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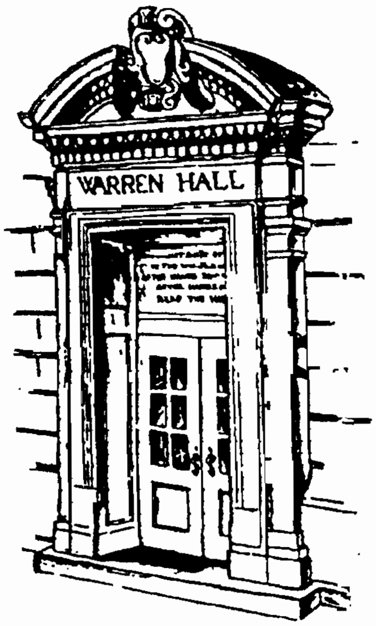

Working Paper

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Measuring the Differences in E(WTP) when Dichotomous Choice Contingent Valuation Responses are Not Independent

by

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Abstract
Dichotomous choice contingent valuation surveys frequently elicit multiple values in a single questionnaire. To the extent that responses are correlated across scenarios, the standard approach of estimating willingness to pay (WTP) functions independently for each scenario, and then evaluating differences in mean WTP distributions across scenarios can provide biased estimates of the actual difference in mean WTP values. This paper develops an alternative bivariate probit approach that explicitly accounts for correlation across responses in the estimation of WTP and mean WTP distributions. Correlation across responses is found to have an effect on the significance of mean WTP difference tests.

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Measuring the Differences in E(WTP) when Dichotomous-Choice Contingent Valuation Responses are Not Independent

1. Introduction

The high costs associated with collecting primary data, coupled with a need for within sample comparisons of Hicksian surplus values, frequently leads researchers to include several contingent valuation questions in a single survey. Multiple scenario questionnaires are particularly common in resource valuation surveys which often elicit surplus values for a baseline level of resource provision (e.g. current hunting conditions) and then ask for values for alternative levels of provision (e.g. improved hunting conditions)[1]. Although this approach reduces data collection costs and allows for the estimation of continuous resource valuation functions [e.g. Boyle, Welsh, and Bishop, 1993], possible correlation between responses complicates policy relevant comparisons of expected benefits across scenarios. There are several plausible reasons that such correlation may exist: there may be omitted relevant variable bias in approaches that require estimation of functional forms; individuals may have strong preferences across resources which are reflected in consistently high or low bids across scenarios; yea or nay saying may occur in discrete choice models; and initial questions may create some sort of starting point bias for follow-up questions.

To the extent that individual responses are correlated across alternative scenarios, the standard dichotomous choice contingent valuation (CV) approach of estimating willingness to pay (WTP) functions independently for each scenario and then evaluating differences in mean WTP distributions across scenarios can provide biased estimates of the actual difference in mean WTP values. This paper develops an alternative bivariate probit approach that explicitly accounts for correlation across responses in a dichotomous choice CV framework and evaluates

[1] Papers by Park, Loomis, and Creel and Ready, Whitehead, and Blomquist provide examples of this format.

whether the standard assumption of independent responses affects the significance of difference of mean WTP tests. The paper is organized as follows. Section 2 provides the conceptual framework for this analysis. Section 3 summarizes the studies used to investigate this issue. Section 4 discusses the empirical results. Implications and conclusions are provided in Section 5.

2. Conceptual Framework

Assume that the ith individual has some true surplus value for the jth scenario (s_{ji}), and that the respondent will indicate ($I_{ji}=1$) that they are willing to pay the bid value (b_{ji}) if $s_{ji} \geq b_{ji}$. If, instead, $s_{ji} < b_{ji}$ then the individual will not be willing to pay this amount and the indicator variable $I_{ji}=0$. Following the random utility framework presented in Hanemann (1984) and Cameron (Cameron; Cameron and Quiggen) further assume that the unobserved value s_{ji} consists of a systematic component, $x'_{ji}\beta_1$, which is a function of the x_{ji} observable attributes of the respondent and dichotomous choice bid value, plus an unobservable random component, ε_{ji}.

Standard approaches to evaluating and testing alternative scenarios assume that the ε_{ji} are uncorrelated. Under this assumption WTP distributions are estimated independently for each scenario, typically using either a logistic or normal specification for the error terms. Approximate distributions of mean WTP are derived from these estimated functions by applying bootstrapping or other repeated sampling techniques [Park, Loomis, and Creel]. Letting $\overline{WTP_j}$ denote the vector of mean WTP bootstrap values for the jth scenario, the approximate distribution of the difference of mean WTP distributions, $V = \overline{WTP_1} - \overline{WTP_2}$, can be defined by the following formula

$$f_V(V) = \int_{-\infty}^{\infty} f_{\bar{WTP}_1,\ \bar{WTP}_2}(v + \bar{WTP}_2, \bar{WTP}_2)\, d\bar{WTP}_2 \tag{1}$$

[Mood, Graybill, and Boes]. For independent distributions, the empirical application of the convolutions formula,

$$f_V(V) = \int_{-\infty}^{\infty} f_{\bar{WTP}_1}(v + \bar{WTP}_2) f_{\bar{WTP}_2}(\bar{WTP}_2)\, d\bar{WTP}_2 \tag{2}$$

can be used to estimate the distribution of the difference and provide a basis for assessing the significance of the difference between two distributions [Poe, Severance-Lossin, and Welsh]. An alternative approach to approximating this difference is to calculate the difference $\overline{WTP_{1L}} - \overline{WTP_{2K}}\ \forall\ L,K$, where L and K represent individual bootstrap values. However, because most bootstrapping applications require large L and K (e.g. > 1000) this latter approach involves a prohibitively large number (L * K) of calculations.

As suggested previously, the assumption of independence may not be appropriate in multi-scenario questionnaires. Econometrically, in a manner analogous to seemingly unrelated regressions, this non-independence between two valuation functions may be accommodated by explicitly accounting for cross equation correlation in the estimation process. Within a discrete choice format this can be accomplished by assuming a bivariate normal distribution $BVN(0,0,\sigma_1,\sigma_2,\rho)$ across WTP distributions, for which the joint density function is given by:

$$\phi(x_1, x_2) = \frac{\exp^{-(z_1 + z_2 - 2\rho z_1 z_2)/2}}{2\pi\sigma_1^2\sigma_2^2} \tag{3}$$

where, $z_1 = X'_1\beta_1$ and $z_2 = X'_2\beta_2$. If ρ is indeed zero, this bivariate normal density function collapses to the product of two independent normal density functions, and the univariate approach outlined previously is appropriate for estimating the WTP distributions, the mean WTP distributions, and the difference of the mean WTP distributions. If $\rho \neq o$, the associated likelihood function for the four possible pairs of responses (no-no, no-yes, yes-no, yes-yes) across equations is given as:

$$L = \prod_i \left[\int_{-\infty}^{\frac{X_1'\beta_1}{\sigma_1}} \int_{-\infty}^{\frac{X_2'\beta_2}{\sigma_2}} \phi(z_1,z_2)dz_1dz_2\right]^{(1-I_1)(1-I_2)} *$$
$$\left[\int_{-\infty}^{\frac{X_1'\beta_1}{\sigma_1}} \int_{\frac{X_2'\beta_2}{\sigma_2}}^{\infty} \phi(z_1,z_2)dz_1dz_2\right]^{(1-I_1)I_2} *$$
$$\left[\int_{\frac{X_1'\beta_1}{\sigma_1}}^{\infty} \int_{-\infty}^{\frac{X_2\beta_2}{\sigma_2}} \phi(z_1,z_2)dz_1dz_2\right]^{I_1(1-I_2)} *$$
$$\left[\int_{\frac{X_1'\beta_1}{\sigma_1}}^{\infty} \int_{\frac{X_2\beta_2}{\sigma_2}}^{\infty} \phi(z_1,z_2)dz_1dz_2\right]^{I_1I_2} \tag{4}$$

Moreover, if the null hypothesis H_o: $\rho = 0$ is rejected, $E(\bar{WTP}_{2L}|\bar{WTP}_{1L})$ is a non-zero function of ρ [Goldberger] and the mean WTP distributions will depend upon the joint distribution of estimated parameters, one of which is ρ. Under these conditions, the convolutions approximation of the difference of mean WTP distributions depicted in Equation 2 is no longer relevant as simulated values from the joint distribution are paired. Instead, the difference of the mean WTP distributions could be estimated by directly bootstrapping the difference, i.e.

$$\overline{WTP_{1L}} - \overline{WTP_{2K}} \;\forall\; L=K. \tag{5}$$

Because L and K are paired in this approach, only L (=K) computations are required.

3. Data and Estimation Procedures

The data for this analysis were taken from three separate dichotomous choice CV mail surveys of recreational resource use. Samples of individual CV questions from each of the surveys are provided in Figures 1 to 3.

The *Escanaba Lake Survey* was conducted as part of a study to assess the validity of CV values by comparing hypothetical WTP to actual WTP.[2] Escanaba Lake is one of five lakes managed by the Wisconsin Department of Natural Resources in the Northern Highland State Forest of Vilas County. It is the only lake in Northern Wisconsin where anglers can fish for walleye after the ice is off the lake and before the regular fishing season. This early season between "ice-off" and the regular fishing season varies from a few days to a few weeks. Individuals who had fished the early season at Escanaba Lake in 1989, 1990, or 1991 were mailed a CV questionnaire in March of 1992 (prior to the early season). Eight hundred twenty questionnaires were mailed and 621 were completed. Adjusting for undeliverable questionnaires, the response rate was 82%. The questionnaire asked two dichotomous-choice CV questions. The first question asked whether the individual would pay $X for a "current level" permit to fish the upcoming early season. The second CV question asked about fishing the upcoming early season if there would be "15% less" walleye in Escanaba Lake.

The 1991 and 1992 *Sandhill Public Deer Hunt Surveys* were part of a larger study to assess the ability of recreationists to recall expenses related to a special deer hunt. Sandhill Wildlife Demonstration Area is a wildlife research property of the Wisconsin Department of Natural Resources in Wood County, Wisconsin. In 1991, 352 one-day deer hunting permits were issued for an either sex deer hunt to be held November 16 and 17. One hundred seventy-seven of the permit holders were sent questionnaires after the hunt. Seventy of the permit holders who were sent a questionnaire did not attend the hunt at Sandhill. Of the 107 hunters

[2] Unfortunately, the actual WTP data was never collected.

who received a questionnaire and hunted, 104 (97%) returned the questionnaire. In 1992, the Sandhill hunt was for antlerless deer only. Two hundred thirty permits were issued and 117 hunters were sent a questionnaire. One hundred seven (91% of the deliverable questionnaires) questionnaires were returned. The questionnaires sent in 1991 and 1992 were very similar. Respondents were asked about their expenses related to the Sandhill deer hunt, the quality of the hunt, some demographic questions, and two dichotomous choice CV questions. One question asked about their willingness to pay for an either sex deer hunting permit and the other asked about their willingness to pay for an antlerless deer hunting permit at Sandhill.

The objective of the *Grand Canyon White Water Boater Survey* was to estimate a statistical relationship between Hicksian surplus values for white-water trips and average daily Colorado River flows between 5,000 and 40,000 cfs (see Boyle, Welsh and Bishop, 1993 for further details). In this survey individual respondents were first asked to answer a CV question for their actual trip attributes (including flow level experienced), and then were asked to provide contingent values for a variety of hypothetical flow levels. Prior to answering the actual trip valuation question, respondents answered a series of questions about the attributes of their Grand Canyon white-water trip, including trip expenditures. Each of the questions for hypothetical flow levels of 5,13,22, and 40 thousand cubic feet per second (cfs) were preceded by a description of the boating and camping conditions associated with that specific flow. Conducted in 1986, a total of 506 usable responses were collected (337 commercial boaters and 169 private boaters), representing 91% of deliverable surveys.

4. Results

CV responses in each of the three surveys were compared with responses to different scenarios in the same questionnaire. The procedure for evaluating the effects of cross scenario correlation was to evaluate each pair of questions as follows. First, bivariate (joint) and univariate (independent) probit models were estimated using maximum likelihood techniques. Likelihood ratio tests were used to evaluate the hypothesis that H_o^1: $\rho = 0$. In the cases where H_o^1 is rejected, 10,000 simulated values of mean WTP were estimated using numerical integration techniques over the non-negative range of the WTP distributions [Hanemann, 1984, 1989] and a parametric bootstrap technique that draws simulated coefficient values from the covariance matrix [Park, Loomis, and Creel; Krinsky and Robb]. For the jointly estimated bivariate model, the mean WTP distributions for each question were approximated after accounting for ρ in the estimated covariance matrix. In both the joint and independent models, pairwise differences were calculated as in equation (5). Comparisons of these approximate distributions of the difference for the joint and independent estimates provide the basis for assessing the effects of the independence assumption on the distribution of the difference. The approximate one-sided significance of the difference is calculated by the proportion of negative values in the distribution of the difference. For comparisons in which H_o^1 is not rejected, no additional analyses were conducted beyond the initial maximum likelihood estimates.

The results of this sequence of procedures are summarized in Tables 1 to 5. Descriptive statistics and definitions of the variables used in the maximum likelihood estimates of the univariate and bivariate probit models are provided in Table 1.

Table 2 summarizes the independent and joint estimation results for the "current level" and the "15% less" valuation questions asked in the Escanaba fishing study. Although varying in significance, the signs of the coefficients on the variables are consistent across equations: the probability of a "yes" response increases with perceived importance of the resource, distance traveled to Lake Escanaba, and the education level of the respondent, but falls with increasing bid values. Importantly, there is an extremely high correlation ($\rho \approx 0.92$) in dichotomous choice response patterns across scenarios. Likelihood ratio tests and asymptotic p tests of the coefficient demonstrate that this correlation is highly significant.

Independent and joint estimation results for the "either sex" and the "antlerless" Sandhill hunting permits are provided in Table 3. The probability of a "yes" response increases with the perceived quality of the hunting experience, but declines with higher dichotomous choice bid values. The coefficient on the year variable was only significant for the antlerless model, indicating that the 1992 respondents had higher values for the antlerless permits. This result is consistent with the fact that the 1992 Sandhill hunt was limited to antlerless deer, and that the respondents generally had a positive experience in spite of the fact that an antlerless hunt is popularly perceived to be inferior. Although the estimated correlation coefficient of 0.39 is much lower than the Escanaba study, it is still highly significant.

Because of the large number of pairwise comparisons in the Grand Canyon White Water Boating Study, only the estimated correlation coefficients are reported in Table 4 (for simple models with expenditures and bid values as explanatory variables). Correlation clearly varies in magnitude and significance across flow levels. Particularly high (>0.50) and significant occur for private boaters along a range of 13 to 22 cfs, corresponding to a similarity of attributes between "moderate" flow levels experienced by many boaters and the hypothetical situation. High and significant correlations also occur on the diagonal for both the private and commercial boaters, indicating that it may be somewhat difficult to distinguish between the attributes of adjacent flows.

Taken together, the results in Tables 2 to 4 demonstrate that there is significant correlation between responses to contingent valuation questions elicited in the same survey. There are some indicators that this correlation is quite high when the attributes of the commodity being valued are similar across questions and declines with dissimilarities (e.g. all comparisons with 5 cfs). In spite of the fact that the attributes may vary widely across scenarios, the sign of the coefficient remains positive, or not significantly different from zero, in all cases. Given that some scenarios have substantially different vectors of characteristics, the lack of any negative correlation coefficients is somewhat disturbing. It suggests that there may be systematic responses attributed to "yea saying" [Kanninen], "symbolic" effects [Boyle, Welsh, and Bishop, 1991], "warm glow" effects [Kahneman and Knetsch], or "starting point" biases [Cameron and Quiggen].

Table 5 provides summary statistics for the approximate WTP distributions estimated for the individual and joint models in which the correlation coefficient was significant at the 10 percent level. The first column repeats the correlation coefficient from the previous tables. The next columns identify the distributions being compared and provide the bootstrap results from the joint and independent estimations of mean WTP. The final column provides a ratio of the variance of the distribution of the differences from the joint model ($\delta^2_{x\text{-}y,\, joint}$) with the variance of the difference from the independent model ($\delta^2_{x\text{-}y,\, indep}$). This latter relationship is of particular interest because correlation in mean WTP values is expected to reduce the variance of the difference, as suggested in the well known formula for the variance of the difference in two normal distributions: $var(X-Y)=var(X) + var(Y) - 2*cov(X,Y)$. Combined, these results suggest that as correlations rise, the distribution of the difference estimated under the independence assumption will tighten up even though there may be no observed effect on individual distributions.

A comparison across columns in Table 5 shows that even when the correlation coefficient is relatively high, there is only a very small effect on the estimated distributions of mean WTP associated with estimating a joint model. This result is consistent with the almost negligible effects of joint modeling on the values of the estimated coefficients observed in Tables 2 and 3.

Table 6 indicates that accounting for the correlation in the estimation process does impact on difference of means tests for comparisons in which the significance of the difference fell in an interesting range (i.e., around 0.10, 0.05, 0.01). Values associated with other comparisons in Table 4 diverged substantially from these critical values (e.g. 0.45 or 0.000000001) and, thus, are not that interesting in terms of this analysis. These values show that accounting for the correlation does have some effect. In certain cases it will force a difference to cross a significance level.

4. Implications and Conclusions

The high correlation coefficients observed and the consequent effects on the difference in means distributions indicate that across scenario correlation may be an important factor in some policy comparisons. As such, this paper provides evidence that standard assumptions of independence in comparing distributions may lead to biased results of the difference, and may lead to erroneous conclusions about the significance of the difference in mean WTP values elicited in the same questionnaire. In all, if it is necessary from a policy perspective to assess the difference in mean benefit measures associated with different levels of resource provision, the correlation should be accounted for. In contrast, if such policy comparisons are not necessary, failure to account for correlation across responses does not appear to provide biased estimates of the individual distributions.

The cause of correlation is not isolated in this study. Future research should be directed towards identifying whether correlation is attributable to perceived similarities in attributes across scenarios, or to a number of psychological response factors that have recently been suggested in the literature.

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Figure 1a: Escanaba Lake Survey "Full Permit"

Your answers to the next two questions are particularly important because they will help us better understand how much it is worth to you to fish Escanaba Lake during the early season. We are using Escanaba Lake to develop better methods to value sport fishing at sites throughout the state. The purpose of this research is to learn more about what sport fishing is worth, and <u>NOT</u> to promote higher license fees.

The situation described below is <u>hypothetical</u>. However, please try to respond as if you really have to make a decision about it.

28. Suppose that a special permit will be required this year to fish Escanaba Lake <u>during the "early season"</u>. Assume that you can order a permit to fish the "early season" at Escanaba Lake by mail. A permit is valid for the two weeks before the open of the regular fishing season (April 17 through May 1, 1992).

- All individuals 16 years old and older wishing to fish Escanaba Lake between April 17 and May 1, 1992 will have to show a permit at the research contact station.
- Individuals with a permit may fish Escanaba Lake as often as they would like between April 17 and May 1, 1992.
- All the regulations currently in force for fishing Escanaba Lake will stay the same as they are now.
- If the ice goes out early, fishing will be free until April 17.
- The revenue from permit sales will go to the Northern Highland Fishery Research Area.

The amount we ask about below may seem very high or low to you <u>but it's very important that you answer the question seriously</u>. The amount written below was randomly assigned to you.

Would you pay $________ for a permit to fish Escanaba Lake between April 17 and May 1, 1992? (CIRCLE ONE NUMBER)

1. No
2. Yes

Figure 1b: Escanaba Lake Survey "15 percent fewer"

29. Assume that permits would be sold as described in question 28. In addition, assume that there will be about 15 percent fewer walleye in Escanaba Lake than usual at the beginning of the "early season". The size of the fish would be the same as now. It is hard to say how this would affect the catch of any one angler. Some anglers may catch just as many fish as usual while others may not do as well. In thinking about how this might affect your success, assume that there will be somewhat fewer walleyes around. As in question 28, the amount written below was randomly assigned to you.

Under these new conditions, would you pay $________ for a permit to fish Escanaba Lake between April 17 and May 1, 1992? (CIRCLE ONE NUMBER)

1. No
2. Yes

Figure 2a: Sandhill Public Deer Hunt Survey 1991

> **In the previous questions, you told us how much you spent on the Sandhill General Public Deer Hunt. In the next question, we would like to ask about the 1992 Sandhill General Public Deer Hunt.**

16. Suppose that next year you apply for a Sandhill General Public Deer Hunt permit but are not chosen to receive a permit. Imagine that as part of a research project you have the chance to <u>purchase</u> an either sex permit. If you were able to buy a 1992 Sandhill <u>either sex</u> permit, would you be willing to pay $__________? (CIRCLE ONE NUMBER)

1 No

2 Yes

17. If you were able to buy a 1992 Sandhill <u>antlerless</u> permit, would you be willing to pay $_________? (CIRCLE ONE NUMBER)

1 No

2 Yes

Figure 2b: Sandhill Public Deer Hunt Survey 1992

> **In the previous questions, you told us how much you spent on the Sandhill General Public Deer Hunt. In the next question, we would like to ask about the <u>1993</u> Sandhill General Public Deer Hunt.**

15. Suppose that next year you apply for a Sandhill General Public Deer Hunt permit but are not chosen to receive a permit. Imagine that as part of a research project you have the chance to purchase an <u>antlerless</u> permit. If you were able to buy a 1993 Sandhill <u>antlerless</u> permit, would you be willing to pay $__________? (CIRCLE ONE NUMBER)

1 No

2 Yes

16. If you were able to buy a 1993 Sandhill <u>either sex</u> permit, would you be willing to pay $_________? (CIRCLE ONE NUMBER)

1 No

2 Yes

Figure 3a: Grand Canyon White Water Boater Survey
"Actual Conditions"

A26. Please estimate how much your trip cost (COSTS FOR YOU INDIVIDUALLY, EITHER PAID BY YOURSELF OR BY OTHERS). Include only money spent on items specifically for this trip. If a certain item was not purchased for this trip, please put $0.

Gas and Oil for vehicle	$______
Airfare	$______
Car Rental	$______
Food and Beverages	$______
Personal gear (suntan lotion, sun glasses, film for camera)	$______
Lodging, Camping (before and after white water trip)	$______
Boat Gear (oars, lines, etc.)	$______
Equipment rental	$______
Take out at Diamond Creek	$______
Vehicle shuttle	$______
Tow across Lake Mead	$______
Other (please specify) ______	$______
TOTAL AMOUNT TRIP COST (Please add all payments and fill in the total on this line)	$______

A27. Would you still have gone on the Grand Canyon white water trip if your costs had been $______ more than the total you just calculated in Question A26? (CIRCLE ONE NUMBER)

1 YES, I WOULD PAY THIS AMOUNT TO TAKE THE TRIP

2 NO, I WOULD NOT PAY THIS AMOUNT TO TAKE THE TRIP

Figure 3b: Grand Canyon White Water Boater Survey
Hypothetical "22,000 cfs"

At moderately high water levels (around 22,000 cfs), the pace of the river is faster than at lower flows, leaving more time for side canyons and stops at attractions. Boating groups do not have a problem staying on schedule. Rapids have larger waves and provide a bigger "roller coaster" ride than at moderate water. Only a few passengers choose to walk around some of the bigger rapids for their safety. Some potential campsites are under water in some areas of the canyon, but generally campsites are plentiful although a bit smaller in size.

D1. Do you think a Grand Canyon white water trip under these conditions (Case 4 above) would be better or worse than your last Grand Canyon white water trip? (CIRCLE ONE NUMBER)

1 MUCH BETTER

2 SOMEWHAT BETTER

3 ABOUT THE SAME

4 SOMEWHAT WORSE

5 MUCH WORSE

We would now like you to imagine that you are presently deciding whether or not to go on a Grand Canyon white water trip. Imagine that the trip would be the same as your last trip (e.g., the people, food, etc.) with two exceptions:

The water level would be constant at 22,000 cfs (see description for Case 4 above)

AND

Your individual costs for the trip increased by $______ (over the total cost you calculated on page 8, question A26)

D2. Would you go on this trip? (CIRCLE ONE NUMBER)

1 YES, I WOULD PAY THIS AMOUNT TO TAKE THE TRIP

2 NO, I WOULD NOT PAY THIS AMOUNT TO TAKE THE TRIP

Table 1: Variable Definitions and Descriptive Statistics for Escanaba and Sandhill Studies

Escanaba	Description	Mean (s.d.)
Import	Categorical response "If I could not go fishing at Escanaba Lake during the 'early season', I would": 1) easily find something else to do; 2) miss it, but not as much as other things that I enjoy; 3) miss it more than the other interests I now have; 4) miss it more than all the other interests I now have.	2.01 (0.89)
Miles	Open ended variable: distance between Escanaba Lake and home (one way).	120.41 (115.05)
Education	Categorical response: 1) less than high school; 2) high school graduate; 3) some college or technical school; 4) technical or trade school graduate; 5) college graduate; 6) advanced degree.	3.20 (1.47)
Bid 1	Dichotomous choice bid value for "current level".	13.60 (12.43)
Bid 2	Dichotomous choice bid value for "15% less".	11.34 (9.62)
Sandhill		
Quality	Categorical response for quality of the hunt: 1) very low quality; 2) fairly low quality; 3) average quality; 4) fairly high quality; 5) very high quality.	3.40 (1.23)
Year	Binary variable: 1991=1, 1992=2.	1.51 (0.50)
Bid 1	Dichotomous choice bid value for "either sex" permit.	27.91 (21.81)
Bid 2	Dichotomous choice bid value for "antlerless" permit.	29.12 (24.58)

Table 2. Escanaba Fishing Study[a,b,c]

	Single Equation	Bivariate
Current Level		
Constant	-0.5859 (0.2492)**	-0.5042 (0.2419)**
Import	0.2172 (0.0777)***	0.2476 (0.0766)***
Miles	0.0014 (0.0061)**	0.0015 (0.0006)**
Educ	0.1356 (0.0489)***	0.1233 (0.0508)**
Bid 1	-0.1229 (0.0131)***	-0.1350 (0.0100)***
15% Less		
Constant	-0.3371 (0.2522)	-0.2996 (0.2573)
Import	0.2685 (0.0760)***	0.2703 (0.07800)***
Miles	0.0012 (0.00590)**	0.0011 (0.0060)*
Educ	0.0208 (0.0466)	0.0222 (0.0474)
Bid 2	-0.1346 (0.01411)***	-0.1392 (0.0126)***
ρ		.9170 (0.428)***
χ_1^2	180.79	
χ_2^2	142.31	
-Log Likelihood[b,c]	-218.63 - 228.02	-391.63

[a] Numbers in ( ) are asymptotic standard errors.

[b] *, **, *** indicate significance levels of 0.10, 0.05, and 0.01 respectively.

[c] $-2\,(LL_s - LL_j) = 110.04$, $\chi^2_{1,0.10} = 2.71$

Table 3. Sandhill Deer Hunting, 1991-1992[a,b]

	Independent	Joint
Either Sex		
Constant	0.9977 (0.4245)***	0.9958 (0.4348)***
Quality	0.1224 (0.0871)	0.1272 (0.0876)
Year	-0.13611 (0.2052)	0.1252 (0.2074)
Bid 1	-0.3688 (0.0056)***	-0.3718 (0.0057)***
Antlerless		
Constant	-0.1378 (0.3919)	-0.1003 (0.3941)
Quality	0.23204 (0.922)***	0.2278 (0.0933)***
Year	1.1225 (0.2197)***	1.1234 (0.2323)***
Bid 2	-0.0704 (0.0129)***	-0.0733 (0.0118)***
ρ		0.3923 (0.1381)***
χ_1^2	60.52	
χ_2^2	82.73	
Log Likelihood[c]	-105.98 - 93.32	-195.47
n	197	197

[a] Numbers in ( ) are asymptotic standard errors.
[b] *,**,*** indicate significance levels of 0.10, 0.05, and 0.01 respectively.
[c] $-2\,(LL_1 - LL_2) = 7.68$, $\chi^2_{1,0.10} = 2.71$.

Table 4. Correlation Coefficients Across Bivariate Probit Models for Different Flow Levels[a,b]

	Private Boats			
	Actual Flows	5 cfs	13 cfs	22 cfs
5 cfs	0.18 (0.20)			
13 cfs	0.93 (0.07)***	0.23 (0.23)		
22 cfs	0.81 (0.10)***	0.02 (0.19)	0.87 (0.08)***	
40 cfs	0.26 (0.21)	0.32 (0.17)*	0.18 (0.26)	0.63 (0.17)***
	Commercial Boats			
5 cfs	0.08 (0.13)			
13 cfs	0.45 (0.10)***	0.12 (0.14)		
22 cfs	0.18 (0.11)	0.41 (0.13)***	0.69 (0.08)***	
40 cfs	0.30 (.11)***	0.05 (0.13)	0.36 (0.11)***	0.62 (0.09)***

[a] Numbers in ( ) indicate asymtotic standard errors.
[b] *,**,*** indicate significance levels of 0.10, 0.05, and 0.01 respectively.

Table 5. Individual and Jointly Estimated Mean Value Distributions[a]

	Distribution 1			Distribution 2			
ρ	Name	Mean (Indep)	Mean (Joint)	Name	Mean (Indep)	Mean (Joint)	$\delta^2_{x\text{-}y,JOINT} / {}^2\text{-}y_{,INDEP}$
0.30	$Comm_{Actual}$	620 [561, 689]	620 [561, 689]	$Comm_{40}$	411 [359, 470]	408 [354, 467]	0.83
0.32	$Priv_{40}$	432 [369, 502]	424 [361, 491]	$Priv_5$	243 [197, 296]	237 [192, 286]	0.83
0.36	$Comm_{13}$	482 [438, 532]	479 [432, 526]	$Comm_{40}$	411 [361, 468]	411 [355, 471]	0.89
0.39	$Sandhill_1$	40.17 [35.40, 44.64]	40.07 [34.85, 44.49]	$Sandhill_2$	18.08 [15.75, 21.35]	17.69 [15.44, 20.66]	0.81
0.40	$Comm_{22}$	589 [539, 646]	588 [536, 642]	$Comm_5$	175 [138, 228]	174 [137, 221]	0.77
0.45	$Comm_{Actual}$	620 [562, 688]	621 [564, 684]	$Comm_{13}$	483 [437, 532]	480 [434, 527]	0.72
0.62	$Comm_{22}$	589 [538, 645]	592 [540, 647]	$Comm_{40}$	411 [358, 472]	411 [358, 469]	0.61
0.63	$Priv_{22}$	522 [451, 595]	523 [445, 600]	$Priv_{40}$	432 [367, 500]	421 [359, 488]	0.78
0.69	$Comm_{22}$	589 [538, 643]	601 [545, 661]	$Comm_{13}$	483 [437, 534]	473 [430, 518]	0.71
0.81	$Priv_{22}$	522 [452, 596]	526 [450, 601]	$Priv_{Actual}$	372 [299, 455]	395 [312, 476]	0.73
0.87	$Priv_{22}$	522 [453, 595]	515 [437, 593]	$Priv_{13}$	518 [457, 585]	516 [447, 582]	0.75
0.92	$Escanaba_1$	5.41 [4.82, 6.06]	5.53 [4.94, 6.15]	$Escanaba_2$	4.74 [4.22, 5.30]	4.74 [4.22, 5.30]	0.55
0.93	$Priv_{Actual}$	373 [299, 454]	405 [335, 477]	$Priv_{13}$	518 [457, 586]	518 [444, 594]	0.56

[a] Numbers in [ ] reflect the 0.90 confidence interval.

Table 6. Significance Levels of Difference X_i-Y_j Across Mean WTP Estimates: Selected Observations

ρ	Comparison	$\hat{\alpha}_{indep}$	$\hat{\alpha}_{joint}$
0.32	$Comm_{13}$ - $Comm_{40}$	0.052	0.049
0.63	$Priv_{22}$ - $Priv_{40}$	0.066	0.030
0.81	$Priv_{22}$ - $Priv_{Actual}$	0.011	0.007
0.92	Escanaba	0.086	0.016
0.93	$Priv_{Actual}$ - $Priv_{13}$	0.010	0.006

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