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Estimating Water Quality Benefits By Combining Revealed and Stated Preference Methods: An Application in the Minnesota River

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Abstract: Data from a 1997 survey of Minnesota residents was used to construct a panel of revealed and stated preference data. Panel regression results yield an estimate of household willingness to pay for phosphorus reductions in the Minnesota River of $38.88 per year.

Estimating Water Quality Benefits By Combining Revealed and Stated Preference Methods: An Application in the Minnesota River

Introduction

With growing use of benefit-cost analysis in environmental policy making and increased use of natural resource damage assessments by the courts, it is becoming more important than ever before to accurately describe benefits of environmental amenities. However the valuation of environmental benefits, like other nonmarket valuation processes, is imperfect and in need of improvement. Combining revealed and stated preference methods to incorporate nonuse or nonuser values in environmental valuation is one way of bettering existing techniques. By combining the two techniques into a joint model, researchers can get a more complete view of preferences than would be realized with either of the techniques alone, and estimation is improved. This paper extends the existing literature by providing an application of this methodology to the valuation of improvements in water quality.

Literature Review

Since markets do not exist for many environmental amenities and natural resources, researchers must rely on nonmarket valuation methods in order to estimate the values of these goods and services. These methods generally fall into two categories: those that rely on stated preference data, such as contingent valuation, and those that rely on revealed preference data, including travel cost models and hedonic price analysis. In the last decade, however, a growing literature of research combining the two types of data has evolved (Cameron; Adamowicz,

Louviere, and Williams; Loomis; Huang, Haab, and Whitehead).

There appear to be two distinct methods that have been used to combine stated and revealed preference data for environmental valuation. In the first technique, either type of data can be used to estimate the parameters of the model but efficiency is improved if the two types of data are combined in estimation. Examples of this method are found in Cameron, Kling, and Adamowicz, Louviere, and Williams. The second type of model that combines stated and revealed preference methods for environmental valuation is distinct from the first in that it is not possible to get the parameter estimates from this model by using just one of the two types of data (i.e., just stated or revealed preference data). Specifically, the model is designed so that the researcher must have both the stated and revealed preference data in order to estimate the value of an environmental quality change. The principal advantage of combining the two types of data in this (second) manner is that the scenario is potentially more realistic: the revealed preference data is based on a true market scenario (based on actual travel costs) and the contingent activity questions provide plausible scenarios for respondents to state their preferences and/or behaviors. Loomis, Cameron *et al*, and Englin and Cameron use this second manner of combining stated and revealed preference methods.

The Study Area

This study was motivated by recent attention given to water quality issues in Minnesota, and the Minnesota River in particular. The EPA has mandated reductions in biological oxygen demand, ammonia, and phosphorus in the Minnesota River, and many individuals have expressed an interest in its water quality. In particular, over 80% of the farmers in the Minnesota River

basin recently stated concern about the River's water quality (McCann). Until 1997, however, there had been no estimation of residents' willingness to pay for Minnesota River water quality improvements.

The single largest recreation area on the Minnesota River is the Minnesota Valley National Wildlife Refuge (MVNWR) which extends for 34 river miles and 11,000 acres along the banks of the River in the Twin Cities metropolitan area. The MVNWR offers multiple access sites including a Visitor's Center in Bloomington; activities include hiking, birdwatching, biking, lake fishing, trapping, snowshoeing, and educational programs.

The fact that both users and nonusers of the Minnesota River may have a willingness to pay for its water quality improvements leads to the conclusion that in order to accurately estimate WTP, it is necessary to use a general population sample that would include both groups. A random sample of Minnesota residents in 1997 were polled via a mail survey. The sample included households in the counties of the Minnesota River basin, plus Ramsey county. Ramsey county was included due to its proximity to the MVNWR, and the expectation that its residents would likely have an interest in Minnesota River water quality.

The Survey Instrument and Data Collection

The survey instrument contained six sections. The introductory section included a description of the study along with a map of the study area and a statement of the water quality problem in the Minnesota River. The section also included scope and budget reminder statements which are recommended in order to prevent overestimation of stated willingness to pay (Cummings, Brookshire, and Schulze; Mitchell and Carson). Section two presented a series of

opinion questions designed to categorize respondent feelings on the amount of money that Minnesota is currently spending on issues such as fighting crime and protecting endangered wildlife species. Again, reminders of one's opportunity costs were used in order to reduce the possibility for respondent overestimation of willingness to pay (Cummings).

In section three a hypothetical water quality program was described that would reduce phosphorus pollution by 40% in the Minnesota River and its hypothesized impacts. Respondents' were then asked their willingness to pay for these water quality improvements in a (dichotomous choice) referendum format. *No* responses were asked a follow-up question in order to categorize protest zero responses. Section four asked respondents about their visits to the MVNWR in the last 12 months, including the frequency, expense, and activities associate with their visits. The fifth section asked respondents contingent behavior question: *would their visits change if water quality were improved in the Minnesota River?*, while the final section asked questions about the sociodemographic characteristics of the respondent.

After two rounds of pre-testing, surveys were mailed to 1044 households in April 1997. Following Dillman's total design method, two follow up mailings were sent; by June 1997, 461 completed, usable surveys had been received indicating a response rate of 44.2%. The respondents consisted of both users and nonusers the Refuge; each was asked both revealed preference and stated preference questions.

Descriptive statistics of respondents are found in Table 1. A majority of the respondents were married, male, and employed, with an average age of 50 years. Most respondents had some education beyond high school, while roughly a third of respondents had at least one child living in the household. The average reported annual household income was $49,615.

Table 1: Respondent Characteristics

Variable	Measure	Mean
Gender	Percent Male	69.2
Age	Years	50.2
Income	Household Average[(a)], $	49,614
Education Beyond H.S.	Percent	79.4
Marital Status	Percent Married	64.6
Children	Percent with Children	34.9
Employment	Percent Employed	68.8
N=461. [(a)]Calculated using the midpoint of given intervals.		

Model and Estimation Procedures

Since the survey data provided multiple responses from each individual respondent which are likely to be correlated, a modeling structure that could accommodate and utilize this information was desired. The random effects probit model was selected, following Loomis, which allows for consistent modeling of actual trip decisions (at current trip costs), the intention to visit at higher trip costs (via a dichotomous choice contingent behavior question), and the intention to visit at hypothetically different quality levels in order to estimate the economic value of changes in water quality.

It is hypothesized that decisions to visit the MVNWR (R) are a function of costs incurred while making the trip (TC) and the water quality of the Minnesota River (Q):

$$R = f(TC,Q) \qquad (1)$$

Trip costs are expected to have an inverse relationship with the trip decision; as costs increase, individuals are less likely to make trips. Water quality improvements are expected to improve the pleasurability of the visit to the MVNWR and thus impact the number of visits in a direct manner.

The survey asked respondents about their current visits to the MVNWR and their contingent visits in two scenarios: if water quality were improved, and their travel costs were higher. The responses to these three questions formed a panel of three equations for each individual respondent described as follows:

$$R_1 = TC_1 + Q \quad (2)$$

$$R_2 = TC_1 + Q \quad (3)$$

$$R_3 = TC_3 + Q \quad (4)$$

where R_1 = Indicator of current visit behavior; 1 if visitor, 0 otherwise

R_2 = Indicator of visit behavior with water quality improvement; 1 if they would visit the MVNWR, 0 otherwise

R_3 = Indicator of visit behavior with higher costs; 1 if they would visit the MVNWR, 0 otherwise

TC_1 = Individual's reported travel cost to the MVNWR

TC_3 = Individual's hypothetical increased travel cost to the MVNWR

Q = Indicator of water quality; 1 for current Minnesota River water quality, 0 otherwise

Empirical Results and Benefit Estimates

The sample rendered 451 usable individual responses, with each individual providing three responses, for a total of 1353 observations. Estimation of the panel was performed using LIMDEP's random effects probit model; results appear in Table 2. Both the coefficients for the travel cost and the indicator variable for water quality are significant at the one percent level, and the coefficients possess the hypothesized (negative) signs. A Chi-squared statistic is used to test the significance of the overall model (for testing the null hypothesis that all coefficients equal zero); its value was 24.246 for this model, which is significant at the one percent level. Rho is the estimated correlation coefficient between responses; its significance at the one percent level indicates that the errors from the three equations in the panel were indeed correlated. This implies that statistical gains were realized by estimating the equations as a panel rather than independently.

Table 2: Estimation Results

Variable	**Coefficient**	**Standard Error**	**t-ratio**
TC	-0.6086E-02	0.2190E-02	-2.779*
Q1	-0.23660	0.7191E-01	-3.290*
Rho	0.22010	0.6938E-01	3.172*
N=1383; χ^2 *= 24.246*; *significant at 1% level*			

The parameter estimates for the travel cost variable (β_{tc}) and the indicator variable (β_q) were used to estimate the mean and median willingness to pay for improved water quality.

Hanemann (1989) showed that with a linear utility difference model both mean and median willingness to pay (WTP) estimates are given by

$$WTP = \beta_q / \beta_{tc.} \qquad (5)$$

When calculated using the coefficient estimates reported in Table 2 above, household WTP for improved water quality is estimated to be $38.88.

Conclusion

In this study both users and nonusers were surveyed about their willingness to pay for quality improvements in the Minnesota River. A large percentage (38%) of survey respondents who were not current visitors of the Minnesota Valley National Wildlife Refuge indicated they *would* visit if phosphorus pollution in the Minnesota River were reduced by 40%. The participation effects of the water quality improvement (Loomis) appear to support the importance of sampling both user and nonuser groups, especially when environmental quality improvements are policy relevant. These participation effects may be most significant when current environmental quality is such that individuals can easily identify the achievement of quality gains.

The combination of stated and revealed preference data for environmental valuation appears to be in its infancy. Several studies indicate a difference in benefit estimates derived from stated and revealed data combinations and those that use only stated or revealed preference data (Huang, Haab, and Whitehead; Cooper; Mathews, Homans, and Easter). Future work in this area shedding light on the reasons behind these differences would be most beneficial.

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