Comparing Models for Contingent Valuation Surveys: Statistical Efficiency and the Precision of Benefit Estimates

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This paper empirically tested the three conditions identified by McConnell for equivalence of the linear utility difference model and the valuation function approach to dichotomous choice contingent valuation. Using a contingent valuation survey for deer hunting in California, two of the three conditions were violated. Even though the models are not simple linear transforms of each other for this survey, estimates of mean willingness to pay and their associated 95% confidence intervals around the mean were quite similar for the valuation methods.

Spurred by the availability of comprehensive, high-quality contingent valuation (CV) survey data, two competing methodologies have emerged for analyzing and calculating welfare measures from referendum data. Hanemann (1984) applied the utility difference model to the analysis of dichotomous choice survey response and derived estimates of willingness to pay (WTP). Cameron (1988) has proposed an alternative model, arguing that referendum data from CV surveys are "very, very distinct from usual discrete-choice data, so that different—and much simpler—interpretations of the responses are available." Cameron's model for referendum data provides estimates of individual WTP along with measures indicating how WTP is affected by changes in resource quality and individual attributes.

This paper is motivated by McConnell's analysis of the theoretical foundations of the Hanemann and Cameron approaches for referendum data and the restrictions linking the two approaches. McConnell showed that interpretation of the income effect plays a key role in defining the relationship between the valuation approaches.

This paper derives the restrictions linking the valuation approaches and provides the first empirical tests of these restrictions. The linear specification of the utility difference model, which omits income, imposes the restriction that the Hanemann and Cameron models are linearly related and essentially identical. This paper develops a more flexible specification of preferences to test the restrictions presented by McConnell. Previous work comparing these models by Patterson and Duffield has focused on the computational and statistical methods for transforming the models. The economic restrictions linking the models were not discussed.

Confidence intervals for the estimated welfare measures are developed and compared along with the mean WTP estimates for the two approaches. Smith, Desvousges, and Fisher have noted that simple comparisons of benefit estimates, although useful to policy makers, provide limited information for valuing nonmarket resources. Cameron (1991b) also recognized the importance of confidence intervals and developed a statistical method for deriving this information. Confidence intervals for mean WTP from both the Hanemann and Cameron approaches using this more flexible specification have not previously been presented.

The next section of this paper outlines the Hanemann and Cameron approaches and derives mean WTPs. The section concludes with a summary of the valuation and modeling principles that form the foundation of each approach. In the third section the two approaches are tested using data from a dichotomous choice, contingent valuation survey of California deer hunters. Benefit estimates from the valuation approaches are compared along with confidence intervals for the estimates.

Welfare Measures from Dichotomous Choice Models

The Utility Difference Model (Hanemann)

Hanemann derives Hicksian compensated measures from a utility difference model estimated

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from dichotomous choice, contingent valuation data. The observed discrete choice response of each respondent is assumed to reflect a utility maximization process. The indirect utility function for each respondent is represented as $U = V(j, Inc; S) + \epsilon_j$. The systematic portion of the indirect utility function, $V(\cdot)$, depends on income (*Inc*) along with individual characteristics and quality measures (*S*) that affect satisfaction obtained from the resource. Let $j = 0$ represent no access to the resource or site and $j = 1$ represent access when the respondent must pay the stated bid amount, *A*. Random elements that influence utility are denoted by ϵ_j.

When faced with an increased bid amount to use a resource, the respondent will pay the amount only if the utility gain is positive:

$$(1)\quad V(1, Inc - A; S) + \epsilon_1 \geq V(0, Inc; S) + \epsilon_0.$$

The random elements ϵ_1 and ϵ_0 are independent and identically distributed random variables with zero means. The yes or no response depends on the difference in indirect utility functions, or $\Delta V = V(1, Inc - A; S) - V(0, Inc; S)$.

The utility difference model yields the logit specification when the probability of a yes response is specified as the cumulative distribution function (c.d.f.) of a standard logistic variate:

$$(2)\quad Prob(Yes) = [1 + e^{-\Delta V}]^{-1}.$$

Recognizing that WTP is a random variable with a c.d.f. defined here as G(**A**), mean WTP from the utility difference model is calculated following Hanemann (1989) as

$$(3)\quad E(WTP) = \int_0^{\infty}[1 - G(\mathbf{A})]d\mathbf{A} - \int_{-\infty}^{0} G(\mathbf{A})\, d\mathbf{A}.$$

The Variation Function Model (Cameron)

In Cameron's variation function, WTP is modeled directly as a function of exogenous variables such as the respondent's income, socioeconomic traits, and quality measures for the nonmarket good. The true WTP of each respondent is an unobserved variable denoted by Y_i, where

$$(4)\quad Y_i = x_i'\beta_i + u_i,$$

and x_i is a vector of explanatory variables. The underlying distribution of Y_i, conditioned on the explanatory variables, is assumed to follow a logistic distribution in this application.

The bid amount, which is randomly assigned to each respondent in the survey, is denoted by A_i. Each individual's yes or no response indicates whether the true WTP (Y_i) for that individual exceeds or is less than the proffered bid amount (A_i). Cameron's censored logistic regression model assumes u_i is identically and independently distributed according to a logistic distribution with mean 0 and standard deviation *b*. The logistic distribution is also characterized by a general scale parameter that can be estimated in the Cameron model, defined as $\kappa = b\sqrt{3}/\pi$.

For a sample of *n* independent observations, the simplified log-likelihood function for the censored logistic regression model is

$$(5)\quad \operatorname{Log} L = \sum_{i=1}^{n} (1 - I_i)[(A_i - x_i'\beta)/\kappa] - \log[1 + \exp[(A_i - x_i'\beta)/\kappa)]],$$

where I_i is the binary response variable. Maximum-likelihood estimates for β and κ, and asymptotic standard errors are obtained using nonlinear optimization techniques.

The censored logistic regression model provides the *conditional* distribution of mean WTP at different levels of the explanatory variables. The *conditional* expectation of WTP is used to evaluate the impact of changes in the level of any specific explanatory variable on WTP. This measure of change in WTP in response to a change in an explanatory variable is conceptually similar to elasticity calculations used by economists.

The *marginal* mean of the distribution of WTP is a summary measure of WTP that takes into account the impact of all the explanatory variables together. The *marginal* mean from Cameron's variation function model is obtained from the model for Y_i,

$$(6)\quad E(WTP) = E(Y_i) = E(x_i'\beta_i + u_i) = E(x_i'\beta_i),$$

since the mean of the logistic distribution is zero. The marginal mean of WTP is evaluated at the mean values of the data.

The utility difference model is usually interpreted to provide an estimate of the *marginal* distribution of mean WTP. Cameron (1988) noted that the two valuation methods result in identical point estimates of *marginal* WTP for specifications of the utility difference model which are linear and additively separable in the bid amount.

Valuation and Modelling Principles

McConnell has suggested that the choice of valuation approaches may be dictated by the preferences of the individual modeler or by the decisionmaking principles that are implicit in each approach. The utility difference model views respondents as evaluating which situation is better or worse, without attaching specific monetary values to their choices. In contrast, the Cameron model views respondents as calculating the dollar value of any change in quality and comparing this against the proffered bid amount.

In Cameron's approach, WTP is modeled as a censored latent continuous variable that is influenced systematically by a variety of explanatory variables. A conventional inverse Hicksian demand curve is estimated directly, dispensing with the need to specify the form of the unobserved utility function and then to derive the corresponding welfare measure, the approach used in the Hanemann model. Cameron (1991a) also suggested that the censored logistic (or normal) regression model has a distinct advantage in predicting the effects of individual characteristics and resource attributes on conditional expectation of WTP.

The foregoing discussion highlights the importance of a direct comparison of the Hanemann and Cameron models. This paper presents an empirical comparison using a specification that does not restrict the models to be linear transforms of each other.

The first empirical test is to determine whether the models satisfy the restrictions derived by McConnell. If the restrictions are met, the two models are linear transforms of each other. Analyzing the properties of the utility difference model, McConnell emphasized the key role of the income variable in contingent valuation models. A specification of the indirect utility function is developed in the next section which relaxes the restriction that the marginal utility of income is constant across the valuation scenarios for the nonmarket resource. Second, estimates of mean WTP and confidence intervals derived from each approach are compared using this specification.

Econometric Specification

The comparison of the two methods for analyzing data from a closed-ended contingent valuation study is based on a study conducted for California deer hunters. The data were collected by surveying California residents and nonresidents who had purchased deer hunting licenses for the 1987 deer hunting season. Following survey procedures proposed by Dillman, a questionnaire in booklet form, along with a postage-paid return envelope, was mailed to the hunters. A reminder postcard and a second mailing of a replacement survey to nonrespondents was used. The response rate after deleting nondeliverable surveys was 60%.[1] The report by Loomis, Creel, and Cooper contains complete details on survey design and bid amounts.

The dichotomous choice approach to CVM was used in the mail survey. Data were obtained on the WTP for deer hunting in the specific hunting zone the hunter visited on his or her most recent trip. An increase in trip cost was proposed: "If the costs of making this most recent trip to this hunt zone had been $X higher, would you still have made the trip?"

McConnell, noting the key role of the income variable in defining the relationship between the Hanemann and Cameron models, proposed three conditions in which the marginal utility of income could be constant. These conditions are tested directly in the utility difference model.

The first condition is that the utility difference model is linear in income. This condition will be tested using a Box-Cox specification developed in a later section.[2] The second condition is that the marginal utility of income is constant across the alternative states of the resource, so that the income variable effectively drops out of the specification of the utility difference model. The third condition is that the marginal utility of income does not vary across individuals, or is independent of the respondent's personal characteristics. The utility difference model and the variation function model are linear transforms of one another if all three conditions hold.

Bockstael, McConnell, and Strand proposed a utility function that permits testing of these conditions. In this application, marginal utility is hypothesized to depend on whether or not respondents are members of hunting clubs. Membership is a proxy for intensity of an individual's preferences or commitment to hunting experiences.

The specification of the indirect utility function is

[1] The 60% response rate is somewhat lower than desirable when attempting to generalize the sample values to the population of deer hunters. The methodological comparison of the Hanemann and Cameron models is of course not affected by the response rate. We expect that the response rate may be slightly lower than other consumptive use surveys due to our inability to personally address the large number of cover letters involved in the statewide survey.

[2] The Box-Cox transformation contains the linear and log-linear models as special cases and is used to test the linear specification. The Box-Cox transformation is defined as

$$g^{\lambda}(x) = \frac{x^{\lambda} - 1}{\lambda}.$$

The linear model results if $\lambda = 1$, while a log-linear model is obtained if $\lambda = 0$.

$$(7)\quad V(j,Inc;S) = \alpha_j + (\beta_{j1} + \beta_{j2}Org)\,Inc + \beta_{j3}Partis + \beta_{j4}Deer + \epsilon_j,$$

where $j = 0$ represents no access to this deer hunting site, and $j = 1$ represents access to the resource when the respondent faces the offered bid amount.

The explanatory variables include the household income of the hunter (*Inc*), a zero/one dummy variable indicating membership in a hunting club, and an interaction term between *Inc* and *Org* reflecting the joint impact of higher income and membership in hunting organizations on intensity of hunting preferences.

The number of other hunting parties seen by the hunter on the most recent trip (*Partis*) and the number of deer seen (*Deer*) are included to represent the quality of the hunting experience. The number of hunting parties encountered reflects the preferences of hunters for isolation in the hunting experience. Fewer hunting parties seen implies decreased competition from other hunters and is positively related to the perceived quality. A complete description of the variables used in the estimation, along with sample means and standard deviations, is presented in Table 1.

Using the specification in equation (7), when faced with the increase in trip costs for hunting, the respondent will accept the bid (defined as *Bid*) only if

$$(8)\quad \alpha_1 + \beta_{11}(Inc - Bid) + \beta_{12}(Inc - Bid)\,Org + \beta_{13}Partis + \beta_{14}Deer + \epsilon_1 \geq \alpha_0 + \beta_{01}Inc + \beta_{02}IncOrg + \beta_{03}Partis + \beta_{04}Deer + \epsilon_0.$$

The utility difference model derived from this specification is

$$(9)\quad \Delta V = \alpha^* + \beta_1^*Inc + \beta_2^*IncOrg - \beta_{11}Bid - \beta_{12}BidOrg + \beta_3^*Partis + \beta_4^*Deer + \eta_1,$$

where η_1 is the difference in the error terms of the indirect utility functions. The starred coefficients represent differences in the estimated coefficients of the indirect utility function across states of the resource, such as $\beta_1^* = \beta_{11} - \beta_{01}$. The specification does not restrict the impact of the quality of hunting variables (*Partis* and *Deer*) to be the same for the no-access and access scenarios. These variables are included in the estimated utility difference model.

Tests of McConnell's constant marginal utility of income conditions based on the income effects in the utility difference model are performed to clarify the relationship between the Hanemann and Cameron approaches.

Table 1. Variables Used in Model Estimation

Variable Name	Variable Mnemonic	Mean
Household income for the hunter	*Inc*	37,367 (21,054)[a]
Interaction between *Inc* and *Org*	*IncOrg*	15,602 (24,417)
Increase in trip costs the hunter is asked to pay	*Bid*	152.67 (178.41)
Interaction between *Bid* and *Org*	*BidOrg*	58.57 (128.03)
The number of hunting parties seen by the hunter on the most recent trip	*Partis*	17.28 (18.17)
The number of deer seen on the most recent trip	*Deer*	89.20 (116.64)
Dummy variable indicating membership in a hunting organization (1 is member, 0 otherwise)	*Org*	0.37 (0.48)

[a]Standard deviations are in parentheses.

Empirical Results for the Utility Difference Model

Maximum-likelihood coefficient estimates of the empirical utility difference model are presented in Table 2. The negative coefficient on the bid amount in the utility difference model indicates that higher bid amounts decrease the probability of a yes response. Increases in the number of parties seen on a trip decreased the probability of a yes response. Increases in the number of deer seen increased the probability of a yes response.

The tests for constant marginal utility of income and the test results are presented in Table 3. The first condition is satisfied if the marginal utility of income is constant, that is, the utility difference model is linear in income. In an alternative specification, the Box-Cox transformation was applied to the income variables, and the λ parameter was estimated jointly with the parameters of the Hanemann model. Linearity in income is not rejected if $\lambda = 1$. The formal hypothesis is H_0: $\lambda = 1$; the asymptotic test statistic is $\chi_2^2 = 2[L(\hat{\lambda}) - L(\lambda = 1)]$. This is not rejected for this model since the χ_2^2 value is 3.048, which does not exceed the critical value of 5.99 for a test at the 0.05 level.

In the second test, the significant coefficients on the income variables indicate that the marginal utility of income does vary across alternative states of the resource. A likelihood ratio test statistic that the income coefficients are all zero ($\beta_1^* = \beta_2^* = 0$)

Table 2. Coefficient Estimates for the Utility Difference Model and the Variation Function Model for Deer Hunting in California

Model	Utility Difference Model[a]	Variation Function Model
Intercept	1.032	87.069
	(3.617)*	(2.378)*
Inc	0.022	2.672
	(2.860)*	(2.787)*
IncOrg	−0.018	−2.716
	(−2.430)*	(−1.992)*
Bid	−0.010	
	(−7.185)*	
BidOrg	0.003	
	(1.837)*	
Partis	−0.007	−0.877
	(−1.118)	(−1.163)
Deer	0.003	0.361
	(2.488)*	(2.423)*
Org		79.911
		(1.419)
κ		113.821
		(8.997)*
% Correct Predictions	77.14	76.53
N	490	490

[a]For the utility difference model and the variation function model, asymptotic *t*-values are in parentheses. An asterisk indicates significance at the 0.10 level.

is 10.300, which exceeds the χ_2^2 critical value. Thus, the set of income variables cannot be omitted from the specification.

The third test examines whether the marginal utility of income is constant across individuals. The likelihood ratio test statistic, $\chi_1^2 = 6.046$, confirms that the coefficient on *IncOrg*, the interaction term between income and membership in a hunter's organization, is significant, which suggests that marginal utility of income varies across hunters.

These results indicate that the utility difference model and the variation model for this CV scenario cannot be interpreted as simple linear transformations of one another. The empirical importance of testing the marginal utility of income conditions should be accounted for in the specification and choice of the Hanemann and Cameron models. McConnell demonstrates that when the marginal utility varies across respondents, the error term associated with the variation function is heteroscedastic. The empirical results which reject the constant marginal utility of income suggest that correct specification of the Cameron model must take into account heteroscedasticity in deriving valid WTP estimates.

A simple test for heteroscedasticity in the variation function derived from this utility difference specification is based on the *BidOrg* variable. Since the coefficient on *BidOrg* is statistically different from zero, the variation function will have a heteroscedastic error term. The likelihood ratio statistic of 3.432 confirms that *BidOrg* is statistically significant. Estimation of the variation model accounts for this heteroscedasticity and is discussed in more detail in the next section.

Empirical Results for the Variation Function

The specification of the variation function, VF, is consistent with the specification of the utility difference model (equation 9):

$$(10)\quad VF = \delta_0 + \delta_1 Inc + \delta_2 IncOrg + \delta_3 Org + \delta_4 Partis + \delta_5 Deer + \eta_{c1}.$$

The error term for the censored logistic regression model varies across individuals: $\eta_{c1} = (\epsilon_1 - \epsilon_0)/(\beta_{11} + \beta_{12}{*}Org_i)$.

Maximum-likelihood estimates of the model are presented in Table 2. The estimated variance-covariance of the model is corrected for heteroscedasticity following the robust estimation techniques developed by Royall for the logit model.

The impact of changes in each explanatory variable on the conditional expected WTP is determined from the model coefficients using Cameron's approach. Respondents who see additional deer are willing to pay more for the hunting experience; each additional deer seen on the hunting

Table 3. Summary of Tests and Results for the Utility Difference Model

Hypothesis #1:	Marginal utility of income is constant.
Test #1:	Utility difference is linear in *Inc* and *IncOrg*. Test linear vs. log-linear model in *Inc* and *IncOrg* using the Box-Cox specification.
Result #1:	Hypothesis is not rejected since χ_2^2 value is 3.048.
Hypothesis #2:	Marginal utility of income is constant across resource states.
Test #2:	Utility difference model is independent of both *Inc* and *IncOrg*. Test $\beta_1^* = \beta_2^* = 0$ for *Inc* and *IncOrg*.
Result #2:	Hypothesis is rejected since χ_2^2 value is 10.300.
Hypothesis #3:	Marginal utility of income is constant across respondents.
Test #3:	Utility difference model is independent of *IncOrg*. Test $\beta_2^* = 0$.
Result #3:	Hypothesis is rejected since χ_1^2 value is 6.046.

trip increases WTP by $0.36. The positive coefficient on the income variable from the Cameron model indicates that hunting is a normal good.

Welfare Measures and Confidence Intervals

Estimates of marginal mean WTP for current deer hunting conditions evaluated at the means of the explanatory variables were developed from both models. The point estimate of WTP from the utility difference model is $183. The marginal mean of WTP from the censored logistic regression model is $190. These mean WTP estimates are essentially the same.

Bockstael and Strand note that the parameter estimates used to calculate welfare measures are themselves random variables. Standard errors for the WTP measures are developed that take into account the variability associated with the complete set of estimated coefficients in the model. Confidence intervals for the utility difference model are developed using a method proposed by Krinsky and Robb.

The estimated WTP function derived from the linear utility difference model is a nonlinear function of the coefficient estimates from the Hanemann model. The Krinsky-Robb technique was implemented using the estimates of the parameter vector and the variance-covariance matrix. Random drawings are made from a multivariate normal distribution with variance-covariance matrix $\hat{V}$ and mean $\hat{\beta}$ to create a new parameter vector $\hat{\hat{\beta}}$. Amemiya demonstrated that the estimated parameters from the logit model are asymptotically normal. For each drawing of $\hat{\hat{\beta}}$, WTP is calculated using the formula for the Hanemann utility difference model. An empirical distribution for WTP from the estimated model is obtained from a large number of random draws. To determine the $(1 - \alpha)$ confidence interval, the empirical distribution of WTP is ranked from highest to lowest, and $\alpha/2$ values from each tail of the distribution are dropped. The results appear in the first column of Table 4.

Mean WTP depends on the estimated parameters of the censored logistic regression model, as shown in equation (6). The Krinsky and Robb technique was again applied to generate an empirical distribution for WTP by drawing from the estimates of the parameter vector and the variance-covariance matrix for the censored logistic regression model. The confidence intervals for mean WTP from the utility difference model and the variation function are developed using the same basic technique to provide a consistent comparison.

Table 4. Mean and 95% Confidence Intervals on Willingness to Pay

Model	Utility Difference Model	Variation Function Model
Upper Bound	$216	$219
Mean	$183	$190
Lower Bound	$159	$159

Using the robust covariance matrix estimates, the 95% confidence interval for WTP from the utility difference model ranges from $159 to $216. The 95% confidence interval for WTP from the variation function model ranges from $159 to $219. The confidence intervals confirm the basic similarity of benefit estimates derived from the two techniques.

Conclusion

Alternative approaches for valuing nonmarket resources using contingent valuation survey data have been proposed by Hanemann and Cameron. Examining the utility theoretic foundations of the models, McConnell has noted that no empirical evidence is currently available to guide in the choice between these approaches. One objective of this paper is to compare the performances of the Hanemann and Cameron models in estimating WTPs from the same closed-ended contingent valuation data.

Our analysis showed that two of the three conditions identified by McConnell for equivalence of the Hanemann utility difference and Cameron variation function model are violated. Despite these violations, the two approaches' estimates of mean willingness to pay and their associated 95% confidence intervals around the mean were quite similar for this data set.

This finding indicates the choice of approach may be based partially on convenience. To derive the average value under existing conditions, either method will suffice. The Hanemann utility difference model is easily estimated using standard binary logit software. The Cameron model requires nonlinear optimization routines, which may encounter convergence problems. Researchers may prefer to impute parameters of the Cameron model, where the utility difference model and the variation function are linear transforms. Cameron's variation function is more convenient for evaluating site quality changes or impacts of changes in respondent characteristics on environmental benefits.

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