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Comparing Methods to Select Functional Form in Dichotomous Choice Contingent Valuation Methods

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Ⅰ. Introduction

In one of the influential nonmarket valuation studies, Bowker and Stoll (1988) noted the importance of the choice of functional form in order for economists to suggest an estimate for applied policy analysis. In a study

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of valuing the whooping crane resource based on a dichotomous choice contingent valuation methods (DC CVM), the authors reported that the mean willingness-to-pay (WTP) estimate from the logarithmic specification seems most credible over the linear and share models. Given the empirical results reported, there existed a substantial difference between welfare measures based on the logarithmic and linear models for a given choice of truncation level. Their research emphasized that models with fairly similar statistical fits can lead to very disparate measures of economic value, regardless of whether the mean or median was chosen to estimate average WTP.

Their preference of the logarithmic model for welfare measures in Bowker and Stoll (1988) was based mainly on statistical fit, pretesting of offer ranges, and other considerations such as the sensitivity of the model to the truncation rule chosen and the nonnegative median value of the specification. Several DC CV studies have showed that logarithmic specifications outperform the alternatives proposed by Hanemann (1984), based on goodness-of-fit statistics(Sellar *et al.*, 1986; Boyle and Bishop, 1988; Duffield and Patterson, 1991). Duffield *et al.* (1992) examined a range of Box-Cox transformation parameters to see whether the true transformation of the bid variable is close to linear or closer to log and adopted the log specification, while Hanemann and Kanninen (1998) suggested that a Box-Cox specification itself be an alternative.

Since the parameter estimates used to calculate welfare measures are themselves random variables (Bockstael and Strand, 1987), the welfare estimates are also random variables with usually unknown probability distributions. Different functional forms imply different transformations from function parameters to welfare measures, and these transformations map instability in parameter estimates into instability of welfare estimates in different ways (Adamowicz *et al.*, 1989). The stochastic properties of welfare estimates indicate that the usual measures of goodness-of-fit such as R-squares, model chi-squares, or t-statistics on parameters in a logit specification need not imply corresponding accuracy of welfare estimates (see also Kling and Sexton, 1990; Lee and Chun, 1999).

In many DC CVM studies, a specific form of logit function has been advocated without full consideration of its effects on the welfare measures. The DC CVM is applied to quantify individuals' economic surplus that, in many instances, is to be used in making a resource allocation decision in a benefit-cost framework. The functional form that yields an accurate expected value of welfare measure therefore should be of interest. It may be undesirable to select a functional form such that over repeated samples very small changes in estimated parameters lead to very large changes in estimated welfare measures (Adamowicz *et al.*, 1989). It may also be undesirable that a functional form yields a nontrivially different welfare estimate, compared to the WTP measure obtained by a nonparametric approach.

An empirical comparison between functional forms based on presentation of confidence intervals for benefits measured with DC CVM was first conducted by Park *et al.* (1991). They estimated the variance of a truncated mean to construct confidence intervals, based on Krinsky and Robb's simulation approach. The authors demonstrated that with confidence intervals around the WTP estimates, different functional forms could yield statistically identical mean estimates of WTP. However, their approach provided no guidance for choosing an appropriate model when the difference in valuation across functional forms are statistically significant because the confidence intervals do not overlap.

Adamowicz *et al.* (1989) argued that in cases where the consumer's surplus is most important, both the expected value and the variance of the welfare measure may be of interest. They used a bootstrapping approach to estimate the variance of welfare measures for several functional forms of the travel cost model, and then computed coefficients of variation for each specification for the consumer surplus estimate. The author suggested a model as an appropriate specification among alternatives that yields a smallest coefficient of variation of the associated welfare measure. The same motivation of this procedure can be applied to any utility theoretic demand function such as DC CV model. While the coefficients of variation can be used adequately to examine the relative precision of welfare estimates, Kling and Sexton (1990) showed that the magnitude of the coefficient of variation varies considerably, depending on alternative bootstrap procedures as well as the number of bootstrap trials to conduct.

While not directly comparable to the simulation approach for calculating the precision of welfare estimates, misspecification tests for DC CV models conducted by Ozuna *et al.* (1993) may be an alternative approach that can be used for selecting functional form in the context of welfare measures. They argued that testing for omitted variables, heteroscedasticity, or the asymmetry of distribution in DC CV models is important because these problems result in inconsistent parameter estimates which in turn yield undesirable welfare measures. Based on the conditional moment testing procedure for binary choice models suggested by Pagan and Vella (1989), the authors summarized that the combined problem of heteroscedasticity and distributional misspecification does have an effect on the precision of welfare estimates.

Comparing welfare estimates from parametric models to those from nonparametric models may also provide some insightful criteria for selecting functional form. Compared to parametric models, nonparametric models are more robust against possible misspecification of the response probability distribution and offer the least restricted characterization of what the data have to say, although they provide less economic information (Hanemann and Kanninen, 1998). If an estimate of WTP obtained using a parametric specification does not differ significantly from that obtained with a nonparametric approach, the functional form is appropriate in terms of welfare measure estimation.

The purpose of this study is to investigate approaches that have been developed or could be adapted to select functional form in the context of welfare measure by finding whether the approaches are in a fairly close agreement. Three approaches examined here are coefficient of variation for welfare measure, misspecification test, and nonparametric approach. The results could be used to adopt appropriate approach to select functional forms that yield relatively accurate benefits measured with DC CVM using a logit model. A dichotomous choice form of contingent valuation is applied to the hunting resource in Korea.

Ⅱ. Welfare Measures and DC CV Models

The theoretic specification of the CV model for deriving Hicksian compensating and equivalent surplus measures is based on a utility-theoretic analysis (Hanemann, 1984). Assume that an individual's utility is given by $u = u(r, y; s)$, where $r = 1$ if the individual is able to participate in recreation and $r = 0$ if the one is not. Income is denoted by y and other individual characteristics which may influence preferences are denoted by s. Because there are unobservable random components in an individual's utility function, utility is treated as a random variable with a given parametric probability distribution with mean $v(r, y; s)$ and stochastic element denoted by ε_r. The random variable $\varepsilon_r (r = 1, 0)$ is an i.i.d. random variable with zero mean.

An individual is assumed to answer yes to an offered cost A for a policy change if $v(1, y - A; s) + \varepsilon_1 \geq v(0, y; s) + \varepsilon_0$. In this case, the probability that the individual is willing to participate in recreation is Prob(yes) $= F_h(dv)$, where dv is the difference in indirect utility, $v(1, y - A; s) - v(0, y; s)$, and $F_h(dv)$ is the cumulative distribution function of the individual's true maximum WTP. As a measure of WTP for a policy change, a measure of the central tendency of the WTP distribution is generally chosen. One is the mean (truncated) of the estimated WTP distribution, m^+:

$$m^+ = \int_0^{A^{\max}} Prob(\text{yes})\, dA \qquad (1)$$

The upper limit of integration is set at $A^{\max}$, the highest offered amount in the valuation survey of respondents, rather than integrating out to infinity. The other is the median, m^*, of the estimated WTP distribution, where $F_h(m^*) = 0.5$. The indirect utility difference model yields the logit specification when $Prob(\text{yes})$ is specified as the cumulative distribution function of a standard logistic variate:

$$Prob(\text{yes}) = [1 + e^{-dv}]^{-1} \tag{2}$$

In this study three functional forms, consistent with the indirect utility difference model, are presented: the linear-logit, Hanemann's log (share), and log-logit specifications. The linear model includes the bid amount and other characteristics of individuals (if necessary) but does not contain the respondent's income:

$$dv = \alpha + \beta_1 A + \beta_2 S \tag{3}$$

The share model includes the income as well as the bid amount and other characteristics in which the bid amount and income is expressed as a share form:

$$dv = \alpha + \beta_1 \ln[1 - (A/Y)] + \beta_2 S \tag{4}$$

In the logarithmic specification, income is included:

$$dv = \alpha + \beta_1 \ln A + \beta_2 \ln Y + \beta_3 S \tag{5}$$

Ⅲ. Empirical Analysis for Model Selection

The data were collected by mail survey from the study population that was the hunter with an appropriate hunting permit for the 1993/94 season. A total of 335 observations were used for the analysis. The relevant questions on the hunting survey are analogous to the DC CV questions used in Park *et al.*'s Montana elk hunting study (1991). A general description of the question has the following form: Would you be willing to pay $A in additional costs for an improvement in each of the following hunting quality attributes: no improvement, increased game populations, and decreased congestion? The offer value $A is varied across the survey respondents but each respondent has only a binary choice (For more details, see Lee and Chun, 1999). The appropriate specification to analyze this type of response data is a dichotomous choice model.

The analysis begins with the estimation of three functional forms of DC CV in (3), (4), and (5), where A is the offer amount, Y is income, and S is the dummy variable representing the experience to hunt big game, such as wild boar or water deer at least one time throughout the season. The results of estimations of the linear, share, and logarithm models are presented in <Table 1>. Coefficient estimates for the models were all consistent with prior expectations. For all alternative models within a given scenario, the coefficients except for some constant terms were all significant at 99% confidence level and have expected signs. Higher bid amounts are negatively related to the probability of a yes response. Respondents with higher incomes and opportunity to harvest large game had a higher probability of a positive response to the CV questions. Inspection of the results indicates that the model specifications all perform well in terms of asymptotic t-statistics on the variables, but the log model in each quality scenario is superior to the linear, and share models in terms of the goodness-of-fit measures based on McFadden R-squares, the model chi-squares, and the percentage of correct predictions.

1. Coefficients of Variation for Welfare Measures

To examine the relative performance of the alternative specifications in calculating the precision of welfare estimates, coefficients of variation were computed for each functional form. The coefficient of variation is the standard deviation of the welfare estimates distribution, divided by the mean WTP of the distribution. Thus, large coefficients of variation imply imprecise point estimates. Based on the model estimation results, the point estimates, m^+ of WTP are calculated using equation (1) <Table 1>.

The mean WTP and the variance of the WTP are estimated using a simulation method proposed by Krinsky and Robb (1986). This method can be applied to construct the empirical distribution of any estimator which is a nonlinear function of the estimated parameters and was demonstrated to develop confidence intervals for welfare measures derived from DC CV models by Park *et al.* (1991). Multiple random drawings to create a new parameter vector are made from a multivariate normal distribution with variance-covariance matrix and mean which are readily available from the estimated logit model. For each drawing of the parameter vector, WTP is calculated using equation (1). An empirical distribution for WTP is obtained from the logit model using the complete set of replications. The standard deviation is then calculated from the empirical distribution. Krinsky and Robb suggested that a thousand

〈Table 1〉 DC CV Logit Models for Alternative Functional Forms

WTP from the *K-R*									
	α	β_1	χ^2	%	R^2	m^+	Mean	*s.d.*	*c.v.*
							…(1,000₩)…		
Current Condition									
Linear	0.065 (0.309)	-0.000004 (-4.529)*	37.0	62.1	0.08	182	182	15	0.082
Share	0.172 (0.845)	120.68 (5.263)*	56.5	69.6	0.12	200	201	14	0.071
Log	-11.377 (-2.646)*	-0.8103 (-5.430)*	72.2	70.1	0.16	178	178	14	0.082
Increased Game									
Linear	-0.082 (-0.377)	-0.000003 (-5.023)*	46.2	67.2	0.10	258	260	22	0.085
Share	0.169 (0.773)	103.89 (6.105)*	82.5	71.0	0.18	274	276	21	0.077
Log	-19.009 (-3.988)*	-0.938 (-5.430)*	97.2	74.0	0.22	247	249	22	0.088
Reduced Congestion									
Linear	0.407 (1.933)**	-0.000003 (-5.394)*	46.1	65.4	0.10	334	334	23	0.069
Share	0.701 (3.283)*	102.00 (6.697)*	91.1	74.0	0.20	358	358	23	0.064
Log	-24.507 (-4.955)*	-0.940 (-5.478)*	113.0	77.3	0.24	329	330	25	0.075

Notes : Asymptotic t-values are in parentheses. Single and double asterisks indicate significance at 0.01 and 0.1 levels, respectively. In the models estimated, only constant term (α) and slope coefficient (β_1) are presented. χ^2 = model chi-square ; % = percent of right prediction; R^2 = McFadden R square; m^+ = point estimate (truncated); Mean = WTP estimate from the Krinsky-Robb method based on 1000 replications; s.d. = standard deviation; c.v. = coefficient of variation.

drawings is sufficient to generate a sufficiently accurate distribution.[1]

The mean, standard deviation, and coefficient of variation are computed for each functional form based on 1000 drawings from a multivariate normal distribution <Table 1>. The means of the Krinsky and Robb analyses and the point estimates derived directly from equation (1) are almost identical. Although the logarithmic specification outperformed the linear and share models in terms of the goodness-of-fit measures, the differences of the coefficients of variation among the functional forms for a given condition are trivial. The coefficients of variation for the linear, share, and log specifications are ranged 7.1% to 8.2%, 7.7% to 8.8%, and 6.4% to 7.5%, respectively, for the given scenarios of current conditions, increased game, and reduced congestion. The results indicate that there is no functional form superior to others in terms of welfare measure. It is noteworthy, however, that the trivial difference itself between the coefficients of variation for welfare measures for a given hunting quality may not guarantee that the three functional forms produce statistically the same benefit estimates.

2. Misspecification Test for DC CV Model

Misspecification tests for heteroscedasticity and the asymmetry of distribution in DC CV model can be adopted to investigate the appropriateness of functional forms for welfare measures. Following

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1) An alternative approach is bootstrapping. The bootstrap is a general resampling procedure for estimating sampling distributions of a function of unknown parameters. The method has been applied to the econometric models for DC CV by several researchers (e.g., Duffield and Patterson, 1991; Cooper, 1994; Lee and Chun, 1999).

〈Table 2〉 Misspecification Test Results for Three Alternative Hunting Conditions

Test	Moment Restrictions	t-statistics[a]		
		Current Condition	Increased Game	Reduced Crowding
Liner				
Distribution[b]	$E(PRED^2 * \varepsilon)=0$	0.899	0.442	0.163
	$E(PRED^3 * \varepsilon)=0$	0.842	0.285	0.234
Heteroscedasticity[c]	$E(X*PRED* \varepsilon)=0$	2.025	0.839	0.269
	$E(S*PRED* \varepsilon)=0$	0.890	0.223	0.865
Share				
Distribution	$E(PRED^2 * \varepsilon)=0$	3.107	3.250	2.971
	$E(PRED^3 * \varepsilon)=0$	3.089	2.775	2.741
Heteroscedasticity	$E[\ln(1-(X/Y))*PRED* \varepsilon]=0$	3.760	2.604	2.818
	$E(S*PRED* \varepsilon)=0$	1.209	1.499	0.816
Log				
Distribution	$E(PRED^2 * \varepsilon)=0$	1.155	0.390	1.263
	$E(PRED^3 * \varepsilon)=0$	0.970	0.352	0.608
Heteroscedasticity	$E(\ln X*PRED* \varepsilon)=0$	0.900	2.136	2.098
	$E(\ln Y*PRED* \varepsilon)=0$	1.198	1.637	2.084
	$E(S*PRED* \varepsilon)=0$	0.680	0.071	0.091

a : Absolute values.

b : PRED are the predictions, $z_i\beta$ and ε are the generalized residuals.

c : X = offer; Y = income; S = dummy variable representing the experience to hunt big game, at least one time throughout the season.

Ozuna *et al.* (1993), the conditional moment testing procedure for binary choice models suggested by Pagan and Vella (1989) can be utilized to choose correctly specified models. In practice, the test for heteroscedasticity requires the estimation of one regression for each variable in equation (3), (4), or (5). The dependent variable in this case is the product of each variable and $[(z_i\beta) * \varepsilon_i]$, where $z_i\beta$ are the predicted values of the logit equation and ε_i are the generalized residuals (see Ozuna *et al.* for the computation of ε_i). The test for distribution misspecification requires the estimation of two regression which have, respectively, the following dependent variables, $(z_i\beta)^2 * \varepsilon_i$ and $(z_i\beta)^3 * \varepsilon_i$.

The tests involve regressing each sample conditional moment restriction on unity and the vector of the scores of the log-likelihood function and then testing if the coefficients on the intercept are zero. If the coefficient on the intercept is not significantly different from zero using t-statistics, the population conditional moment restrictions hold and therefore the model is correctly specified. The results of the misspecification tests for the three functional specifications are presented for each hunting quality level in <Table 2>. All statistical tests are performed at the 0.05 level of significance.

The t-statistics on the asymmetric distribution tests for current conditions indicate that the assumption of a logistic distribution is correct for all functional forms but the share model. Heteroscedasticity affects one regressor in each of the linear and share models. These results indicate that the log model is appropriate for the computation of welfare measures. For the case of increased game populations, the asymmetric distribution tests indicate that the logistic distribution is appropriate for the linear and log models. The distributional problem is somewhat severe in the share model. Heteroscedasticity does not affect any regressor in the linear model while affecting one regressor in the share and log models. For reduced crowding, the asymmetric distribution tests indicate that assuming a logistic distribution is correct for the linear and log models but not appropriate for the share model. Heteroscedasticity affects one regressor in the share model and two regressors in the log model.

Ozuna *et al.* (1993) implied that unless the problem of heteroscedasticity is quite severe, distributional misspecification does not have an effect on the estimation of WTP welfare measures. None of the functional forms for all three scenarios in the present study shows the combined problem with heteroscedasticity and distributional misspecification. The results, therefore, indicate that each functional form for a given environmental quality is appropriate in estimating WTP.

3. Comparing to Nonparametric Approach

From the misspecification test, however, it is not clear how much misspecification really matters in terms of welfare estimation. To provide some insight on this issue, the WTP measures derived from the three functional forms across alternative hunting quality conditions are compared to the WTP estimates obtained by nonparametric approach. The nonparametric approaches in DC CVM studies were introduced by Kriström (1990) and Duffield and Patterson (1991).

For this study, the method used by Duffield and Patterson (1991) is employed in the light that the variance required for constructing

〈Table 3〉 Mean and 95% Confidence Intervals on WTP

	Current Condition	Increased Game	Reduced Crowding
			…(1000₩)…
Linear Model			
Upper Bound	214	307	378
Mean	182	260	334
Lower Bound	155	218	291
Share Model			
Upper Bound	230	319	403
Mean	201	276	358
Lower Bound	174	238	314
Log Model			
Upper Bound	208	272	377
Mean	178	249	330
Lower Bound	150	210	281
Nonparametric Model			
Upper Bound	210	309	375
Mean	186	270	335
Lower Bound	162	233	295

confidence intervals can be derived. The nonparametric approach leads to an alternative estimator for the truncated mean which is obtained by integrating *Prob*(yes) of left hand side in equation (2) from 0 to T by a piecewise linear function through the points $(0, p_1)$, (X_1, p_1), (X_2, p_2), $\cdots$, (X_k, p_k), (T, p_k), where p_i is the observed proportion of yes responses at offer X_i. The truncation value T is obtained via linear extrapolation.

The variance of the nonparametric estimator is also readily calculated under the assumption of independence of the responses (Duffield and Patterson, 1991). Duffield and Patterson (1991) compared the estimated truncated means from the log-logit model with the nonparametric estimates for several data sets and found them generally to be close. As a similar finding, given adequate sample sizes, large differences between the two would reflect a lack of appropriateness of the chosen functional form in parametric logit model.

The nonparametric mean WPT estimates and its 95 percent confidence intervals for the welfare measures are presented with those of the logit models in <Table 3>. Confidence intervals around welfare measures estimated from the logit models can be readily constructed from the empirical distribution of WTP estimated using the Krinsky-Robb's procedure with 1000 replications. A $(1-a)$ confidence interval is obtained by ranking the distribution of calculated WTP values and dropping the $a/2$ values from each tail of the ranked distribution. The results show that the parametric mean welfare estimates substantially fall into the confidence intervals on nonparametric WTP for any given level of quality, indicating that the parametric welfare estimates are fairly close to the nonparametric welfare estimate. It, however, should be noted that the p_i's (observed proportions of positive responses at offers) are not guaranteed to be nondecreasing particularly if sample sizes are small (Duffield and Patterson, 1991). It also needs to be noted that since the nonparametric approach uses the sample data to extrapolate an upper bound on WTP, the truncation value T is highly variable for given methods used to extrapolate(Ready and Hu, 1995).

Ⅳ. Conclusions

This paper examined a set of combined procedures of testing the appropriateness of functional specifications for welfare measures in DC CV studies. Since none of the approaches that has been developed so far is not completely proved as a true testing strategy, depending upon only one of them may lead undesirable outcomes for welfare measures. In this study, three methods that have appeared in literature were applied in an empirical setting to the recreational hunting resource in Korea to provide the appropriate model specifications for welfare measures on hunting quality changes.

From the integrated use of the three methods to select appropriate functional forms, it was found that any choice of the functional forms to estimate hunting benefits was appropriate, at least for this data set. This finding can be confirmed from <Table 3>. The mean WTP estimates among the functional forms are not significantly different for a given alternative condition because the confidence intervals substantially overlap. Thus, we can expect that any functional form chosen yields statistically the same WPT estimate for given levels of hunting quality.

Each of the procedures of selecting functional form was in a fairly close agreement and, more adequately to say, complementary to the others. To use all of the three methods for selecting an appropriate functional form for WTP may require a heuristic econometric effort. However, the integrated use of the existing approaches could affirm to produce the best model for welfare estimates measure with DC CVM using a logit model. It also needs to be noted that negligible differences of the coefficients of variation for welfare estimates, misspecification problems not combined, and fairly close agreement between the parametric and nonparametric estimates may indicate that the logit models fit the data well. A similar result can be found in Duffield and Patterson (1991). They found that the parametric and nonparametric mean estimates are similar when the logit model fits the data well. Even though data used for the analyses were split into three pieces according to the scenarios, a more rigorous analysis should be performed since only one data set was examined.

Based on the log-logit model and 95 percent confidence intervals, the results indicates that a certain type of public policy needs to be implemented to increase the quality of recreational hunting experiences because the two proposed policy changes result in higher benefits than do-nothing. More specifically, the results suggest that controlling congestion provide higher satisfaction than increasing the number of game.

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ABSTRACT

양분선택형 비시장가치평가법에 있어서 함수모형선택을 위한 제 방법론 비교

이 희 찬

본 논문의 목적은 양분선택질문형 비시장가치평가법을 통한 편익추정에 사용되는 제 함수의 적합성 여부를 검증하기 위해 사용될 수 있는 방법론들을 비교·검토하는 것이다. 여가수렵의 환경적 요인의 변화에 따른 편익추정에 사용된 함수의 적합성을 판단하기 위해 변이계수접근법, 함수설정 오류 테스트, 그리고 비모수접근법 등이 각 함수에 적용되었다. 결과에 따르면, 편익추정에 이용된 세 가지 로짓함수(선형, 로그, 쉐어모형) 모두 적합한 것으로 판정되었다. 주어진 함수형태에 적용된 세 방법론간에 밀접한 일치성을 보였으며 경우에 따라서는 상호보완적이라는 함축성을 보이기도 하였다. 이와 같은 결론은 로짓함수로부터 추정된 값들에 Krinsky-Robb 시뮬레이션을 이용하여 구축한 신뢰구간의 함수간 비교를 통해서도 확인되었다. 주어진 환경 시나리오에 대해 각 함수로부터 도출된 평균 추정치의 신뢰구간이 모두 충분히 중복되었기 때문에 편익추정과 관련하여 함수형태간에 유의적 차이가 없음이 입증된 것이다.