	2.17	2.34	-0.17

Note: * and ** denote significance at the 10% and 5% levels respectively.

When comparing average bids by individuals who eat or purchase the commodities with those who do not, the difference in bids is greater and statistically significant at the 10% significance level for Plain label and GM Free broccoli and tomatoes. This result is in line with expectations in that regularity of consumption and purchase are proxies for individual preferences for the commodities.

While the unconditional analysis of bids presented in table 2 does not provide substantial evidence as to whether inventories affect bid prices, this is not an unexpected result given that other individual-specific factors affecting WTP are not controlled for. Regression analysis presented in the following section yields more conclusive evidence on the impact of inventories.

Econometric Model and Estimates

In order to isolate whether quantity owned impacts bid-prices and to control for other potential confounding factors, a linear fixed-effects model is estimated. The dependent variable is consumers' bid-prices stacked over the three commodities (broccoli, tomato, and potato) and the two labeling treatments (Plain label and GM Free). Fixed effects are included for each of the auctioned commodities. The two key independent variables for this study are dummies for *have* and *purchase* which respectively denote if the participant responded that he/she currently have the vegetable in inventory at home and if he/she regularly purchases the vegetable.[4] Additional explanatory variables were included to control for other demographic and preference attributes that may affect bid-prices include: dummy variables for each *information treatment* (no information treatment dummy omitted), *income* (in thousands), *gender* (1 if female), *informed* (1 if participant responded as being well or extremely well informed about GM), *opinion* (1 if the participant responded as having a supportive opinion of GM), *education* (years of schooling), environmental member (1 if member of an environmental group), and *healthiness of diet* (self assessed healthiness of diet on a 10 point scale). Regression estimates are presented in table 3.

The coefficient estimate associated with *have* is negative (-0.238) and statistically significant at the five percent level (p=0.030). This result shows, controlling for other confounding factors, that participants with product inventories acquired outside of the auction do submit lower bids than those individuals who do not have outside inventories.

[4] Due to the high multicollinearity between responses to regularity of "purchase" and "eat", only a dummy variable for purchase is included.

This result supports the hypothesis that consumers in an experimental auction, even conducted in a laboratory style setting, do submit bids reflecting their global willingness to pay - conditional on both their monetary and non-monetary endowment - as standard theory suggests. In addition, this result gives further credence that despite the partially "artificial" nature of experiments, consumers evaluate their willingness to pay considering outside factors just as occurs when making decisions in a conventional market.

Table 3. Fixed Effects Regression Results (N=342)

Variable	Parameter Estimate	Standard Error
Have	-0.238*	0.109
Purchase	0.384**	0.115
Info Treatment 1	0.127	0.147
Info Treatment 2	-0.197	0.165
Info Treatment 3	0.456**	0.151
Info Treatment 4	-0.374*	0.176
Income	0.004**	0.001
Informed	0.285	0.223
Opinion	0.222	0.147
Gender	-0.072	0.131
Education	-0.059*	0.025
Envi Member	-0.600*	0.285
Healthiness of Diet	0.034	0.029
Constant	1.962**	0.432

Note: * and ** denote significance at the 5% and 1% levels respectively.

The coefficient for *purchase* is positive (0.384) and significant at the one percent level indicating that individuals who regularly purchase the commodity in the outside market are willing to pay more in the auction than those who do not regularly purchase the commodity. This falls in line with expectations in that we would expect individuals who are regular purchasers in the outside market (i.e. individuals with a WTP greater than the market price) to bid more than non-regular purchasers (i.e. individuals with a WTP less than the market price).

Several additional variables, which we do not focus on here, were found to be significant in explaining bid-prices including income, education, environmental member, and two of the information treatments.

Conclusion

While most studies utilizing experimental auctions take care to avoid possible bid biases arising from substitution and negatively sloped demand-curve effects within an auction, this is the first study to the knowledge of the authors to consider the impact of demand-curve effects arising from inventories acquired outside the auction. The implications of this study are a bit double-edged. On the positive side, the estimates of the impact of quantity owned on bidding behavior agree with basic economic demand theory and indicate that participants in auctions do in fact consider their non-monetary endowment when placing bids. If this were not the case, it would raise the question of whether experimental auctions truly capture consumers' market decisions.

Given these demand-curve effects of inventories, problems arise in interpreting bids submitted in other experimental auctions. If information on whether individuals have quantity owned is not solicited from auction participants, then it is not possible to distinguish where individuals are on their demand curve. Hence, it is not possible to distinguish whether a low bid is because an individual in fact has a low WTP for the product, or simply because they are further along their demand curve due to quantity already owned. Whether experimental auction bids are used for assessing market demand, policy impacts, or welfare effects, this uncertainty about what bids actually reflect presents a problem and could lead to biased or simply incorrect estimates and conclusions.

The results of this study raise a number of potential avenues for further research. A common dilemma in experimental auctions is the prevalence of bids of zero. The author is left asking whether for many experimental auctions that consider valuations for products with steep or binary demand curves if a portion of the zero bids could be explained by quantity already owned. A second issue, not considered explicitly in this study, is what is the impact of substitute or complement goods that are already in a household's inventory? This is an interesting question not only because of the potential impact on bidding behavior, but also because it raises the possibility that researchers might need to assess a wide array of demand curve effects for each auctioned commodity. Finally, one shortcoming of this paper is that we did not ask consumers to report the exact quantity of fresh vegetables held in inventory coming into our experimental auction. While this was done by design over concerns regarding the vagaries of vegetable sizes and weights, future research might elicit this information and permit an in depth analysis of inventories on WTP curves.

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