Dichotomous-Choice, Contingent-Valuation Questions: Functional Form Is Important

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A variety of questioning formats have been used in contingent-valuation studies, with dichotomous-choice questions becoming the preferred format. However, as with any empirical technique, continued applications raise questions that require attention if the credibility of the procedure is to be maintained. It is shown that estimated Hicksian surplus can be substantially affected by the selection of a functional form when analyzing responses to dichotomous-choice questions. Given that theory, intuition, and empiricism all play a role in developing these estimates, several maxims are suggested for evaluating and/or mitigating such effects in future studies.

A variety of questioning formats are used to ask contingent-valuation questions. First used by Bishop and Heberlein, the dichotomous-choice, or closed-ended, format has become the preferred procedure for asking contingent-valuation questions (see also Bishop, Heberlein, and Kealy). Hanemann (1984) clarified the theoretical underpinnings of dichotomous-choice questions. Seller, Stoll, and Chavas demonstrated that dichotomous-choice value estimates are comparable to those derived from travel-cost models. Heberlein and Bishop, as well as Welsh, found that dichotomous-choice questions can work equally well in simulated markets using actual cash transactions and in contingent markets. Finally, Hoehn and Randall conclude that dichotomous-choice questions, vis-a-vis other contingent-valuation questioning formats, are consistent with the basic principles of welfare economics used in cost-benefit analyses.

As with any empirical technique, however, continued applications raise questions and problems requiring attention (Boyle, Welsh, and Bishop; Cameron and James; Duffield and Patterson; Hanemann 1984 and 1989; Johansson, Kristrom, and Maler). A particularly difficult issue that has plagued applications is the specification of a functional form for the variables included in the equations used to analyze responses to dichotomous-choice questions (Bowker and Stoll; Boyle and Bishop; Loomis; Seller, Stoll, and Chavas). Given that a decision has been made as to which variables should be included in the analysis (variable selection), functional form relates to how these variables should be modeled. The effect on estimated Hicksian surplus from the choice of a specific functional form is explored in this paper.

Dichotomous-Choice Questions

As is done for all contingent-valuation questioning formats, dichotomous-choice questions are implemented in a survey by presenting participants with a contingent market. The unique aspect of dichotomous-choice questions is that respondents are asked if they would pay a fixed sum of money for the item being evaluated. Responses (yes/no), the fixed sum of money, and socioeconomic variables are commonly used to estimate a probabilistic model from which expected values are calculated.

Analyses of responses to dichotomous-choice questions require that three specification issues be addressed. First, a probabilistic model must be chosen based on assumptions regarding error terms; there are a substantial number of such probabilistic models from which an analyst may choose (Johnson and Kotz). Logit and probit models are commonly used in the contingent-valuation literature.

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For large sample sizes, the choice of a probabilistic model should not have a substantial effect on estimated expected values (Amemiya; Bowker and Stoll; Maddala). Beyond this decision, variables must be selected for inclusion in the analysis, and a functional form needs to be specified for the selected variables. Potential variables, at first blush, may appear somewhat limitless (Walsh, Loomis, and Gillman). Potential functional specifications also present a substantial number of choices (Griffin, Montgomery, and Rister). Economic theory helps guide such decisions, but an empirical investigator is still left with substantial latitude as to actual choices.

Hanemann (1984) argues for the use of economic theory to guide variable selection and, in particular, functional-form specification. This is opposed to ad hoc, intuitive specifications of a functional form. Empirically, Boyle and Bishop found that specifications consistent with utility theory, a la Hanemann, "may not provide statistically significant estimates of coefficients, and some coefficients may have the wrong signs." In contrast, an ad hoc specification used by Bishop, Heberlein, and Kealy did yield statistically significant coefficients with signs meeting a priori expectations in the Boyle and Bishop study.

Going beyond these results, a large number of functional forms can be consistent with economic theory. Bowker and Stoll contribute to the investigation by employing a number of scalar measures of goodness of fit to select among estimated logit equations in a contingent-valuation study of whooping cranes (McFadden's R^2, Akaike Information Criterion, and proportion of correction predictions). They found that two utility-theoretic specifications and an ad hoc functional specification yielded statistically significant coefficients with appropriate signs. The ad hoc functional form fits the data best according to the scalar measures of goodness of fit. However, the goodness-of-fit measures reported by Bowker and Stoll did not vary substantially across functional specifications. The percent of correct predictions, for example, ranged from 74% to 78%. McFadden R squares range from .15 to .21. These are not large margins from which to make a selection of a functional specification. Furthermore, the average difference in Hicksian surplus across the two utility theoretic specifications was 25%. Cummings, Brookshire, and Schulze have argued that contingent-valuation estimates are accurate to plus or minus 50%. Thus, an average difference of 25%, with the largest individual difference being 36%, is well within observed margins of error. Bowker and Stoll conclude that "clearly professional judgment plays a major role in making use of dichotomous-choice survey methods."

For the application reported in the present paper, the selection of a functional form is shown to be more complicated than perceived by Boyle and Bishop (problems with statistical estimates) or Bowker and Stoll (selection according to scalar measures of goodness of fit). It is shown that scalar measures of goodness of fit can be nearly identical, while expected values vary substantially across functional specifications.

Application

The application was to estimate the value users' and nonusers' place on the preservation of the Illinois Beach State Nature Preserve, located at the southern end of Illinois Beach State Park on the shore of Lake Michigan. Rising water levels in Lake Michigan and man-made developments north of the nature preserve along the shore of Lake Michigan are accelerating the erosion of a ridge of sand dunes separating the nature preserve from the lake. Continued erosion would allow the lake to breach the dunes and flood the nature preserve, thereby destroying the unique components of the area which constitutes the nature preserve. The valuation question, therefore, is whether to maintain the nature preserve.

Model Specification

The value to be estimated is specified as

$$(1) \quad V(t, NP=1, P, Y-TV) = V(0, NP=0, P, Y),$$

where $V(*)$ is an indirect utility function, / is an individual's optimal choice of visits to the nature preserve, NP represents the existence (1) or nonexistence (0) of the nature preserve, P is the price of a visit to the state park, Y is income, and TV is the Hicksian equivalent variation measure of total value. Other arguments in the indirect utility function are assumed to be constant and are suppressed for notational convenience.

Visits to the nature preserve are modeled as a quantity variable in the indirect utility function since an individual must visit the state park in order to visit the nature preserve. However, it is not necessary to visit the nature preserve when one visits the state park. Simply put, the nature preserve is only one attribute of the state park, and the marginal cost of visiting the nature preserve is only comprised of the time spent in the preserve. The nature preserve existence argument allows individuals who do not visit the preserve *(t* ~ 0) to place a value on the continued existence of the preserve in its current state. Finally, the price of visiting the state park is constant across states of the world because the potential flooding would only affect the nature preserve.

Application of the dichotomous-choice questioning format converts the equality in equation (1) to the following inequality:

$$(2) \qquad V(t, NP = 1, P, Y - A) \lesseqgtr V(0, NP = 0, P, Y),$$

where *A* is the fixed dollar amount in the valuation equation, and *A* g *TV.* Following Hanemann (1984), not all components of the indirect utility function are observable and, as such, the error terms (w,) are random variables. Thus, the probability that an individual will answer no to the valuation question is expressed as

$$(3) \qquad \begin{aligned} \Pr(NO) &= \Pr\{V(t, NP = 1, P, Y - A) + u_1 \\ &\qquad < V(0, NP = 0, P, Y) + u_0\} \\ &= F(\Delta V), \end{aligned}$$

where /-"(•) is a cumulative distribution function (CDF) and

$$(4) \qquad \Delta V = V(t, NP = 1, P, Y - A) - V(0, NP = 0, P, Y).$$

Assuming the error terms are independent and identically distributed nonnegative random variables with a Weibull distribution, the CDF can be written as

$$(5) \qquad \Pr(NO) = F(\Delta V) = [1 + \exp(\Delta V)]^{-1},$$

where the right-hand side of equation (5) is a logit model.

The specification issue addressed here examines the selection of a functional form for the utility difference, AV. An ad hoc specification of AV would be a functional form that could not be taken back to an indirect utility function (Hanemann 1984).

Two specifications of the indirect utility function were employed:

$$(6a) \qquad V(\bullet) = a_0 + a_1 t + a_2 NP + a_3 Y,$$

$$(6b) \qquad V(\bullet) = b_0 + b_1 \ln(t + 1) + b_2 NP + b_3 \ln Y,$$

where the *a_f* and *bj* are coefficients to be estimated. The price of a visit to the nature preserve is suppressed since it is assumed to be unaffected by the existence or nonexistence of the nature preserve. The term (/ + 1) in equation (6b) represents a log adjustment for individuals who did not visit the nature preserve.

The equations for estimation purposes are

$$(7a) \qquad \Pr(NO|t, NP = 1, A) = [1 + \exp(a + a_1 t - a_3 A)]^{-1},$$

$$(7b) \qquad \Pr(NO|t, NP = 1, A) = [1 + \exp(b + b_1 \ln(t + 1) + b_3 \ln(1 - A/Y)]^{-1}.$$

The nature preserve existence argument (/VP - 1) is constant across respondents and becomes part of the constant terms *(a* and *b)* for estimation purposes. All coefficients, except the constants, are specified with their expected signs. Equations (7a) and (7b) will be referred to as the linear and log models, respectively.

The valuation question was posed as an annual payment, so all variables are measured in annual units. The dollar amounts entered in the valuation question were selected using the procedure outlined by Boyle, Welsh, and Bishop.

Estimation Results

Two independent, random samples of Illinois heads of households were purchased from National List Services, Donnelly Marketing of Oakbrook, Illinois. Individuals at least 18 years of age were included in the sampling frame. A total of 200 individuals were selected from Lake and McHenry Counties, the two counties adjacent to the nature preserve. This was done to increase the probability of selecting individuals who had actually visited the nature preserve. An additional 400 individuals were selected from all other Illinois counties. Although it is unlikely that individuals from these counties visited the nature preserve during the sample period, they could still place a value on the preservation of this area. These two sample groupings will be referred to as Samples A and B, respectively. The valuation exercise was conducted via mail survey, and the response-rates as a percent of deliverable mailings were 67% for Sample A and 61% for Sample B.

Equation Estimates

Maximum likelihood estimates of the logit coefficients are presented in Table 1. Note that the number-of-trips variable does not enter the equations for Sample B because these individuals, as expected, did not visit the nature preserve in the year preceding the study.

All coefficients are significant at the .05 level, and only three coefficients are not significant at the

Table 1. Estimated Logit Coefficients

	Sample A		Sample B	
	Linear Model	Log Model	Linear Model	Log Model
Coefficients				
Constant	1.225*"	4.871*	9.594*	0.568*
	(0.410)[b]	(1.973)	(0.233)	(0.201)
/	1.442**			
	(0.619)			
\n(t + 1)		0.618**		
		(0.272)		
A	-0.067*		-0.028*	
	(0.021)		(0.011)	
ln(1 - *A/Y*)		654.1*		367.5**
		(253.4)		(145.0)
χ^2	31.82"	27.49*	.17.03*	8.93
N	93	93	173	173
Goodness-of-Fit Measures				
Proportion of correct predictions	.71	.75	.62	.60
McFadden's R^2	.23	.23	.07	.04

[a] A single asterisk denotes significance at the 1% level and a double asterisk denotes significance at the *5%* level.
[b] Numbers in parentheses are asymptotic standard errors.
[c] A plus denotes significance at the 1% level.

.01 level. All signs are consistent with a priori expectations. Thus, there is no way to distinguish between the equations based on these statistical results.

The reader will also note that the goodness-of-fit measures are quite similar. For Sample A, the proportion of correct predictions is 71 % for the linear model and 75% for the log model. The McFadden's 7?^{2}s from the two models are identical for Sample A. For Sample B, the proportion of correct predictions ranges from 60% to 62%, and the McFadden's /?^{2}s range from .04 to .07. The similarities in these scalar measures also do not provide guidance in the selection of a functional specification. Furthermore, these results support the Bowker and Stoll finding that theoretically consistent functional forms can provide satisfactory statistical results.

Expected Values

Expected values were calculated for Sample B's linear model according to the general formula presented by Hanemann and modified by Boyle, Welsh, and Bishop. For al! other equations, trips and income are treated as discrete variables, and conditional and unconditional expected values are computed according to the general formula presented by Boyle and Bishop. That is, the sample is stratified by the number of visits to the nature preserve, and the mean income is computed for each of these groups. Conditional expected values are derived by plugging the desired level of trips and corresponding income into the estimated logit function and integrating the area under [1 - *Pt(NO)]*. All expected values were computed via numerical approximation.

Given the stability of the equation estimates, it is surprising to find that calculated expected values vary dramatically across functional specifications (Table 2). Conditional estimates for Sample A, based on the number of trips taken, range from $22 to $669 for the linear model and range from $55 to $768 for the log model. The unconditional estimates are $41 and $111, respectively, for the linear and log models. Thus, the log model yields an unconditional estimate that is more than two times greater than that calculated for the linear model for Sample A.

This same relationship of expected values is replicated for Sample B. The expected values are $37 for the linear model and $96 for the log model. Once again, the log model yields an estimated value that is more than two times greater than that calculated for the linear model. Recall that Sample B corresponds to all other Illinois counties, and conditional expected values are not included since respondents in this sample did not visit the nature preserve during the study period.

Thus, for both Samples A and B, the log model yields estimates of Hicksian surplus that are more than twice the comparable estimates derived from the linear model. This result is in direct contrast to the Bowker and Stoll result where the average difference across models was only 25%.

Which model provides expected-value estimates that are closest to the "truth"? This question is particularly important since the ultimate objective

Table 2. Expected Values Estimates for Sample A[a]

Per Capita Visits in 1984	Linear Model	Log Model"
0	$22	$55
1	41	293
2	61	161
3	83	316
5	126	602
10	233	263
12	276	219
30	669	768
Overair	$41	$111

" Conditional expected values are calculated by evaluating the trip variable at each observed level in the sample data and calculating conditional expected values by numerical approximation (i.e., as proposed by Hanemann (1984) and modified by Boyle, Welsh, and Bishop).

[b] Estimated Hicksian surplus does not increase monotonically in income because respondents in each of the stratifications of visits to the nature preserve had different average incomes. That is, the mean income for individuals who only took one trip exceeds the mean income for those who took two trips. Thus, estimated surplus for one trip ($293) exceeds estimated surplus for two trips ($161). Likewise, individuals who took ten and twelve trips had lower mean incomes than individuals who took three or five trips.

[c] This expected value, which is not conditional on per capita visits, is computed by applying the sample proportions for the observed levels of per capita trips and computing a weighted average, i.e., the expected value of a discrete random variable.

of the exercise is to compute expected values, and, as demonstrated, different functional forms can give dramatically different estimates of an expected value which could very possibly lead to a wrong recommendation from a cost-benefit analysis. The information presented here does not provide guidance to answer this question. Comparison studies reveal that no single contingent-valuation questioning format is neutral in the estimation of Hicksian surplus (Boyle and Bishop; Seller, Stoll, and Chavas; Smith, Desvousges, and Fisher). Thus, the issue of concern here should not be interpreted as a statement implying that dichotomous-choice questions should not be employed. Rather, this issue should be evaluated as one of the pros and cons to consider when choosing a contingent-valuation questioning format.

Implications

Economic theory allows the formation of hypotheses about relevant variables for inclusion, relationships among included variables, expected signs of estimated coefficients, and possibly even statements regarding relative magnitudes of estimated coefficients. However, intuition must also play a role, and, as Smith has stated, there is also a role for letting the data tell its story. Given that theory, intuition, and empiricism allow for the estimation of a number of functional specifications, several maxims are worth heeding when estimating Hicksian surplus from dichotomous-choice valuation questions.

When theory and empirical measures of goodness of fit do not allow for the selection of a single model for policy analyses, the first step that I would suggest is to conduct sensitivity analyses to determine whether Hicksian-surplus estimates are sensitive to the functional specification of the explanatory variables in the probabilistic model. If estimated Hicksian surplus is not sensitive to the selection of a functional form, the problem presented here is not an issue. In this case, one might select the model that is the most convenient to operationalize the policy analyses at hand.

If Hicksian surplus is found to be sensitive to the choice of a functional form, evaluate the validity of the Hicksian-surplus estimates. This can be accomplished by employing more than one contingent-valuation questioning format or by simultaneously employing alternative valuation procedures (e.g., travel-cost and hedonic-price models). Statistical comparisons of the various estimates allow one to make inferences about convergent validity. Convergent validity, different contingent-valuation questioning procedures providing statistically similar estimates of Hicksian surplus, would allow for the selection of the functional form that satisfies this condition.

It is important to recognize that travel-cost and hedonic-price models are also prone to issues of selecting an appropriate functional form. Convergent validity in these cases might be accomplished by developing a complete "marriage" of the various valuation procedures by deriving the valuation models from the same theoretical construct. This allows one to make statistical inferences about differences in the structural parameters between models, and, as such, comparisons of models do not need to simply focus on testing for significant differences in estimated-mean Hicksian surplus. Hup-pert, and McCollum, Bishop, and Welsh have made some inroads in this area of research, but neither of these pieces of research accomplished a complete marriage of the contingent-valuation and travel-cost models via a single theoretical model. If these analyses prove successful in the future, models that satisfy convergent validity in terms of the structural parameters would be selected for policy analysis.

Finally, it is important to ask the right question when evaluating various functional forms. As noted above, the travel-cost literature contains numerous articles dealing with functional-form issues (Anderson and Bishop; Ward and Loomis). Recently, Ozuna, Jones, Stoll, and Capps employed Box-Cox procedures to select an appropriate functional form when estimating a travel-cost model; Milon applied the same procedure for selecting a functional form when analyzing dichotomous-choice, contingent-valuation data. The point that I would like to make is that goodness-of-fit measures or Box-Cox procedures may not address the relevant issue. The objective of selecting a functional form should be that it yields unbiased estimates of Hicksian surplus (validity) with a minimum variance (reliability) (Mitchell and Carson). The functional specification that fits any given data set "best" may or may not meet these criteria. That is, the long tails on probabilistic models can substantially affect estimated means, and an estimated function is simply an artifact of the range of data available for estimation, which generally does not include the entire range of the distribution function being estimated. It seems, then, that more basic research is needed to facilitate the selection of an appropriate functional form when analyzing responses to dichotomous-choice, contingent-valuation questions.

In practical terms, no single functional specification is likely to be universally applicable, and analysts are likely to continue to dwell on specification issues in the future. As noted by Smith, Desvousges, and Fisher, application of contingent valuation, regardless of the questioning format employed, ". . . is not a mechanical process. Judgment, combined with sensitivity analysis and plausibility checks, are likely to be more important to the quality of resulting benefit estimates. ..." It would seem, then, that functional-form issues should not be a death knell for dichotomous-choice questions given the desirable features of this questioning format.

Rather, recognition of and sensitivity toward these issues can improve the usefulness and credibility of future applications. Future research on functional-form issues when analyzing responses to dichotomous-choice questions must focus on selection procedures that facilitate the best (valid and reliable) estimates of Hicksian surplus and should not be overly concerned with identifying functional forms that best fit the data. This can best be accomplished by designing studies to enable analyses of convergent validity and by exploring new techniques for selecting among functional forms that recognize that estimated Hicksian surplus is the policy variable of concern.

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