DRAFT: Do not quote without authors' permission

Exploring Respondent's Perception of Bid Precision in Non-Market Valuation

Christopher D. Azevedo
Department of Economics and Finance
University of Central Missouri
Warrensburg, MO 64093-5074
(660) 543-4219
cazevedo@ucmo.edu

John R. Crooker
Department of Economics and Finance
University of Central Missouri
Warrensburg, MO 64093-5074
(660) 543-8601
jcrooker@ucmo.edu

Brian Pattiz
Department of Economics
Iowa State University
bpattiz@iastate.edu

April 2007

Abstract

Bid design is an important component of the nonmarket valuation process. To date, no research has been done on the possible effects of using round dollar amounts. It seems reasonable to believe that respondents may respond to round dollar amounts differently than they would respond to bids that include both dollar and cent amounts. One possibility is that the respondent may infer that the dollar/cent bids are more precise estimates of the true cost than the round dollar amount, and therefore put more thought into their response to survey questions.

In order to explore this idea, we test whether the use of a precise versus imprecise bid design influences respondent's willingness to pay. In particular, our sample of survey recipients was stratified into two groups based on whether they were presented with imprecise or precise bids (round dollar bids or dollar/cent bids). Precise bids were generated by adding or subtracting a randomly-drawn number of cents (between -200 and +200 cents) to each of the imprecise bid levels.

We explore this issue in the context of a valuation project concerned with The Battle of Lexington State Historic Site in Lexington, MO.

Introduction

The use of Stated Preference (SP) estimation techniques in non-market valuation has increased dramatically over the past couple of decades. A variety of SP methods have been created and refined including the Contingent Valuation (CV) method, the Contingent Behavior (CB) method, and the Choice Experiment (CE) methods. These methods have been used to value a variety of goods from water quality to cultural heritage.

An important consideration in the use of these methods is the design of the bids that are presented to the respondents. A great deal of work has been done on the issue of bid design in both single and double-bounded frameworks, including the effect of changes in bid range and interval on willingness to pay (wtp) estimates, the effect of changing the number of surveys at each bid level on wtp estimates, and the effect of truncating the bid distribution. See Cameron and Huppert (1989), Duffield and Patterson (1988, 1991), Cooper and Loomis (1992), Alberini (1995), Boyle, MacDonald, Cheng, and McCollum (1998), Scarpa and Bateman (2000), and Roach, Boyle, and Welsh (2002).

To date, no work has been done on whether the dollar/cent presentation of the bid has any impact on willingness to pay estimates. It may be the case that respondents perceive bids presented in whole dollar amounts differently than bids that are not presented in whole dollars. One possibility is that the respondent may infer that the dollar amount they have been presented with is a more precise representation of the true cost if it contains cents. This in turn might cause them to answer the question differently than if they were presented with a round dollar amount and felt that this was an imprecise guess by the researcher at the true cost. This issue is similar to discussion in the literature concerning the respondent's budget constraint. Some researchers have argued that respondents may ignore or downplay their budget constraint when answering valuation questions, and reminding them of their budget constraint prior to asking the valuation question can have an impact on their answer (Arrow et al. 1993; Loomis, Gonzalez-Caban, and Gregory 1994; Kemp and Maxwell 1993).

To examine the issue of whether the exact form of the bid influences the respondent's willingness to pay, we used a standard contingent valuation question with a variation on the standard bid design. In particular, we presented one half of the respondents with bids in round dollar amounts, which we refer to as the "imprecise" bids, and the other half we presented with bids in dollar/cent amounts, which we refer to as the "precise" bids. In the following sections we describe the survey, the bid design, the models estimated with each subsample, and the conclusions we draw.

The Survey

The data used in this investigation was gathered using a survey designed to elicit information about respondent's attitudes and values for the Battle of Lexington State Historic Site (SHS) located in Lexington, Missouri. Lexington was the site of an important Civil War battle that took place in 1861. The battle, and the events that took place immediately after it, played a key role in determining the fate of the State of Missouri during the Civil War. The site, which is located approximately 40 miles east of Kansas City, draws approximately 29,000 visitors per year. The site includes a visitor's center with a variety of exhibits designed to interpret the event before, during, and after the war. The preserved portion of the original battlefield is relatively modest in size, but contains the remains of the original entrenchments as well as a preserved antebellum home that played a key role in the battle.

The Battle of Lexington SHS Survey was designed in cooperation with the Missouri Department of Natural Resources, and was sent to a sample of 400 park visitors. The sample was randomly drawn from visitors who signed the guest registry located in the visitor's center. It is important to note that this sampling procedure is less than ideal. Visitors who did not sign the registry have zero probability of being selected, while visitors who visited the park several times and signed the registry more than once have a higher probability of being selected than visitors who signed only once. Though this may result in a biased sample, for the purposes of this investigation it matters little.

Standard survey procedures were followed with the Battle of Lexington SHS Survey. In particular, recipients who had not replied within two weeks of the initial mailing were sent a reminder postcard. Recipients who had not replied within an additional two weeks were sent a second copy of the survey. Those who did not reply to the second survey were not contacted further. Of the 400 surveys mailed, 66 were returned by the post office as undeliverable. The response rate for deliverable surveys was 40.42%.

Bid Design and Model

The survey included a dichotomous choice contingent valuation question that was designed to allow for estimation of the total value that respondents place on the site, including its values as both a recreation and cultural heritage good. The contingent valuation question took the form, "Would you vote 'yes' on a referendum that would create a Battle of Lexington State Historic Site Fund? This fund would insure that the site is maintained it its current state and would be used to fund all expenditures including administrative expenditures and visitor services. Failure of the referendum would result in closure of the park. Suppose passage of the referendum would result in a one-time increase in your tax bill of $\$Bid$ (payable in five $\$Bid/5$ installments over a five year period)." Values of the bid varied across respondents according to a bid design of the following form: five bid level of $50, $150, $300, $600, and $1000 were used, with each bid level allocated to 20% of the respondents. Half of the survey recipients received a survey with this bid design.

The other half of the recipients received a survey with a slightly modified bid design. To generate the bids for this subsample, a randomly-drawn amount of cents was added to the original bid design. The amount of cents added was drawn from a uniform distribution with a minimum of -$2 and a maximum of +$2. For example, the first 20% of the first subsample was presented with a bid of $50, while the first 20% of the second subsample was presented with bids that might look like: $49.63, $50.76, $51.12, $48.42, etc. The mean bid for the first 20% of the second subset is $50 by design. The resulting bid design presented to the second subset of recipients consists of 200 unique bids, although the bids are tightly clustered around the bid levels presented to the first subset of recipients.

The valuation model we use is based on the approach taken by Cameron (1988). In particular, the respondent will answer "yes" to the dichotomous choice contingent valuation question if their willingness to pay for the good in question is greater than the bid they are presented with. We can characterize the probability of respondent i answering "yes" in the following manner

$$\Pr\left[yes_i\right] = \Pr\left[wtp_i > Bid_i\right]. \tag{1}$$

Assume that the respondent's willingness to pay takes the form

$$wtp_i = \beta X_i + \varepsilon_i, \tag{2}$$

where wtp_i represents consumer i's willingness to pay, β is a parameter vector, X_i is a data matrix, and ε_i is a mean zero, iid random error. Combining (1) and (2), we get

$$\Pr\left[yes_i\right] = \Pr\left[\beta X_i + \varepsilon_i > Bid_i\right]. \tag{3}$$

This statement can be further modified to

$$\Pr\left[yes_i\right] = 1 - \Phi\left[\frac{Bid_i - \beta X_i}{\sigma}\right]. \tag{4}$$

Equation (4) can be used to estimate the parameters of the willingness to pay function as well as the standard deviation, σ.

Model Results and Hypothesis Tests

The first step in estimating the model discussed above is the explicit specification of the willingness to pay function described in equation (2). We assume that willingness to pay takes the following form

$$wtp_i = \beta_0 + \beta_1 Inc_i + \beta_2 Gen_i + \beta_3 Age_i + \beta_4 Ed_i + \varepsilon_i, \tag{5}$$

where wtp_i represents consumer i's willingness to pay, Inc_i represents income, Gen_i represents gender, Age_i represents age, Ed_i represents education, and ε_i represents the random error. This model was estimated using both the precise and imprecise subsamples. The results of these estimations are shown in Table 1.

Column two of Table 1 contains the raw parameter estimates and t-statistics for the precise subsample. These parameters must be adjusted in order to correctly interpret them. An examination of equation (4) shows that the parameter associated with the bid is actually the reciprocal of the standard deviation. The other raw parameter estimates are also confounded with the standard deviation and must be adjusted. Column three contains the adjusted parameter estimates for the precise subsample. Columns four and five contain the raw and adjusted parameter estimates for the imprecise subsample.

An important thing to note about the precise and imprecise results is that the parameter associated with the bid is statistically significant for the subsample estimated with precise bids while it is not statistically significant for the subsample estimated with imprecise bids. This presents a problem because we cannot reliably form the bid function if we cannot argue that the coefficient on bid is statistically different from zero.

In order to explicitly test whether this difference in the way the bid is presented to the respondent has an effect on the way people respond to the valuation question, we conduct a hypothesis test of equality between the bid parameters for the precise and imprecise samples. The null hypothesis is that all parameters between the precise and imprecise models are equal, while the alternative hypothesis is that all parameters except the bid parameter are equal between the precise and imprecise models. Specifically, the hypothesis test takes the following form:

$$H_0 : \beta_{Bid}^{\mathrm{P}} = \beta_{Bid}^{\mathrm{I}} \text{ and } \beta_0^{\mathrm{P}} = \beta_0^{\mathrm{I}} \text{ and } \beta_1^{\mathrm{P}} = \beta_1^{\mathrm{I}} \text{ and } \beta_2^{\mathrm{P}} = \beta_2^{\mathrm{I}} \text{ and } \beta_3^{\mathrm{P}} = \beta_3^{\mathrm{I}} \text{ and } \beta_4^{\mathrm{P}} = \beta_4^{\mathrm{I}}$$

$$H_A : \beta_{Bid}^{\mathrm{P}} \neq \beta_{Bid}^{\mathrm{I}} \text{ and } \beta_0^{\mathrm{P}} = \beta_0^{\mathrm{I}} \text{ and } \beta_1^{\mathrm{P}} = \beta_1^{\mathrm{I}} \text{ and } \beta_2^{\mathrm{P}} = \beta_2^{\mathrm{I}} \text{ and } \beta_3^{\mathrm{P}} = \beta_3^{\mathrm{I}} \text{ and } \beta_4^{\mathrm{P}} = \beta_4^{\mathrm{I}}$$

where P indicates precise and I indicates imprecise. This hypothesis can be tested using a likelihood ratio test. The test statistic has a χ^2 distribution with one degree of freedom. The value of the test statistic for this hypothesis test is 3.59 while critical value for a 10%

level of significance is 2.71. We therefore reject the hypothesis that the bid parameter is equal between the precise and imprecise subsamples.

The result of this hypothesis test is evidence that respondents very well may respond differently to bids that are presented in round numbers than to bids that are presented in dollars and cents. It also implies that the model estimated with imprecise bids results in a variance that is larger by a statistically significant amount than models estimated with precise bids. Recall that the bid coefficient is the reciprocal of the standard deviation. As there is an inverse relationship between the estimate of the willingness-to-pay variance and the coefficient on the bid amount, we cannot reject the notion that the variance in willingness-to-pay for the imprecise bid subsample is infinite. This divergence in estimation results is perplexing if it results solely from a difference in the way in which bid amounts were presented to the respondents. Before we move towards that conclusion, we discuss the contingent valuation literature regarding willingness-to-pay variance estimation.

Monte Carlo Analysis

One possible explanation of the observed difference between the precise and imprecise results could be that differences in the structure of the two bid designs may lead to differences in the statistical results. If this can be eliminated as a cause of the observed differences, the implication would be that our empirical results suggest a behavioral difference among respondents presented with imprecise bid levels and those with precise bid levels.

We examine this issue with a Monte Carlo simulation. Crooker and Herriges (2004) formally explore the effect of bid design on estimators of willingness to pay variance. Their results suggest that highly flexible semi-nonparametric techniques are much more sensitive to bid design than more commonly-used parametric techniques. In particular, poor bid design and outliers can have more estimation influence in the semi-nonparametric estimation setting. As the model we have used in this investigation is an example of the traditional parametric approach, our estimation results are likely not being driven by the bid design. In fact, we would note that although the precise bid amounts include a different bid amount for all respondents, the bid amount values are clustered at the same percentiles of the willingness-to-pay distribution as the imprecise bids.

The bid designs considered in the Crooker and Herriges (2004) experiment spanned the percentiles of the willingness-to-pay distribution. Considering the percentiles of the population willingness-to-pay distribution, our precise bid design is virtually identical to the 5 bid level imprecise bid design. However, to remove doubt regarding the spread of bid designs used influencing our results; we design and explore the following Monte Carlo investigation.

We take the estimation results from a model that restricts all parameters to be equal between the precise and imprecise models and treat those parameters as the actual population parameters. The results of estimation of this model are shown in Table 2. Next, we randomly draw a subsample from the population by assigning the population parameters of willingness-to-pay and drawing a disturbance term from a normal distribution with the variance again coming from the estimated population variance parameter. This process creates a simulated draw from the population having precisely the characteristics imposed by the population parameters.

With the sample created, we form two distinct pseudo-samples. For the first pseudo-sample, we mimic the data that an econometrician would observe when presenting the imprecise bid design to the simulated respondent. The imprecise bid design is precisely the bid design we used in the actual survey. We simulate respondent behavior by recording a “yes” for the CV question if the simulated willingness-to-pay we generated is greater than the bid amount and a “no” otherwise. Using this data, we estimate our willingness-to-pay model described above as if this was the observed data.

For the second pseudo-sample, we mimic the data an econometrician would collect by presenting the precise bid design to the simulated responded. Again, we use the same bid design mechanism as that used in the actual survey. The simulated respondent behavior is recorded as a “yes” to the CV question when simulated willingness-to-pay exceeds the bid amount and a “no” otherwise. We then use this data to estimate willingness-to-pay while storing the results.

The result of this simulation and estimation process is two sets of parameter estimates for exactly the same set of respondents with one set corresponding to the precise bid design format and one set corresponding to the imprecise bid design format. Any difference in parameter estimates must be due to the statistical ramifications of presenting bid levels at different willingness-to-pay percentiles. Yet, as these percentile differences are largely negligible, as the bid amount for the precise bid design is less than $2 from the imprecise bid design, we anticipate the resulting two sets of parameter estimates will be virtually identical. Recall that the variance of willingness-to-pay we are imposing on the population is 1,562,500 (the standard deviation is 1250). This implies that the difference of $1 in bid amount is 0.0008 standard deviations in willingness-to-pay. Again, this suggests the bids are nearly identical across imprecise and precise bid designs in terms of willingness-to-pay percentiles.

As noted above, if our Monte Carlo results indicate convergence between the two sets of parameter estimates, we must conclude that the empirical divergence we observed between precise and imprecise bid levels is not due to statistical design. The implication is that our empirical results suggest that respondents react differently to precise bids than they do to imprecise bids.

The Monte Carlo results do indicate that the two sets of parameters are virtually identical. We generated 1,000 samples as described above and estimated the two sets of parameters. The average difference in the mean log-likelihood function across pseudo-samples was -0.000011. The average difference in coefficients on bid amounts across pseudo-samples was -0.000000347594. The Monte Carlo results suggest that the differences in empirical estimates we observed for the imprecise and precise bid amounts does not stem from statistical explanations. This suggests that the dollar/cent form of the bid may influence the way in which respondents answer stated preference questions.

Conclusions

In this paper, we have taken a closer look at the effect that the form of the bid presented to the respondent has on their response to a valuation question. An obvious explanation is that respondents may infer that a bid presented in dollars and cents is a more accurate estimate of the true cost of the good being asked about, whereas a bid presented in round dollars may signal that the bid is simply a guess at the true cost. This may lead to a behavioral difference in the way respondents answer the valuation question. We test this proposition using a survey designed to gather contingent valuation information concerning the Battle of Lexington State Historic Site, and find statistical evidence indicating that the dollar/cent form of the bid does indeed affect the behavior of the respondents.

References

Alberini, Anna, "Optimal Designs for Discrete Choice Contingent Valuation Surveys: Single-bound, Double-bound and Bivariate Models," *Journal of Environmental Economics and Management*, 28, 187-306. (1995)

Arrow et al. 1993

Boyle, K. J., H. F. MacDonald, H. Cheng, D. W. McCollum. 1998. Bid Design and Yea Saying in Single-Bounded, Dichotomous-Choice Contingent Valuation Questions. *Land Economics*, 74(1):49-64. (1998)

Cameron, T. "A New Paradigm for Valuing Non-market Goods Using Referendum Data: Maximum Likelihood Estimation by Censored Logistic Regression." Journal of Environmental Economics and Management 15(1988): 355-379.

Cameron, T.A. and J. Quiggin (1994):"Estimation Using Contingent Valuation Data from a `Dichotomous Choice with a Follow-Up' Questionnaire," Journal of Environmental Economics and Management, 27, 218-234.

Cooper, Joseph and John Loomis, "Sensitivity of Willingness-to-Pay Estimates to Bid Design in Dichotomous Choice Contingent Valuation Models" *Land Economics,* Vol. 68, No. 2. (May, 1992), pp. 211-224.

Crooker, John and Joseph Herriges, "Parametric and Semi-Nonparametric Estimation of Willingness-to-Pay in the Dichotomous Choice Contingent Valuation Framework," *Environmental & Resource Economics*, vol. 27(4), pages 451-480.

Duffield, J. and D. Patterson. 1991. Inference and Optimal Design for a Welfare Measure in Dichotomous Choice Contingent Valuation. *Land Economics* 67(2):225-239.

Kemp, M. A., & Maxwell, C. (1993). Exploring a budget context for contingent valuation estimates. In J. A. Hausman (Ed.), *Contingent valuation: A critical assessment*. Amsterdam: North Holland Press.

Loomis, John, Armando Gonzalez-Caban, and Robin Gregory "Do Reminders of Substitutes and Budget Constraints Influence Contingent Valuation Estimates?" Land-Economics; Volume 70 #4, November 1994

Roach, Brian, Kevin J. Boyle, and Michael Welsh, "Testing Bid Design Effects in Multiple-Bounded, Contingent-Valuation Questions" *Land Economics,* Vol. 78, No. 1. (Feb., 2002), pp. 121-131.

Scarpa, Riccardo and Bateman, Ian NMI, "Does a Third Bound Help? Parametric and Nonparametric Welfare Measure from a CV Interval Data Study" . Fondazione Eni Enrico Mattei Working Paper No. 51.98.

Table 1: Raw and transformed parameter estimates

Parameter	Precise (raw)	Precise (adjusted)	Imprecise (raw)	Imprecise (adjusted)
Bid	.0010 (2.013)*	1000	0.0007 (1.254)	1428.57
Constant	1.1890 (1.605)	1189.00	1.0046 (0.6467)	1435.14
Income	0.0013 (0.297)	1.30	-0.0011 (-0.251)	-1.57
Gender	-0.2170 (-0.620)	-217.00	0.1504 (0.478)	214.86
Age	-0.0125 (-1.200)	-12.50	-0.0189 (-1.948)	-27.00
Education	0.6847 (1.928)*	684.70	0.2361 (0.732)	337.29
n	64		70	

Table 2: Constrained model (both precise and imprecise data used)

Parameter	**All Data (raw)**	**All Data (adjusted)**
Bid	.0008 (2.295)*	1250
Constant	0.9604 (2.023)*	1175.50
Income	-0.0003 (-0.101)	-0.375
Gender	-0.0272 (-0.119)	-34.00
Age	-0.0133 (-1.952)	-16.63
Education	0.4853 (2.079)*	606.63
n	134	