Demand Curve Shifts in Multi-Unit Auctions:

Evidence from a Laboratory Experiment [a,b]

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Abstract

Basic economic theory predicts that a consumer's willingness to pay for a good is affected by the presence of complements and substitutes. In an auction setting, this theory implies that the presence of complements would increase bid prices for a good, while the presence of substitutes would decrease bid prices for a good. However, several experimental auction studies have sold complementary or substitutable products without regard for the effects these actions could have on bidding behavior. Using data from an experimental auction specifically designed to test the effect of complements and substitutes on bids, we used both unconditional tests and conditional tests where we derived demand flexibilities to analyze whether selling complementary and substitutable products has an effect on bids. Our results show that the availability of complementary and substitutable products affects bids in the expected directions. This finding has important implications for researchers who design experimental auctions.

Introduction

One of economic theory's most basic predictions is that consumer demand is affected by the availability of substitutes or complements. In the context of auctions, this prediction implies that the bids submitted for a good should increase when auction participants also have the chance to win a complementary good, and that these bids should decrease when they also have the chance to win a substitute good.[1] But researchers who use experimental auctions in consumer demand studies are typically only interested in estimating the value of a good in isolation, and therefore wish to avoid the confounding effects introduced by complements and substitutes. To deal with this potential problem, many researchers choose to elicit bids for several products, with the understanding that only one of the products being bid on will actually be sold (e.g., Roosen et al., 1998). Other researchers allow for the possibility that a participant may win more than one good, but are careful to ensure that those goods are unrelated (e.g., Rousu et al., 2004). Others, despite the predictions of economic theory, allow participants to win multiple goods that are clearly complements or substitutes for one another (e.g., Noussair et al., 2002; Umberger et al., 2002; Noussair et al., 2004).

While economic theory predicts auction participants will change their bids in the presence of complements or substitutes, we know of only one paper that has addressed this issue. List and Lucking-Reiley (2000) examine sales of multiple units that were identical (i.e., perfect substitutes) and find that consumers lower their bids for the second unit of a commodity, as expected. However, no research has examined the impact that selling complements or non-identical substitutes will have on bids submitted in experimental auctions.

This paper contributes to the literature in two important ways. First, we report the results of an experimental auction for three commonly consumed food products to test if consumers change their bidding behavior when they may win multiple products that are complements or substitutes. Given the explosion of papers using experimental auctions, this paper provides timely insight into an issue that is often overlooked by experimental economists. Second, to assist in estimating the effects of complements and substitutes, our experimental design allows us to estimate demand flexibilities (the inverse-demand counterpart to demand elasticities). To our knowledge, this is the first paper to estimate demand flexibilities using experimental auctions. Given the fundamental nature of elasticities and flexibilities in economics analysis, we hope this paper will help assist in expanding the use of demand flexibilities in experimental auctions.

Experimental Design

Ninety-four undergraduate students took part in this study. All of these students were enrolled in Principles of Economics courses at a large Midwestern university. The participants bid on combinations of the following three food products in a series of 25 rounds: a 16-ounce jar of salsa, an 8-ounce bag of plain-labeled tortilla chips, and an 8-ounce bag of tortilla chips labeled "Made in America from American Ingredients." We chose these specific products because we believed it was likely that the participants would be familiar with them. The labels were kept basic to avoid the potential of a label's design affecting bids and confounding our results.

Three elements of our experimental design warrant careful discussion: the auction mechanisms used, the rounds of bidding, and the specific steps in the auction.

To ensure that our results were not simply an artifact of the auction mechanism used, we varied the auction mechanism across treatments. Participants in both treatments bid using auction mechanisms that are demand revealing (i.e., bidding one's true value is a weakly dominant strategy). In the first treatment, participants bid on goods using the second-price, sealed-bid auction (Vickrey, 1961). In the second treatment, participants bid on goods using the random *n*th-price auction (Shogren et al., 2001). In the second-price, sealed-bid auction, each participant submits a sealed bid for a product. The auction monitor sorts the bids from highest to lowest and the highest bidder wins the auction and pays the second highest bid price for the product. The random *n*th-price auction differs only in that the monitor randomly selects a number between 2 and N (where N is the number of participants), and the bid price corresponding to that number becomes the *n*th price. The $n - 1$ bidders who submitted bids higher than the *n*th price then purchase the product paying the randomly selected *n*th price.[2]

Participants bid on the food products in two sessions, each with multiple rounds. The ordering of these sessions was varied across treatments, and the ordering of rounds was varied across participants. Participants understood that, though they were submitting bids in multiple rounds, only one of those rounds would be chosen as binding (or valid). In order to avoid affiliation of bids across participants, no market prices were posted.

Session A consisted of 19 rounds of bidding. In each round, participants bid on various combinations of food products, as described in Table 1. These participants bid on one unit of each product individually, two units of each product individually, and three units of each product individually. They also participated in 10 additional rounds, where they bid on different combinations of multiple products. Structuring the experiment in this way allows us to obtain own-price flexibilities, because participants are bidding on more than one unit of each product. We can also obtain cross-price flexibilities, because participants are bidding on combinations of different products.

Session B consisted of six rounds of bidding. Participants understood that, if one of these six rounds was chosen as the binding round, each of the participants would be endowed with one unit of a good and that they were bidding to purchase an additional unit (of the same good or of a different good, depending on the round).[3]

The experiment included seven steps. In Step 1, the participants arrived, completed a consent form, and were paid $5 for participating. Each participant was also assigned an I.D. number, in order to maintain anonymity.

In Step 2, participants were given instructions (both written and oral) on the auction mechanism to be used in that treatment. Participants then took a short quiz on the specific details of the auction mechanism.

In Step 3, participants took part in a series of three practice auctions. In the first practice round, all participants submitted a sealed bid to purchase one Hershey's candy bar. In the second practice round, participants submitted a sealed bid to purchase one Hershey's candy bar *and* one Krackel candy bar. In the third practice round, participants were told that, if this round were chosen as the binding round, everyone in the room would be given a Hershey's candy bar, and the auction winners would also purchase a Krackel candy bar. The participants then submitted a sealed bid to "upgrade" from a Hershey's bar to a Hershey's bar and a Krackel bar. After these rounds were completed, the monitor announced which round was to count as the binding round and determined the winner(s) (by determining the second price in the second-price treatment or by choosing the *n*th price in the *n*th-price treatment). These practice rounds were sufficient to ensure that participants understood both the auction mechanism and the format of the upcoming rounds—that the auction would involve several rounds, that only one round would be binding, and that in some of the rounds they would be bidding to upgrade from one unit to two.

In Step 4, participants were given the chance to examine the three food products for sale in the auction. Depending on the experimental unit, they began by bidding in either Session A or Session B. In both sessions, the order that participants bid on the food products was randomized to reduce any potential order effects.[4]

In Step 5, participants bid in Session A or Session B, whichever session they did not bid in during Step 4.

In Step 6, the monitor announced the binding round. If the binding round was from Session B, the endowed good was distributed at this point in the experiment. Next, the auction winners were determined, and any transactions agreed to were carried out.

In Step 7, all participants completed a questionnaire eliciting background and demographic information, which concluded the experiment.

While we followed standard experimental auction procedures (e.g., Shogren et al., 1994), we made several refinements to enhance our experimental design. First, we did not post market prices for products, as recent evidence indicates that experimental participants can be influenced by a "posted-price" effect (List and Shogren, 1999; Corrigan and Rousu, 2003). Second, we randomized the order of the rounds across participants. Doing so ensured that the order of bidding did not systematically influence our results. Third, we sold multiple units of commodities across rounds, thus allowing us to estimate demand flexibilities. Most experimental auctions only sell one unit of a good, which prevents estimation of demand flexibilities.

Econometric Model

Participants in our auctions bid on multiple units of the three products. To examine preferences for these products, we first needed to determine the marginal valuations (prices) for each product. When only one unit of a product was available, this task was trivial, because we could simply use the bid price submitted. However, when two units were available, the process was more complicated. To obtain the marginal valuation for the second unit, we took a participant's total bid for two units and subtracted his bid for one unit of the product.[5] This formula allows us to calculate a bid price for the second unit of the commodity. We used a similar process to determine the bid price for the third unit of the commodity.[6]

We used logarithmic models to estimate inverse demand equations, as we expected a nonlinear demand curve. An advantage to using logarithmic models when estimating conventional demand equations is that the coefficients represent demand elasticities. In these conventional markets, quantity is a function of price, given that consumers face a fixed price and must then determine the quantity they demand. In an auction framework, however, price is a function of quantity, given that participants face a fixed shift in quantity and must then determine the price they are willing to pay. Because of this feature, we estimate the inverse demand for these products. Thus, our measures of responsiveness are demand flexibilities rather than elasticities. Demand flexibility measures the responsiveness of consumer bid prices to the quantity available and is analogous to the more familiar price-elasticity measures used in analyzing regular demand curves.

The bid prices submitted in our auctions for each of the three products are hypothesized to be dependent on the quantity of the product available, the presence and quantity of complementary or substitutable products, and the participants' demographic characteristics, as shown for each product in Equations 1 through 3:

$$(1) \qquad \ln P^{Salsa} = \alpha + \beta_1 \ln Q^{Salsa} + \beta_2 \ln Q^{pl\text{–}ch} + \beta_3 \ln Q^{US\text{–}ch} + \gamma X + \varepsilon$$

$$(2) \qquad \ln P^{pl\text{–}ch} = \alpha + \beta_1 \ln Q^{Salsa} + \beta_2 \ln Q^{pl\text{–}ch} + \beta_3 \ln Q^{US\text{–}ch} + \gamma X + \varepsilon$$

$$(3) \qquad \ln P^{US\text{–}ch} = \alpha + \beta_1 \ln Q^{Salsa} + \beta_2 \ln Q^{pl\text{–}ch} + \beta_3 \ln Q^{US\text{–}ch} + \gamma X + \varepsilon$$

In Equations 1 through 3, P is the bid price submitted by the participants, Q is the quantity of each product available and β the corresponding coefficient, X is a vector of demographic characteristics, γ is the corresponding set of coefficients, and ε is the random error term. The *pl-ch* superscript refers to plain-labeled chips. The *US-ch* superscript refers to chips labeled "Made in America from American Ingredients."

Because we used a log specification, zero bid prices cannot be used. Thus, bid prices of zero were changed to equal bid prices of 1/100th of a penny ($0.0001).[7] In addition, when one of the complementary or substitutable products was not available to be bid on (i.e., a zero quantity was available); we changed the zero quantities to 0.0001, so that the model was defined.

In only one of the 19 rounds were all three products available in positive quantities. To accurately estimate the own bid price for the regressions shown in Equations 1 through 3, rounds where the quantity of the own good was zero were deleted. For example, to estimate Equation 1 (the log bid price for salsa), we only use the observations where there were one, two, or three units of salsa available, not the observations where zero units of salsa were available.[8] For each equation, there are 10 observations for each participant; therefore, we estimated Equations 1 through 3 using a random effects model.[9]

Results

We discuss both unconditional results and conditional results from estimating demand flexibilities. First consider the unconditional results. The mean bids for the products are shown in Table 2. To better understand how movements of a participant's demand curve could affect bidding behavior, consider Equation 4, which would hold in the absence of demand curve shifts or a binding budget constraint:

(4) $$Bid(A) + Bid(B) = Bid(A+B)\ .$$

According to Equation (4), if participants place separate bids on products A and B (when they know they cannot win both products), the sum of their bids to purchase both products individually should equal their bid to purchase both products A and B together. When products are complements, economic theory predicts that the right-hand side of Equation 4 will be greater than the left-hand side. When the products are substitutes, theory predicts that the right-hand side of Equation 4 will be less than the left-hand side. Figure 1 shows the expected shift in demand when a complementary product is presented to consumers.

Table 3 compares the sum of the individual bids for two products with the bids for the pair of products sold together. This comparison allows us to test Equation 4, which will provide insight into how bidding behavior changes in the presence of complements or substitutes. When the two products sold are complements, the bid for the pair of items when sold together is greater than the sum of the bids for each item individually. A nonparametric, one-sided Wilcoxon signed-rank test shows that these results are statistically significant at the 1-percent level for the American-labeled chips and salsa, but only marginally significant for the plain-labeled chips and salsa (p value = 0.06).[10]

When the two products are substitutes (the two bags of tortilla chips), the bids for the pair of products when sold together is smaller than the sum of the bids for each item individually. This result is statistically significant at the 1-percent level using a one-sided Wilcoxon signed-rank test (at the 5-percent level using a one-sided t-test). Our results show that both complementary and substitutable products affect consumer bids in a way that is consistent with economic theory. Further, more than 44 percent of participants shifted their demand when presented with multiple products.[11] These results have implications for researchers who wish to use experimental auctions to estimate the value of multiple goods. With a large percentage of participants changing their bids in the presence of complements or substitutes, researchers who sell related products in an experimental auction run the risk of biasing their results either upward or downward.

Tables 4, 5, and 6 show the conditional results from the random effects regressions. Table 4 shows the results of the regression examining the bid price for the bag of plain-labeled tortilla chips. The coefficients for the log of the quantities available are of most interest in this analysis, because these coefficients are the demand flexibilities. The own-quantity flexibility is approximately –1.1, which indicates that a 10-percent increase in the quantity of tortilla chips available would cause consumers to bid approximately 11 percent less.[12]

The cross-flexibilities show how a change in the quantity of American-labeled chips or salsa available changes the bid price for plain-labeled tortilla chips. The cross-flexibility for American-labeled tortilla chips is approximately zero. The cross-flexibility for salsa on the price of plain-labeled tortilla chips is small, 0.06, but is statistically significant. This relationship indicates that a 10-percent increase in the availability of salsa would yield a 0.6-percent increase in the bid prices for plain-labeled tortilla chips, thereby indicating that the consumers in the experiment considered tortilla chips and salsa complements, as expected.

Tables 5 and 6 show the demands for the American-labeled chips and the jar of salsa. The own-price flexibility for American-labeled tortilla chips is close to –1, while the own-price flexibility for the jar of salsa is approximately –2, confirming that consumers are very sensitive to the quantity of salsa available, because the price participants would pay diminishes rapidly with an increase in the quantity sold. The cross-price flexibilities are similar to those for the plain-labeled tortilla chips, in that the cross-price flexibilities for the American-labeled tortilla chips and the jar of salsa are small but display the expected complementary relationship.

In addition, we include several background and demographic variables in order to examine their impact on the bids for these three products. However, only the participants' race had a statistically significant impact on the bid prices; white participants bid less for all products. This result is statistically significant at the 5-percent level for tortilla chips but only significant at the 10-percent level for the jar of salsa and the bag of American-labeled chips.

While we think that designing an experimental auction such that it allows researchers to estimate demand flexibilities is a methodological advancement, two caveats should be mentioned. First, we found evidence of colinearity in some regressions. Thus, the regression coefficients should be interpreted with some care. Second, in order to estimate our model, we had to correct for the zero quantities available in the auction. However, given that elasticities and flexibilities are commonly reported in almost all other fields within economics, we think this paper provides an important first step in introducing a design that allows for the estimation of demand flexibilities.

Conclusion and Significance

Despite the predictions of economic theory, several recent experimental auctions examining consumer behavior have allowed auction participants to win several goods that were close substitutes. Until this study, however, there was no empirical evidence that selling complements or substitutes together in the same auction could affect consumer bids. This paper reports the results of an experimental auction designed to test whether complements or substitutes affect participants' bids.

We find that, when bidding on a product, participants bid more when also bidding on a complementary product and bid less when also bidding on a substitutable product. These findings suggest that value estimates from auctions where participants could possibly win multiple substitute goods may understate the goods' values in isolation. This is likely to occur in the experimental auction studies that have allow consumers to win multiple products that are close substitutes. The opposite is true if the goods are viewed as complementary. We also estimated demand flexibilities that confirmed the unconditional results: the presence of complements increased bids, while the presence of substitutes decreased bids.

These results have implications for the design of experimental auctions. Researchers who wish to sell multiple goods should attempt to ensure that the goods are neither complements nor substitutes (e.g., Huffman et al., 2004). Another alternative is to collect bids on multiple products in different auction rounds and then randomly select one binding round. Using this method, participants can win one good at most (e.g., Roosen et al., 1998). This paper has shown that the results from studies that sell complementary or substitutable goods may be confounded by the effects of demand-curve shifts.

Footnotes

[1] Ausubel and Cramton (2002) developed a theory that explores this point for substitutes. The FCC's spectrum auctions are an example of a non-experimental auction where participants may bid on many complementary and substitutable items (e.g., see Cramtom, 2003).

[2] The complete set of instructions given to participants is available from the authors upon request.

[3] The results from these six rounds are not reported in this paper but instead are reported in a complementary paper that examines the persistence of the endowment effect.

[4] For evidence on how ordering matters in experimental auctions, see Huffman et al. (2003).

[5] Note that in rounds where multiple products were being auctioned, participants placed one bid price for obtaining a bundle of multiple products.

[6] Recall that we used different auction mechanisms for different participants. Statistical tests could not reject the null hypothesis that there was no difference between the bids from participants using the separate auction mechanisms. Because the treatments were independent of one another and the bids did not differ significantly, we pooled the data across auction mechanisms.

[7] We also ran regressions with zero bid prices estimated at 0.001 (higher) and 0.00001 (lower). The results were qualitatively similar to the results we report in this paper.

[8] We could have estimated a "choke price" (i.e., the price at which quantity demanded would be zero) and then used all observations. But, because the choke price would have been estimated by the regressions shown in Equations 1 through 3, we saw no advantages to using that method.

[9] We also ran a fixed effects model and found the same qualitative results, which are available from the authors upon request. A Hausman test indicated no significant differences between the fixed and random effects models (Hausman and Taylor, 1981).

[10] Using a t-test, we obtain similar results with two-sided p-values of 0.01 and 0.07, respectively.

[11] The table that contains this result can be obtained from the authors upon request.

[12] We also ran these models correcting for censoring of the dependent variable and found similar results. This is to be expected because approximately 90 percent of the bids were greater than zero.

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Table 1. The 19 Rounds of Bidding in Session A

Round	Quantity of Plain-Labeled Chips	Quantity of Made-in-America-Labeled Chips	Quantity of Salsa
1	1	0	0
2	2	0	0
3	3	0	0
4	0	1	0
5	0	2	0
6	0	3	0
7	0	0	1
8	0	0	2
9	0	0	3
10	1	1	0
11	1	0	1
12	0	1	1
13	2	1	0
14	2	0	1
15	0	2	1
16	1	2	0
17	0	1	2
18	1	0	2
19	1	1	1

Table 2. Mean Bids (N=94)

Part A: Bids for 1, 2, and 3 Units of Each Commodity

Product(s)	Mean	Median	Standard Deviation	Minimum	Maximum
First bag of plain-labeled chips	$0.51	0.28	0.51	0	2.00
Second bag of plain-labeled chips	$0.45	0.25	0.50	0.00	2.00
Third bag of plain-labeled chips	$0.40	0.25	0.77	-3.00	5.00
First bag of American-labeled chips	$0.58	0.48	0.56	0	2.25
Second bag of American-labeled chips	$0.52	0.25	0.62	-0.50	2.80
Third bag of American-labeled chips	$0.45	0.25	0.65	-3.00	2.30
First jar of salsa	$0.65	0.50	0.57	0	2.30
Second jar of salsa	$0.55	0.36	0.62	-0.20	2.50
Third jar of salsa	$0.40	0.25	0.70	-2.50	2.01

Part B: Bids for Combinations of 2 Items

1 bag of plain-labeled chips and 1 bag of American-labeled chips	1.03	0.95	0.95	0	4.25
1 bag of plain-labeled chips and 1 jar of salsa	1.24	1.00	1.10	0	5.50
1 bag of American-labeled chips and 1 jar of salsa	1.31	1.00	1.08	0	5.00

Table 3. How Do Bids Change in Bundles of Complements or Substitutes? The Value Is the Bid for the Bundle of Goods Minus the Sum of the Individual Bids for the Products (N=94).

Products	Mean Deviation
Plain-labeled chips and jar of salsa	0.09
Standard deviation	(0.58)
American-labeled chips and jar of salsa	0.16 **
Standard deviation	(0.57)
Plain-labeled chips and American-labeled chips	-0.06 **
Standard deviation	(0.30)

** Statistically significant at the 1-percent level (using a one-sided Wilcoxon signed-rank test)

Table 4. Random Effects Model

Dependent variable: log of bid price for plain-labeled tortilla chips

	(1)	(2)	(3)	(4)	(5)
Intercept	–1.63**	–0.29	–0.41	0.91	1.08
	(0.30)	(1.35)	(1.41)	(1.56)	(1.64)
Log (quantity of plain-	–1.09**	–1.09**	–1.09**	–1.09**	–1.09**
labeled tortilla chips)	(0.17)	(0.17)	(0.17)	(0.17)	(0.17)
Log (quantity of American-	0.00	0.00	0.00	0.00	0.00
labeled tortilla chips)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Log (quantity of salsa)	0.06**	0.06**	0.06**	0.06**	0.06**
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Female			0.12	0.11	0.12
			(0.58)	(0.58)	(0.58)
Race: white				–1.38*	–1.40*
				(0.61)	(0.61)
Log (income)		–0.27	–0.26	–0.33	–0.31
		(0.27)	(0.28)	(0.27)	(0.27)
GPA					–0.07
					(0.20)

** Statistically significant at the 1-percent level.
* Statistically significant at the 5-percent level.

Table 5. Random Effects Model

Dependent variable: log of bid price for American-labeled tortilla chips

	(1)	(2)	(3)	(4)	(5)
Intercept	–1.49**	–0.39	–0.43	0.61	0.66
	(0.29)	(1.26)	(1.38)	(1.47)	(1.54)
Log (quantity of plain-	0.00	0.00	0.00	0.00	0.00
labeled tortilla chips)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Log (quantity of American-	–1.00**	–1.00**	–1.00**	–1.00**	–1.00**
labeled tortilla chips)	(0.17)	(0.17)	(0.17)	(0.17)	(0.17)
Log (quantity of salsa)	0.05**	0.05**	0.05**	0.05**	0.05**
	(0.015)	(0.002)	(0.002)	(0.02)	(0.02)
Female			0.03	0.02	0.03
			(0.55)	(0.54)	(0.55)
Race: white				–1.08	–1.08
				(0.60)	(0.60)
Log (income)		–0.22	–0.22	–0.27	–0.27
		(0.25)	(0.26)	(0.25)	(0.26)
GPA					–0.07
					(0.20)

** Statistically significant at the 1-percent level.
* Statistically significant at the 5-percent level.

Table 6. Random Effects Model

Dependent variable: Log of bid price for salsa

	(1)	(2)	(3)	(4)	(5)
Intercept	–1.24**	–0.99	–0.44	0.53	0.31
	(0.28)	(1.24)	(1.34)	(1.43)	(1.50)
Log (quantity of plain-	0.02	0.02	0.02	0.02	0.02
labeled tortilla chips)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Log (quantity of American-	0.01	0.01	0.01	0.00	0.00
labeled tortilla chips)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Log (quantity of salsa)	–1.94**	–1.94**	–1.94**	–1.94**	–1.94**
	(0.19)	(0.19)	(0.19)	(0.19)	(0.19)
Female			–0.56	–0.57	–0.58
			(0.53)	(0.53)	(0.53)
Race: white				–1.01	–0.98
				(0.55)	(0.56)
Log (income)		–0.05	–0.11	–0.17	–0.17
		(0.24)	(0.25)	(0.25)	(0.25)
GPA					0.10
					(0.18)

** Statistically significant at the 1-percent level.
* Statistically significant at the 5-percent level.

Figure 1. When Complements Are Present, What Should Happen to Bids in an Auction?