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Using Contingent Valuation with Respondent Uncertainty to Estimate the Costs of Climate Change Programs: An Application to Canadian Landowners

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Abstract:

Using a survey of western Canadian agricultural landowners, we examine the cost and viability of two distinct afforestation options for carbon-uptake purposes. Responses to two separate, but most-likely related willingness to accept compensation questions are elicited using the contingent valuation method. Respondents then select the level of certainty with which they believe their responses were given. This paper provides a framework for estimation of the bivariate model with certainty and a modification of the model to incorporate uncertainty based on Li and Mattson's approach to preference uncertainty. While highly preliminary results are given for the bivariate model with certainty, applications of both models will be presented at the 2003 AAEA Meetings.

Introduction

Uncertainty is often a vague concept in economics since it can arise from many different parts of the modeling process. While preference certainty is generally assumed to ensure concave utility functions, second-order conditions of the correct signs, and overall rational behavior, developments have been made to challenge its assumption. (e.g. Hanemann). Econometric models and techniques give rise to even more sources of uncertainty and generally rely on random components to capture any information not observed by the researcher. Additionally, while assuming preference certainty would indicate that individuals should be able to make choices even in the absence of markets, it has been demonstrated in practice, that contingent and actual behavior do not always coincide for a variety of reasons (Bishop and Heberlein, e.g.). Furthermore, when the policy or program being proposed is abstract or not well known, such as climate change, uncertainty becomes an important obstacle in accurate quantification of the costs and benefits of programs.

The purpose of this research is twofold. First, the cost of two different but related afforestation programs in Western Canada is estimated based on the willingness to accept of landowners to convert farmland to forestry. While it has been shown from this data that significant transactions costs may exist, the costs and feasibility of conversion for programs over different time horizons provide important policy information as well as an indication of the significance of landowner discount rates (van Kooten, *et al*. (2002)). The second objective of this study is to understand how uncertainty affects respondents' willingness to accept responses and consequently overall cost estimates of the program.

Using contingent valuation survey data from Western Canadian landowners, a bivariate-probit model for different but related climate-change afforestation programs is estimated. The results are given and suggestions for model enhancement are provided. The model specification is then augmented to include the post-decisional confidence measures given by the respondents using the approach of Li and Mattson and proposed for estimation for the final draft of this paper.

The remainder of the paper is organized as follows. The survey methodology and data is described, along with a detailed description of the hypothetical afforestation programs. The bivariate willingness to accept model with certainty is illustrated for the two afforestation programs based. A discussion of uncertainty in contingent valuation responses is provided and the model is extended accordingly. Preliminary estimation results are given for the bivariate model with certainty. Issues concerning the certainty model are briefly discussed and the remainder of the research for this paper is outlined.

This paper is preliminary and provides a framework for the model estimation, which will be presented at the American Agricultural Economics Meetings in Montreal in July, 2003.

Background: Survey of Canadian Farmers

An objective of this research is to determine the potential for afforestation as a cost-effective means for meeting goals related to Canadian climate change and greenhouse gas emissions. In particular, the role of agriculture is considered due to the large amounts of land currently in production in eastern Canada.

A questionnaire was mailed in July 2000 to 2,000 randomly selected Canadian farmers from the grain belt region of northeastern British Columbia, Alberta, Saskatchewan and Manitoba. Farmers with less than 160 acres of land were omitted from the survey sample since small landowners were unlikely to contribute significant amounts of land. Dairy farmers were also excluded from the sample for their presumed high opportunity cost of tree planting due to value-added production. A total of 379 surveys were returned undelivered, due to the lack of available updates of the mailing list purchased from Watts Brokerage Listing. Reminder cards were sent out three weeks after the first mailing. The effective response rate (corrected for returned/undelivered surveys) was 13%, slightly higher than the 12% rates reported by the Environics Research Group (2000) in their study of stewardship of Canadian farmers and by Bell et al. (1994).

The survey included a brief, personalized cover letter explaining the purpose of the questionnaire and a definition of carbon credits. In addition to willingness to accept compensation for tree planting, the actual survey also elicited detailed information on a farmer's agricultural operations including activities on marginal fields, farmers' opinions about and awareness of climate change issues and carbon credits, and personal characteristics and demographics. Initial information and questions were meant to reduce information biases by familiarizing respondents with the topic and issues under investigation before asking them about their willingness to plant trees. Respondents seemed fairly familiar with tree conversions as 66% of respondents indicated that they had read or heard about the possibilities for planting trees on marginal agricultural land to mitigate climate change.

Landowners were presented a hypothetical tree-planting program that covers all costs of tree planting while compensating for lost agricultural production. A compensation amount or "bid" was offered with the program to convert their least productive land to forest under a 10-year contract. In the absence of *a priori* valuation information, the bid compensation levels were selected on the basis of results from a pilot study, and range from \$1 to \$60 per acre per year (see Suchánek 2001). The distribution of these bids is skewed towards the lower bound of the range in order to provide more efficient estimates of WTA (Cooper 1993). The contingent contract indicates that farmers cannot harvest the trees before the contract expires, but trees become their property at the end of the contract period. The contract provides no compensation for the conversion of land back to agriculture. Farmers were then asked to respond to a second, follow-up bid for the same type of program but with a 40-year contract. Both WTA questions were immediately followed by a certainty scale follow-up question similar to that used by Champ, *et al*. Respondents were asked to rate the degree of certainty with which they gave their dichotomous-choice WTA response.

The program description, and set of two WTA questions and follow-up certainty ratings from the survey shown in Figure 1:

Figure 1: Contingent Valuation Question Format[1]

Suppose you were to enter a contract that permits someone to plant trees on (some proportion of) your land. All direct costs of tree planting (e.g. establishment, monitoring, management, maintenance costs) are covered, AND you are provided annual compensation. You DO NOT have any right to harvest the trees before the contract expires. However, when the contract ends, trees become your property.

Suppose a block tree-planting program (planting of entire fields) is available, and at least one of your fields is identified as a potential site for tree plantations. Would you be willing to accept ANNUAL compensation of **$xx** per ACRE for a 10-year contract? (**Please 3**)

YES

NO

On a scale 1 to 10, how certain are you of your answer to questions 9? **Please circle** the number that best represents your answer if **1= not at all certain** and **10 very certain.**

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
not at all certain				somewhat	certain				very certain

Again, suppose a block tree-planting program is available and your land is eligible for tree plantations. Would you be willing to accept an ANNUAL compensation of **$yy** per ACRE for a 40-year contract?

YES

NO

On a scale 1 to 10, how certain are you of your answer to questions 10? **Please circle** the number that best represents your answer if **1= not at all certain** and **10 very certain.**

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
not at all certain				somewhat	certain				very certain

1. Several questions were asked in between the program description and the first WTA question. See Suchanek (2001) for details.

Empirical Model

The two WTA responses are expected to be related since respondents likely refer to the same information or set of preferences when determining their responses. In this case, the bivariate probit format is useful for the initial model of the two responses with certainty. While this format is commonly used for dichotomous-choice follow-up questions (Cameron and Quiggin), it is also useful for responses to two separate, but related programs (Poe, *et al.*).

Based on Hanemann's random utility model framework, the farmer will accept land conversion as long as the bid is at least as much as the opportunity cost (OC) of the market value of the land in production plus any non-market values associated with farming the land. Expressed as utility differences as in the random utility model, the decision to accept the proposed compensation is based on the returns from the least productive acre of land, comparing $v_1(m+B-OC, s)$ and $v_0(m, s)$, where v is the indirect utility measure for a given alternative, B is the bid amount, OC is the opportunity cost or current per acre agricultural returns, and s is the vector of observable characteristics of the individual that affect valuation. While the opportunity cost represents foregone agricultural net returns from accepting a tree-planting program, the total compensation required by the farmer may be increased by other non-market values associated with keeping the land in agriculture, and/or reduced by non-market values associated with forestry. The presence of these non-market values makes the contingent valuation approach a useful tool in capturing the full cost of land conversion.

The probability of accepting an offered bid amount is given as:

$$\Pr(\text{yes to bid}) = \Pr\{v_1(m+B-OC, s) + \varepsilon_1 \geq v_0(m, s) + \varepsilon_o\}$$

$$\Pr(\text{no}) = 1 - \Pr(\text{yes}),$$

where ε_1 and ε_0 are the random disturbances associate with the unobservable factors which may affect utility. Adjusting the bids by the known opportunity cost directly incorporates the market component of the opportunity cost into the decision.

Both valuation questions follow this framework and result in four outcomes to the two bid offers: (1) yes, yes (2) yes, no (3) no, yes and (4) no, no. Following Cameron and Quiggin, the dichotomous indicator variables are defined as I_1 and I_2, where if the first bid is accepted, $I_1=1$ indicates that $WTA_1 \leq (B_1\text{-OC})$. Expressing the valuation functions as:

$$WTA_1 = x_1'\beta_1 + e_1$$

$$WTA_2 = x_2'\beta_2 + e_2,$$

where x_1 and x_2 are the variables influencing valuation, β_1 and β_2 are the estimated parameters, and e_1 and e_2 are the error terms associated with unobservable information. Expressing WTA_1 as a standard normal random variable results in $(\varepsilon_1/\sigma_1) \leq (B_1\text{-OC-}\ x_1'\beta_1)/\sigma_1$. Following the same procedure for I_2, results in $(\varepsilon_2/\sigma_2) \leq (B_2\text{-OC-}\ x_2'\beta_2)/\sigma_2$. Using z_1 and z_2 to represent the standard normal errors (ε_1/σ_1) and (ε_2/σ_2) respectively, the two are distributed as BVN(0,0,1,1, ρ). Using Cameron and Quiggin's notation, the bivariate standard normal density function is denoted as:

$$g(z_1,z_2) = \frac{1}{\sqrt{2\pi(1-\rho^2)}}\, e^{\frac{-(z_1^2 - 2\rho z_1 z_2 + z_2^2)}{(2-2\rho^2)}}.$$

The log-likelihood function for the model is then given as:

$$
\begin{aligned}
L = \sum_{i=1}^{n} \Big\{ &(I_1 I_2)\log\left[\int_{(-B_1-OC-x_1\beta_1)/\sigma_1}^{\infty}\int_{(-B_2-OC-x_2\beta_2)/\sigma_2}^{\infty} g(z_1 z_2)\,dz_2\,dz_1\right] \\
&+ (I_{11})(1-I_{22})\log\left[\int_{(-B_1-OC-x_1\beta_1)/\sigma_1}^{\infty}\int_{-\infty}^{(-B_2-OC-x_2\beta_2)/\sigma_2} g(z_1 z_2)\,dz_2\,dz_1\right] \\
&+ (1-I_{11})(I_{22})\log\left[\int_{-\infty}^{(-B_1-OC-x_1\beta_1)/\sigma_1}\int_{(-B_2-OC-x_2\beta_2)/\sigma_2}^{\infty} g(z_1 z_2)\,dz_2\,dz_1\right] \\
&+ (1-I_{11})(1-I_{22})\log\left[\int_{-\infty}^{(-B_1-OC-x_1\beta_1)/\sigma_1}\int_{-\infty}^{((-B_2-OC-x_2\beta_2)/\sigma_2} g(z_1 z_2)\,dz_2\,dz_1\right]\Big\}
\end{aligned} \tag{1}
$$

Uncertainty and the Bivariate Model

Uncertainty in contingent valuation responses has been treated in several different ways. Li and Mattson weigh the “yes” and “no” responses by the probability of certainty based on a continuous post-decisional confidence response ranging from 0% to 100%. Champ, *et al.* used an integer-scale certainty follow-up question to identify the respondents’ confidence with their response. In their earlier study, Ready, *et al.* (1995) deviate from the usual dichotomous-choice questionnaire framework by asking respondents’ to choose from six response options; definitely yes, probably yes, maybe yes, probably no, and definitely no, to a proposed bid amount. Their resulting estimates of WTP were found to be higher when uncertainty was taken into account. In a more recent study, they utilize a similar approach to compare a dichotomous-choice response format with a payment card approach (Ready, *et al.* (2001)). In a distinct approach, van Kooten, *et al.* (2001) assume that respondents never fully know their utility functions and assume utility to be a “fuzzy” number. Loomis, *et al.* compare the approaches of Li and Mattson, Champ, *et al.*, Ready, *et al.* (1995) to find that the extreme recoding approach of the latter two reduces goodness of fit and model precision, while incorporating the degree of uncertainty using a modification of the Li and Mattson approach, results in the least variance of mean WTP. They also find that the respondents are more certain of their responses at extremely low and high bid amounts.

The certainty question format used in this survey most closely resembles the format of Champ, *et al.* with the rating scale of 1 to 10 from not certain to very certain. However, based on the findings of Loomis, *et al.* and discussion of Hanemann and Kristrom, we adopt a probability weighting procedure similar to that of Li and Mattson.

Transforming our integer-based scale to a percentage and translating Li and Mattson's approach to the bivariate case, results in a likelihood function of the form[2]:

$$
\begin{aligned}
L = \sum_{i=1}^{n} \Bigg\{ (w_1 \cdot w_2) \cdot \Bigg(& (I_{11} I_{22}) \log_e \left[\int_{(-X_{11}\omega_{11})/\sigma_{11}}^{\infty} \int_{(-X_{22}\omega_{22})/\sigma_{22}}^{\infty} g(z_1 z_2) dz_2 dz_1 \right] \\
(2) \qquad & + (I_{11})(1 - I_{22}) \log_e \left[\int_{(-X_{11}\omega_{11})/\sigma_{11}}^{\infty} \int_{-\infty}^{(-X_{22}\omega_{22})/\sigma_{22}} g(z_1 z_2) dz_2 dz_1 \right] \\
& + (1 - I_{11})(I_{22}) \log_e \left[\int_{-\infty}^{(-X_{11}\omega_{11})/\sigma_{11}} \int_{(-X_{22}\omega_{22})/\sigma_{22}}^{\infty} g(z_1 z_2) dz_2 dz_1 \right] \\
& + (1 - I_{11})(1 - I_{22}) \log_e \left[\int_{-\infty}^{(-X_{11}\omega_{11})/\sigma_{11}} \int_{-\infty}^{(-X_{22}\omega_{22})/\sigma_{22}} g(z_1 z_2) dz_2 dz_1 \right] \Bigg) \Bigg\}
\end{aligned}
$$

where w_1 and w_2 represent the confidence weight from the certainty follow-up questions to the two WTA responses.

Variable Description

The explanatory variable of greatest interest is the level of compensation that landowners require. Compensation equals the bid minus opportunity cost (*B–OC*) as noted above. The calculation of opportunity cost deserves further attention. Farmers were asked to provide information for up to four of their least productive fields. Land uses were combined into three

2. Note that this model is highly preliminary and makes a restrictive assumption that the errors related to uncertainty from both responses are uncorrelated. Results of the uncertainty model are contingent upon further specification, which attempts to relax this assumption.

categories: pasture, hay and grain (which includes wheat, canola, barley, rye, oats, flax, lentils, peas and summer fallow). Average contribution margins were calculated using crop revenues and variable costs of production for these three commodities in different soil zones and provinces; average prices for the past four to eight years were employed[3]. The distribution of the types of crops across respondents (not in total acres) are given in Table 1:

Table 1: Percentage of Respondents Indicating Crop Type on Least Productive Land

Type of Crop	Percentage of Respondents
Hay	32.42
Pasture	10.44
Grain	57.14

Each field provided by a farmer was assigned an opportunity cost based on how it was used. The opportunity cost is simply the minimum of the value of the least productive fields. These are provided in Table 2.

Table 2: Opportunity Cost Values For A Given Land-Use

Land-use	Per Acre Opportunity Cost (dollars)
Pasture	42.00
Hay	47.25
Grain	71.85

In addition to compensation, variables that represent farm or landowner characteristics and other variables that may indicate any non-market values associated with land in production were included. Provincial indicators are used to account for differences in jurisdictional factors across

3. Values are based on information supplied by provincial governments; details are found in Suchánek (2001).

provinces (with policy in northeastern B.C. generally following that in Alberta). Soil zone dummies are used to take into account weather, terrain, soil fertility and other productivity factors.

A visual scale variable is used to incorporate farmer opinions about their viewpoint on the aesthetic benefits of tree cover, which is likely to influence acceptance positively. The value of the visual variable ranges on an integer scale from 1 if the respondent strongly disagrees with the statement that increased tree cover in the region will detract from the visual appeal of the landscape, to 5 if she strongly agrees; zero corresponds to “no opinion” or “do not know”. As the number of acres of farmland covered by trees increases, we postulate that the likelihood of accepting the bid amount will increase since existing tree cover is an indicator of some preference for forest. Likewise, whether or not a respondent had previous experience with tree-planting contracts is thought to have a positive effect on the probability of accepting the bid to plant trees.

Respondents were asked to indicate whether they would adapt to climate change by leaving agriculture altogether. We postulate that those who are most likely to leave agriculture as a response to climate change would be more likely to accept the bid amount. Further, a farmer’s age would likely influence participation positively, as contracts reduce workloads while ensuring a steady income. Increased education, on the other hand, could influence the likelihood of accepting the bid amount negatively, because those with a higher education are more likely to view tree plantations as a restriction on future land-use flexibility.

A priori, one might expect that, when a farmer expects to bequeath the farm to an heir, this will increase participation in tree planting because standing timber is a form of wealth. Conversely, contracts reduce the long-term flexibility of land use.

Finally, we employ a measure of net worth to capture a farmer's wealth and size and scale of farm operations. Net worth is measured as a categorical variable, with ten categories starting with $100,000 and less, and increasing by $100,000 to a maximum of $1million. It is hypothesized that larger and wealthier farmers are probably less likely to accept a bid to plant trees because they have greater flexibility to pursue future opportunities.

Descriptive statistics for relevant variables are given in Table 3.

Table 3: Descriptive Characteristics of Farms and Landowners

Variable	Mean	Std. Dev.	Min	Max
Age of Respondent	56.55	9.58	33	68
Net Worth of Farm Operation	586,527	339,801	50,000	1,000,000
Years of Family Ownership	33	11.49	0	70
Percent of Existing Unused Land in Tree Cover	0.43	0.42	0	1
Years of Post-Secondary Education	1.44	1.68	0	7

Preliminary Results

Estimation is underway for the models given in Equations (1) and (2), and expected to be completed shortly. Initial results for the bivariate model with certainty are provided in Table 4, however the results are highly preliminary.

Table 4: Initial Bivariate Probit Results

Contingent Valuation Question 1			*Contingent Valuation Question 2*		
Variable Name	Coefficient Estimate	t-Ratio	Variable Name	Coefficient Estimate	t-Ratio
Constant	-1.4996	-1.044	Constant	-1.7513	-0.918
BOC1	0.0367	3.814	BOC2	-0.0511	-2.482
Soilbr	0.6156	1.170	Soilbr	1.9693	2.095
Age	0.0247	1.460	Age	0.0050	0.178
Visual	-0.1103	-0.643	Visual	-0.5991	-1.870
Educ	-0.1465	-1.527	Educ	0.2085	1.488
ProvSK	-0.1985	-0.374	ProvSK	-1.1493	-1.665
ProvAB	-1.0249	-1.917	ProvMB	0.4394	0.549
Soildb	-0.3439	-0.863	Soildb	1.2181	1.879
Trees	0.0026	2.096			
Leave	0.5456	1.892			
Networth	-0.1730	-1.076			
Correlation	-0.4864	-0.742			
Log-likelihood Value (unrestricted)		-54.1355			
Log-likelihood Value (restricted)		-80.5084			

Given the preliminary nature of these results, little inference is done to interpret coefficients. At this stage, the estimation procedure is focused on the best model fit and precision of estimates. Due to the high collinearity of the independent variables, a subset of variable is used based on the significance levels of estimates from repeated estimation.

Overall, this model is significant on the basis of a likelihood ratio test comparing the model to a restricted one, which includes only the two constants and the correlation variable. The correlation, however, is not significant, indicating at this point that there is no significant correlation between the errors from the WTA repsones. While different specifications have resulted in a significant correlation coefficient, the overall model estimation has been somewhat problematic and further estimation is required.

Summary and Further Work

While still preliminary, this paper provides detail on models with both certainty and uncertainty in valuation for agricultural land conversion programs. Further work to be completed for the 2003 AAEA meeting includes final specification and estimation of the biviate probit model under the assumption of certainty. A larger component of the research involves extending Li and Mattson's weighted probabilistic model to the bivariate case. This extension is more involved than indicated so far in this paper due to the inclusion of additional error terms, which may or may not be correlated. Correlation of more than two error terms will require more complex estimation procedures such as simulations. Finally, inference on all model results will provide mean estimates of WTA under both certainty and uncertainty for the two afforestation programs. Since the two programs differ mainly in contract length, the differences in the distribution of WTA will shed light on relative discount rates and hopefully, provide important climate-change and agricultural policy information.

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Endnotes