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Improving Willingness to Pay Estimates for Quality Improvements Through Joint Estimation with Quality Perceptions

John C. Whitehead

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Abstract. Willingness to pay for quality change may depend on heterogeneous perceived quality levels. In these instances, contingent valuation studies should include measures of quality perceptions as covariates in the willingness to pay model in order to avoid omitted variable bias. Variation in quality perceptions across respondents leads to a potential endogeneity of quality perceptions. We address the potential for endogeneity bias using an instrumental variable approach in which a measure of quality perceptions is included as a determinant of willingness to pay and is simultaneously determined by various exogenous factors. The willingness to pay model is estimated jointly with quality perceptions allowing for correlation of the error terms. Using data on willingness to pay for water quality improvements in the Neuse River in North Carolina we reject exogeneity of perceived quality. Correcting for endogeneity improves the measurement of willingness to pay by differentiating willingness to pay among respondents with heterogeneous quality perceptions.

Key Words: Willingness to pay, quality perceptions, endogeneity

Subject Matter Classifications: 15 Valuation Methods, 10 Economic Damages/Benefits 2 Water Pollution

1. Introduction

The contingent valuation method (CVM) is a stated preference approach to the measurement of the value of changes in the allocation of non-market environmental and natural resources (Mitchell and Carson, 1989). The CVM has clear advantages when compared to revealed preference methods in which actual behavior is used to develop estimates of value (e.g., hedonic price method, travel cost method). Stated preference methods are most useful when an *ex-ante* policy analysis must consider proposals that are beyond the range of historical experience. The CVM is more flexible than the revealed preference methods, allowing the estimation of the impacts of a wide range of policies. The CVM can be used to estimate non-use values (i.e., passive use values) and *ex-ante* willingness to pay under uncertainty (Whitehead and Blomquist, forthcoming).

Several issues indicate that the CVM is not a flawless approach to measuring environmental values for policy analysis.[3] The methodological challenges include the potential for hypothetical bias, temporal bias, sensitivity of willingness to pay estimates to multi-part policy (i.e., embedding, sequencing), and the bias of a reliance on willingness to pay, relative to willingness to accept questions, when the appropriate property rights are held by the respondent (Whitehead and Blomquist, forthcoming). Hoehn and Randall (1987) define a "satisfactory benefit cost indicator" as one that does not overstate the present value of net benefits of policy. Whitehead and Blomquist (forthcoming) conclude that more methodological research is needed before we can conclude that the CVM estimates of willingness to pay are satisfactory benefit-cost

[3] See the symposium on the contingent valuation method in the Fall 1994 issue of the *Journal of Economic Perspectives*.

indicators. For example, if willingness to pay suffers from hypothetical bias benefits will be overestimated. Nevertheless, the CVM (and other stated preference approaches) are the only option for estimation of the benefits of a broad range of policy questions.

This paper addresses a potential problem where willingness to pay statements are based on subjective perceptions about the environmental quality change instead of the objective change that is prescribed by the policy. In this case, willingness to pay may be biased if the subjective change in the resource allocation diverges from the objective change in the resource allocation. We argue that standard attempts to control for this divergence may fail. An alternative instrumental variables approach is introduced that may improve the accuracy of willingness to pay estimates.

The rest of the paper is organized as follows. In the next section we describe the relationship between willingness to pay and quality perceptions and the potential empirical problem. Next, the theoretical and empirical willingness to pay models are formally described. The survey used to collect the data and the data used to implement the model are then described. The application is to water quality improvements in the Neuse River, North Carolina. Willingness to pay empirical results using two different quality variables are presented. A summary and conclusions follow.

2. Willingness to Pay and Quality Perceptions

The theoretical construction of willingness to pay for quality improvement shows that willingness to pay is a function of pre-policy and post-policy quality levels, among other variables (Whitehead, 1995). CVM surveys should carefully describe both quality levels and ask for respondent willingness to pay for the change in quality (Mitchell and

Carson, 1989). A crucial assumption is that respondents are valuing the objective quality improvement that the survey asks them to value. This assumption may not hold in many applications, especially those in which one or both quality levels are not explicitly described and when heterogeneous respondents have varying levels of prior information about the quality change.

For example, in a well-funded study that employed in-person interviews Carson and Mitchell (1993) thoroughly describe baseline national water quality as “not boatable” and improved water quality as “boatable, fishable, and swimmable” using visual aids and extensive text. In contrast, many CVM research budgets are not adequate to pursue extensive descriptions of existing quality and changes in quality. With smaller research budgets that may lead to mail or telephone interviews, important text detailing the environmental quality change may be discarded. For example, in the CVM application presented here respondents are asked to value a water quality improvement from the current water quality level to a water quality level that is fishable, swimmable, and drinkable. The current water quality is not explicitly described to respondents during the telephone interview. We rely on existing respondent knowledge about current water quality.

Heterogeneous respondents may have varying subjective perceptions about the current environmental quality level and the hypothetical changes described during the CVM interview. This may be true even when current quality and the quality change are thoroughly described, as in Carson and Mitchell (1993); but it is especially true when the quality change is not explicitly described assuming that perceptions about quality are homogeneous. In the current application, some might consider current water quality to be too poor for fishing and swimming. Other respondents might consider current water quality to be fishable but not swimmable. With either explicitly described quality change or implicitly understood quality change, CVM questions elicit willingness to pay values that may vary based on differences in respondent quality perceptions. The variation in willingness to pay due to the variation in quality perception will not be accounted for by the researcher who ignores the differences in quality perceptions across respondents, adding to the error of the willingness to pay estimates.

Ignoring the divergence between perceived quality and objective quality (i.e., quality as described in the survey) in empirical models of willingness to pay leads to the well-known omitted variable problem. For examples of studies that may suffer from omitted variables problems, Hurley, Otto, and Holtkamp (1999) estimate the willingness to pay for delaying nitrate contamination in drinking water and Stumborg et al. (2001) ask for respondent willingness to pay for a reduction in phosphorus pollution. In both cases the perceived quality change is likely to vary across respondents. Neither of these studies includes measures of attitudes or perceptions about the pollution problem in their models of willingness to pay. These omitted variables may cause bias in the estimates of coefficients on variables that are correlated with perceived environmental quality. In general, omitted variable bias may help explain some poor results from CVM research such as poor fits and even unexpected signs.

One solution to the omitted quality variable problem is to include a proxy variable for quality in the model. In the case of willingness to pay for quality improvements the approach is to elicit perceived quality, or variables that may be related to quality (e.g., attitudes, satisfaction ratings), from survey respondents and include these measures as determinants of willingness to pay. Many CVM studies have followed this approach. For example, Kwak, Lee, and Russell (1997) and Yoo and Yang (2002) measure status quo drinking water quality with scale variables measuring "the respondent's attitude toward current tap water quality" and "degree of satisfaction the respondent has with current tap water quality." Both studies find that as satisfaction with current drinking water quality increases willingness to pay decreases. Clearly, subjective perceptions are potentially important determinants of willingness to pay. See Um, Kwak, and Kim (2002) for another example using the averting behavior method.

Most studies that include quality perceptions in the willingness to pay model ignore the fact that varying subjective quality perceptions are due to the heterogeneity of respondents and the information and attitudes that they bring to the CVM survey. In contrast, Danielson et al. (1995) estimate the determinants of perceived air and water quality and find that they depend on demographics, environmental knowledge, and environmental attitudes. This approach reveals a problem with including quality perceptions in willingness to pay models. Quality perceptions may be affected by the same unobserved characteristics that influence willingness to pay. For example, unobserved tastes may be correlated with both perceived quality and willingness to pay. If the empirical explanations of willingness to pay and quality perceptions are related, the coefficient on the quality perception variable will be biased in an empirical willingness to pay model. The bias is due to the correlation in the error terms in the willingness to pay and quality perceptions models. Including the perceived quality variable without accounting for the correlation in the error terms will cause the perceived quality variable and the willingness to pay error term to be correlated, biasing the coefficient on the quality variable.

Including quality perceptions in empirical models of willingness to pay is policy-relevant. The validity of willingness to pay is always of critical concern when CVM estimates are used for policy. Including quality perceptions in an appropriate way allows a richer assessment of validity of the model. As quality perceptions vary willingness to pay should vary in the expected direction. Willingness to pay should be greater in magnitude the greater the quality change. In this sense the effect of the perceived quality variable on willingness to pay is a form of scope test (Whitehead, Haab, and Huang, 1998). Further, sensitivity analysis should be conducted in policy analysis. One type of sensitivity analysis is the variation of the scope of the policy. For example, are net benefits of water pollution policy greater for a 10% reduction or for a 25% reduction of pollution? Incorporation of changes in quality perceptions in willingness to pay models allows the development of different willingness to pay estimates for different policy goals.

3. Model

Suppose consumers have the utility function $u(x,q,z)$, where x is natural resource use, q is a measure of environmental quality, and z is a composite of all market goods. The expenditure function, $m(p, q, u)$, is found by solving the consumer problem: min $(z + px)$ s.t. $u = u(x,q,z)$ where p is the use price and $p_z = 1$. Willingness to pay is the maximum amount of money consumers would give up in order to enjoy an improvement in quality. The willingness to pay for the improvement in quality is

(1) $$WTP = m(p,q,u) - m(p,q^*,u)$$

where q is the current level of quality and q^* is an improved level of quality. Expenditures to maintain the utility level decrease with the increase in quality so that $WTP \geq 0$.

Assume the reference level of utility is $u^* = v(p,q^*,y)$, where y is income and $v(.)$ is the indirect utility function found by solving the problem: $\max[u(x,q,z)]$ s.t. $y = z + px$. Substitution of the indirect utility function into the willingness to pay equation yields the Hicksian variation function

(2) $$\begin{aligned} WTP &= m[p,q,v(p,q^*,y)] - y \\ &= s(p,q,q^*,y) \end{aligned}$$

where $s(.)$ is the equivalent variation measure of welfare. According to reasonable assumptions and economic theory, the variation function is decreasing in own-price, decreasing in current quality, q, increasing in improved quality, q^*, and increasing (decreasing) in income for q normal (inferior) (Whitehead, 1995).

CVM study design should include each of the four variables in the variation function, among other relevant variables, but few studies do. While the own-price variable is easily constructed as the travel cost, distance is often included as a proxy. In the case study described below, construction of the travel cost variable is problematic because the respondents are in close proximity to natural resource access limiting the variation in the own-price variable. A further problem is that there are a large number of potential access points. Perceptions about the potential to reach the improved quality level are easily elicited from respondents. Yet few studies consider this issue. The current study design also did not elicit perceptions about improved quality. We proceed assuming that the own-price and improved quality variables are constant.

The empirical willingness to pay model that corresponds to the theoretical model and the simplifying assumptions is

$$(3) \qquad WTP_i = \alpha' X_{1i} + \beta q_i + \varepsilon_{1i}$$

where α is a coefficient vector, β is a lone coefficient, and X_{1i}, $i = 1, \ldots$, n, is a vector of independent variables including a constant, income, and other variables that may affect willingness to pay. Omission of the current quality variable results in the following model

$$(4) \qquad WTP_i = \alpha' X_{1i} + e_{1i}$$

where the new error term, $e_{1i} = \beta q_i + \varepsilon_{1i}$, is not independent of the explanatory variables if perceived quality is correlated with any of the elements of the X_{1i} vector, violating one of the classical assumptions of regression. This will cause bias in the coefficients on the variables of X_{1i} that are correlated with perceived quality. In other words, biased coefficients may result if any of the elements of X_{1i} are also determinants of perceived quality.

Including perceived quality as an independent variable can potentially cause other econometric problems. The current level of quality is a subjective measure of quality that varies across individuals, q_i. For example, different individuals might consider current quality to be "good" or "poor" depending on the knowledge and experience they bring to the survey. Assuming these quality perceptions are continuous, quality can be explained by the model

$$q_i = \gamma' X_{2i} + \varepsilon_{2i} \tag{5}$$

where γ is a coefficient vector, X_{2i} is a vector of variables that explain the variation in perceived quality, and ε_{2i} is a normally distributed error term.

With perceived quality as the measure of quality the willingness to pay equation becomes

$$\begin{aligned} WTP_i &= \alpha' X_{1i} + \beta q_i + \varepsilon_{1i} \\ &= \alpha' X_{1i} + \beta(\gamma' X_{2i} + \varepsilon_{2i}) + \varepsilon_{1i} \end{aligned} \tag{6}$$

In this formulation the error terms are correlated if the same unobserved factors influence both perceived quality and willingness to pay. This correlation will cause the quality variable and the error term to be correlated, biasing the coefficient on quality, β. Positive correlation will bias the coefficient upwards while negative correlation will bias the coefficient downwards. An instrumental variable technique can be used to avoid the endogeneity bias.

In the application described below the willingness to pay variable is continuous and censored at zero

(7) $$WTP = \begin{cases} WTP^* & if \quad WTP^* > 0 \\ 0 & if \quad WTP^* \leq 0 \end{cases}$$

where WTP^* is the unobserved true willingness to pay. In this case the Tobit model is appropriate. In order to avoid endogeneity bias, the empirical willingness to pay model is a simultaneous equations instrumental variables model. The willingness to pay model is a Tobit regression and the quality model is an ordinary least squares regression

(8) $$\begin{aligned} WTP_i &= \alpha' X_{1i} + \beta q_i + \varepsilon_{1i} \\ q_i &= \gamma' X_{2i} + \varepsilon_{2i} \\ \rho &= \text{corr}[\varepsilon_{1i}, \varepsilon_{2i}] \end{aligned}$$

The estimation method is full information maximum likelihood allowing for correlation in the normally distributed error terms, ρ. The test for the exogeneity of q_i is a t-test for $\rho = 0$. The model is described in Smith and Blundell (1986) and estimated with the LIMDEP econometric software (Greene, 2002).

The variables in the X_{2i} vector but not in the X_{1i} vector are the identifying variables. These variables should have high explanatory power in the instrumenting (i.e., quality) equation and low correlation with willingness to pay and its error term. We test this last condition with a Bassman-type identification test. We regress the error terms from the jointly estimated willingness to pay model on all of the explanatory variables

(9) $$\hat{\varepsilon}_{1i} = \delta' X_{2i} + \upsilon_i$$

where $\hat{\varepsilon}_{1i}$ are the residuals from the Tobit regression, δ is a vector of coefficients and υ_i is a normally distributed error term. The test statistic is the product of the sample size and the R^2 value and is distributed chi-squared with degrees of freedom equal to the number of variables in the X_{2i} vector, *j*, minus the number of variables in the X_{1i} vector, *k*, minus 1

(10) $\chi^2 = n \times R^2 (d.f. = j - k - 1)$

If the test statistic is less than the critical value then we conclude the model is properly identified.

Since the willingness to pay data is modeled with the Tobit in this application the expected willingness to pay value is a nonlinear function

(11)
$$E(WTP) = \Phi(Z)\left(\alpha' \overline{X}_1 + \beta\overline{q} + \sigma\lambda\right)$$
$$Z = \frac{\alpha' \overline{X}_1 + \beta\overline{q}}{\sigma}$$
$$\lambda = \frac{\phi(Z)}{\Phi(Z)}$$

where the mean values of the independent variables, $\overline{X}_1$ and $\overline{q}$, are used, $\phi(\cdot)$ is the standard normal density function, $\Phi(\cdot)$ is the standard normal distribution function, and σ is the standard error of ε_{1i}. The standard errors for the expected willingness to pay are constructed using the Delta Method (Greene, 1997). The marginal effect of quality on expected willingness to pay is

$$(12) \qquad \frac{\partial E(WTP)}{\partial q} = \beta\Phi(Z)$$

where Z is evaluated at the mean of all variables including quality. Since $0 < \Phi(Z) < 1$, the marginal effect will always be smaller in absolute value than the coefficient estimate.

4. Data

The data is from a 1998 "landowner survey to evaluate implementation of best management practices" in the Neuse River basin in North Carolina (Hoban and Clifford, 1999).[4] A CVM water quality valuation scenario was also included but water quality valuation was not the primary purpose of the original project. As such, the data has several limitations. Despite these limitations, the data is useful to illustrate the potential for endogeneity bias.

A stratified random sample telephone survey of landowners from the 12 counties of the upper, middle, and lower Neuse River basin was employed. Forty percent of the landowners are from the upper, 33% are from the middle, and 27% are from the lower Neuse River basin. The sample includes 41% farm and 59% non-farm landowners. All summary statistics and empirical results are weighted to reflect the geographic and farm/non-farm stratification of the sample. The telephone survey response rate (completions divided by completions plus refusals) is 75%. After deleting cases with missing data on variables used in this study the sample size is 663 for a 48.7% useable response rate.

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[4] A copy of the report is available from the author.

Survey respondents are presented with the contingent valuation scenario: "We already pay for government environmental programs through taxes, water bills, and other means. However, government will need more money if water quality in the Neuse River is to be protected. This money would pay for government programs to control pollution, monitor water quality, protect fish habitat, and educate people about ways to reduce pollution. The goal would be to make sure water quality in the Neuse River is safe enough for fishing, swimming, and drinking treated water from the River." [5]

A popular survey design for eliciting willingness to pay is the dichotomous choice (DC) question. With a DC question respondents are asked whether they would be willing to pay a randomly assigned dollar amount (e.g., $*A1*) for the improvement in quality. This single question is relatively easy to answer but provides a limited amount of information about willingness to pay. The DC valuation question presents respondents

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[5] No information was provided in the survey about how the "government programs to control pollution, monitor water quality, protect fish habitat, and educate people about ways to reduce pollution" would be implemented. The payment vehicle is (implicitly) an increase in "taxes, water bills, and other means" that are used to pay for environmental programs. The CVM scenario is, admittedly, vague compared to those found in surveys with a primary purpose of valuation. The expected effect of the vagueness of a CVM scenario is to increase uncertainty about the outcome of the environmental program. Risk averse respondents will be less likely to be willing to pay, driving willingness to pay downward. The increased uncertainty could also lead to an increased variance around the point estimate of willingness to pay.

with a hypothetical situation: "Would you and your household be willing to pay $*A1* each year for these programs, if you knew the money would be used to make sure water quality in the Neuse River is safe?" The dollar, hereafter tax, amount in the first willingness to pay question (*A1*) took on nine values with a random start ranging from $10 to $200 (10, 25, 50, 75, 100, 125, 150, 175, 200). The tax amounts were pre-tested to determine if the range covered the expected range of willingness to pay.[6]

Follow-up iterative bidding (IB) DC questions with the next highest or lowest tax amount provide more information about willingness to pay. When respondents change their answer in response to a change in the price (e.g., yes/no, no/yes) the responses are used to construct upper and lower bounds for individual willingness to pay and the continuous willingness to pay variable is measured at the midpoint between the bounds. For respondents who are not willing to pay $10, willingness to pay is equal to the response to the follow-up question: “What is the most that you and your household would be willing to pay each year for these programs?” For respondents who are willing to pay $200 the willingness to pay variable is conservatively top-coded at $200. In this paper we use the IB willingness to pay variable, *MAXWTP*, since it facilitates the joint estimation of willingness to pay and quality perceptions with existing econometric software (Greene,

[6] A crucial test of internal validity of willingness to pay estimates developed from DC data is the relationship between the respondent’s willingness to pay the cost of the policy and the magnitude of the cost. As the cost rises, the proportion of respondents willing to pay should fall. The first yes/no responses in this application pass this crucial validity test. These results are available from the author.

2004).[7]

We use two water quality perception variables to implement the model. The first is the general question (*WQRATE*): "When you think of water quality please consider its suitability for various uses (such as swimming, fishing, or drinking). Would you say it is excellent, good, fair, or poor?" The second quality variable is specific to drinking water (*WQDRINK*): "How would you rate the quality or purity of your home drinking water as it comes from the faucet? Would you say it is excellent, good, fair, or poor?" For each of the water quality variables the scale variable is increasing in quality. "Excellent" water quality is coded at 4, "good" is coded at 3, "fair" is 2 and "poor" is 1.

Income (*INCOME*) is measured at the midpoint of income categories following the question: "Which of the following categories best represents your family's 1997 total income before taxes?" The categories are less than $5000, between $5000 and $10,000, between $10,001 and $20,000, between $20,001 and $30,000, between $30,001 and $40,000, between $40,001 and $50,000, between $50,001 and $60,000, between $60,001 and $80,000, between $80,001 and $100,000, between $100,001 and $200,000, and more than $200,000. Those respondents who state that income is more than $200,000 are top-

[7] The IB approach introduces two types of bias that typically drive willingness to pay estimates downward: anchoring (i.e., starting point bias) and incentive incompatibility (e.g., Whitehead, Hoban and Clifford, 2001; Whitehead, 2002). We urge caution upon those researchers who may be considering a benefit transfer exercise with the willingness to pay estimates.

coded at $200,000.

Several dummy variables measure the respondent's proximity to water and water-related problems. *RURAL* is equal to one if the respondent's home is in a "rural area" and equal to zero if the home is in a city, suburb, or small town. *SEPTIC* is equal to one if the respondent answers either "septic" or "both septic and sewer" to the question: "Does your home have central sewer service or a septic tank?" *PRIVWELL* is equal to one if the respondent answered either "private well" or "both city and well" to the question: "Does your home get its water from a public water system or your own private well?" *PROPERTY* is equal to one if the respondent answered "yes" to the question: "Is your property located next to any rivers, streams, or other bodies of water?" For each question, the variable is equal to zero if it is not equal to one.

Information about water quality is measured by three dummy variables: "Have you ever heard of the term watershed?" (*WATERSHD*), "Have you ever heard of the term nonpoint source pollution?" (*NONPOINT*) and "Have you ever heard of the term Pfiesteria?" (*PFIESTER*). Each dummy variable is equal to one if the respondent had heard of the term and zero otherwise.

Finally, several demographic variables are included in the analysis. *NONWHITE* is equal to one if the respondent is "black," "American Indian," "Asian," "Mixed Race" and equal to zero if "white." *FEMALE* is equal to one if the respondent is female and zero if male. *AGE* is the age of the respondent. *FARM* is equal to one if the respondent is part of the farm sample and zero otherwise.

Average willingness to pay is $76 (Table 2). The average tax amount initially presented to respondents is $103. The average family income is $71,290.[8] Drinking water quality is the higher rated of the water quality variables, 3.03 on the 4 point scale. The average general water quality rating is 2.46. Fifty-two percent of the sample lives in a rural area. Sixty-four percent of the sample is on a septic tank, 41% gets their water from a private well, and 37% lives near water. Only 16% of the sample had heard of nonpoint source pollution. Seventy-seven percent of the sample had heard of both Pfiesteria and watershed. Fourteen percent are nonwhite. Forty-three percent are female. The average age is 51 years. Thirty-five percent is part of the farm sample.

The largest group of respondents is willing to pay zero (29%) (Table 3). The next largest groups of respondents are willing to pay $62.50 (15%), $112.50 (12%), and $200 (11%). In the other categories, 17% are willing to pay between zero and $37.50, about 11% are willing to pay between $137.50 and $187.50, and 5% percent are willing to pay $87.5.

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[8] Missing income data are imputed with the conditional mean from a wage equation used to estimate the determinants of income. The income model is estimated with 758 cases and specified with the standard variables including education, potential experience, race and gender. Also, dummy variables are included for the farm sample and respondents who lived in a city. The dependent variable is the log of income. Missing income data are replaced with the midpoint of the income interval closest to the exponential of the predicted log income value.

Forty-two percent consider general water quality to be fair, 41% consider it good, and 13% consider it poor (Table 4). Only 4% consider general water quality excellent. Fifty-one percent rate drinking water quality good, 26% rate it excellent, 19% rate it fair, and only 4% rate it poor.

5. Results

We estimate independent and joint quality/willingness to pay models for the two quality variables. We use all exogenous variables as instrumental variables in the X_{2i} vector. Quality is specified to depend on the tax amount, income, knowledge, water-related, and demographic variables. We have no a priori expectations of the signs of the coefficients in the quality model.

The demographic variables are excluded in X_{1i} and serve as the identifying variables. We choose these demographic variables as the identifying variables because they are strongly related to perceived quality and unrelated to willingness to pay. The willingness to pay equation is specified to depend on the tax amount, income, knowledge, water-related variables, and perceived quality. [9]

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[9] We use the Tobit model to analyze these data. The mid-point method for assigning values within willingness to pay intervals can lead to biased coefficient and willingness to pay estimates if the midpoint values are not equal to the expected value of willingness to pay. Cameron and Huppert (1989) use the interval data model and show the bias that results when the data obtained from the mid-point method is used with ordinary least squares regression. The choice of empirical model in this study depends on conflicting

The coefficient on the tax amount will be statistically significant if the data is subject to starting point bias.[10] The coefficient on *INCOME* will be positive (negative) if quality is a normal (inferior) good. The coefficient on the quality variable is expected to be negative; higher perceived quality leads to lower willingness to pay for quality improvements. We have no a priori expectations of the signs of the other coefficients in the willingness to pay model.

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aspects of these data. The coarser the intervals the greater chance of bias if interval regression is not used. The greater the ratio of zero willingness to pay values to positive willingness to pay values the greater chance of bias if Tobit is not used. These data contain a high ratio of zero values and relatively narrow intervals so we proceed with the Tobit model. Using similar data, Whitehead, Hoban, and Clifford (1995) find only minor differences between coefficient estimates and willingness to pay values between the Tobit and interval regression models

[10] If the respondent anchors his or her answers to the follow-up valuation questions because of the perception that the first tax amount is "about right" or for some other reason then the final willingness to pay estimate is biased towards the starting tax amount. Anchoring will upwardly bias the willingness to pay estimate if the average of the starting tax amounts is greater than the sample's true willingness to pay value and downwardly bias the willingness to pay estimate if the average is lower than the sample's true willingness to pay value (Whitehead, Hoban, and Clifford, 1995). Since the tax amount is randomly assigned and not correlated with other independent variables, starting point bias will not affect the results that are the focus of this paper.

General Water Quality

In the independently estimated model the determinants of perceived general water quality (*WQRATE*) are estimated by ordinary least squares (Table 4). Perceived water quality increases with income and if the respondent gets their drinking water from a private well. Perceived water quality is lower if the respondents' property is located near water or if they had heard of the term watershed. No other coefficient on the independent variables is statistically significant. The model has low explanatory power.

In the independently estimated willingness to pay model, the coefficient on the tax amount is positive and statistically different from zero indicating starting point bias. The coefficient on income is positive and statistically significant indicating that quality is a normal good and providing evidence of the internal validity of willingness to pay. Willingness to pay is lower for rural respondents and higher for those with property near water. General perceived water quality is not a factor affecting willingness to pay.

Next the water quality and willingness to pay models are jointly estimated. In the water quality model most of the coefficients retain their statistical significance. The coefficient on *PROPERTY* is no longer statistically significant. Those who are older perceive higher quality when the model is jointly estimated. In the willingness to pay equation the coefficients on *RURAL* and *PROPERTY* are no longer statistically significant. Most importantly, the coefficient on *WQRATE* is negative and statistically significant, as expected. This indicates that as perceived general water quality increases the willingness to pay for improved water quality decreases, as expected. One conclusion with the independent model would be that the willingness to pay estimate lacks validity due to the statistical insignificance of the coefficient on the quality variable. The joint model provides evidence that the willingness to pay estimate has some degree of internal validity; in other words, willingness to pay passes a scope test.

The correlation of the error terms in the willingness to pay and quality equations, ρ, is positive and statistically different from zero indicating that the perceived water quality variable is endogenous in the willingness to pay equation. The positive correlation is consistent with the upwardly biased coefficient on water quality. The result from the Bassman-type test indicates that the joint model is appropriately identified ($\chi^2 = 7.48[3\,d.f.], p = .05$).

Drinking Water Quality

In contrast to the paucity of statistically significant coefficients in the *WQRATE* model, seven of the thirteen variables have significant coefficients in the drinking water quality model (Table 5). Perceived drinking water quality is higher for rural respondents, and if the respondent gets their drinking water from a private well. Quality increases with age and for farm residence. Perceived water quality is lower if the respondent is on a septic tank and if the respondents' property is located near water. Those who are nonwhite perceive lower water quality.

In the independently estimated willingness to pay model, the coefficient on the tax amount is positive and statistically different from zero indicating starting point bias. The coefficient on income is positive and statistically significant indicating that quality is a normal good. Willingness to pay is lower for rural respondents and higher for those with property near water. Drinking water quality has a negative effect on willingness to pay.

In the jointly estimated quality equation most of the coefficients retain their statistical significance. The coefficients on *SEPTIC* and *NONWHITE* are no longer statistically significant. Those with higher incomes and who have heard about Pfiesteria perceive higher water quality. Female respondents perceive lower water quality when the model is jointly estimated. In the willingness to pay equation the coefficients on *RURAL* and *PROPERTY* are no longer statistically significant. Those who get their drinking water from a private well are willing to pay more. Those who have heard of the terms Pfiesteria and watershed are willing to pay more. Again, the income effect provides evidence of the internal validity of willingness to pay. Most importantly, the coefficient on *WQDRINK* is negative and statistically significant. This indicates that as perceived drinking water quality increases the willingness to pay for improved water quality decreases, as expected. The scope test in the joint model provides evidence that the willingness to pay estimate has some degree of internal validity.

The correlation of the error terms in the willingness to pay and quality equations is statistically different from zero indicating that the perceived water quality variable is endogenous in the willingness to pay equation. The positive correlation is consistent with the upwardly biased coefficient on water quality. The result from the Bassman-type identification test indicates that the joint model is appropriately identified ($\chi^2 = 7.13[3\,d.f.], p = .05$).

Quality and Willingness to Pay

The marginal effects of quality perceptions on willingness to pay are computed at the means of the independent variables. The marginal effect estimates from the independent models are low (less than $10) relative to those from the joint models and only one is statistically different from zero. The marginal effects from the joint models vary. The lowest estimate is from the *WQDRINK* model. The marginal effect from this model suggests that a one unit increase in drinking water quality perceptions (e.g., “fair” to “good”) reduces mean willingness to pay by $53. The marginal effect from the *WQRATE* model suggests that a one unit increase in general water quality perceptions reduces mean willingness to pay by $123. The differences in the marginal effects between the independent and joint models are a measure of the extent of the potential bias from ignoring the endogeneity of water quality perceptions.

Expected willingness to pay estimates are constructed for each of the jointly estimated quality models (Table 6). Willingness to pay is assessed at each of the four perceived water quality levels. In the *WQRATE* model, willingness to pay decreases from $288 to $0 as baseline water quality perceptions increase from “poor” to “excellent.” Willingness to pay falls from $254 to $19 as drinking water quality perceptions increase from “poor” to “excellent.” The willingness to pay estimates from the independently estimated models are not shown in this table. However, considering the marginal effects, willingness to pay does not significantly differ with differences in water quality perceptions. The range of expected willingness to pay estimates is large and differences are economically significant with the more appropriate jointly estimated instrumental variable quality and willingness to pay model. Using the inappropriate independently estimated willingness to pay model would lead to a reduction in the magnitude of the effect of the baseline quality on willingness to pay.

6. Conclusions

Our results indicate that the endogeneity of quality perceptions in willingness to pay models is a potential econometric problem. The coefficients on quality variables are biased in independently estimated willingness to pay models that do not account for endogeneity. In jointly estimated willingness to pay models, current quality has negative effects on willingness to pay as expected. In other words, respondents who perceive that current water quality is “poor” are willing to pay more for a quality improvement than those who think current water quality is “fair” or better. The marginal effects of these variables are of realistic magnitude.

Policy analysts require benefit estimates that correspond to the true, or objective, change in resource allocation (e.g., quality) that will result from the policy or program. One problem that most CVM research faces is that an attempt is made to describe the objective quality change to respondents, yet willingness to pay statements are made based on subjective quality. As such, willingness to pay estimates from CVM research would be improved and more useful to policy makers if adjustments can be made so that subjective willingness to pay is consistent with objective willingness to pay.

This paper demonstrates that when estimated appropriately the marginal effects of perceived quality can be used to adjust willingness to pay estimates so that they are more consistent with objective quality. For example, if most respondents believe that current water quality is "fair" but experts believe that water quality is "good", the willingness to pay estimate associated with "good" quality could be used for policy analysis. This, of course, ignores another policy analysis problem. It is possible that benefits can be achieved by changing perceptions through an information campaign even if objective quality is not changed. In this case, benefits are real only if the information moves perceptions more closely to reality.

As mentioned previously, the data used in this paper was not designed to examine the effects of quality perceptions on willingness to pay. Future research into this issue should begin with a survey design focused on pre- and post-policy quality perceptions, their determination and the relationship between quality perceptions and willingness to pay. Also, future research should also consider joint estimation of quality perceptions and the theoretically preferred dichotomous choice willingness to pay data. This effort will require econometric models not provided in current econometric software packages.

CVM researchers should consider the implications of omitted variable bias and endogeneity bias whenever quality or other changes are to be valued by respondents and there is the potential for a divergence between perceptions and reality. For example, this issue might be especially important for environmental amenities that generate non-use values and for which respondents are not familiar (e.g., preservation of the Alaska National Wildlife Refuge). Modeling the endogeneity of the change in the resource allocation might especially be important when environmental risk is considered. There is much research that finds a divergence between subjective and objective risks (e.g., Viscusi, 1989). Identification of situations with divergence between subjective and objective risks is important. Valuation of these risks should consider their subjectivity and determination.

Finally, another avenue for future research is the role of information in minimizing the divergence between subjective and objective quality and risks. Information provision in the survey instrument can lead to improvements in the accuracy of willingness to pay as subjective quality converges with objective quality (Blomquist and Whitehead, 1998; Hoehn and Randall, 2002). Variations in information treatments could be used to determine the type of survey information that would make explicit modeling of quality and risk change unnecessary.

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Table 1. Variables

Variable	Description	Mean	Std.Dev.
MAXWTP	Maximum willingness to pay	75.95	70.57
WQRATE	Perception of general water quality	2.46	0.73
WQDRINK	Perception of drinking water quality	3.03	0.82
A1	Randomly assigned tax amount	103.13	62.44
INCOME	Family income (in thousands)	71.29	61.50
RURAL	1 if rural resident	0.52	0.50
SEPTIC	1 if has septic tank	0.64	0.48
PRIVWELL	1 if gets water from private well	0.41	0.49
PROPERTY	1 if property is near water	0.37	0.48
NONPOINT	1 if heard of nonpoint source pollution	0.16	0.37
PFIESTER	1 if heard of Pfiesteria	0.77	0.42
WATERSHD	1 if heard of watershed	0.77	0.42
NONWHITE	1 if nonwhite	0.14	0.35
FEMALE	1 if female	0.43	0.49
AGE	age	51.09	14.75
FARM	1 if family owns farm	0.35	0.48
Cases	663		

Table 2. Willingness to Pay Frequency Distribution

MAXWTP	Frequency	Percent
0	191	28.81
5	2	0.3
17.5	48	7.24
37.5	63	9.5
62.5	102	15.38
87.5	31	4.68
112.5	82	12.37
137.5	13	1.96
162.5	38	5.73
187.5	17	2.56
200	76	11.46

Table 3. Water Quality Perception Frequency Distribution

	WQRATE		WQDRINK	
	Frequency	Percent	Frequency	Percent
Poor	88	13.27	28	4.22
Fair	278	41.93	124	18.7
Good	273	41.18	336	50.68
Excellent	24	3.62	175	26.4

Table 4. Willingness to Pay and Quality Models: WQRATE

	Independent				Joint			
	WQRATE		MAXWTP		WQRATE		MAXWTP	
	Coeff.	t-ratio	Coeff.	t-ratio	Coeff.	t-ratio	Coeff.	t-ratio
ONE	2.416	14.94	18.608	1.08	2.298	15.66	403.223	2.65
A1	0.000	0.94	0.309	5.54	0.000	0.77	0.351	3.86
INCOME	0.001	2.26	0.110	1.88	0.001	3.04	0.305	2.61
RURAL	-0.054	-0.65	-29.094	-3.00	-0.058	-0.70	-24.114	-1.42
SEPTIC	-0.021	-0.24	15.366	1.42	-0.084	-0.94	4.055	0.20
PRIVWELL	0.311	4.51	-11.966	-1.38	0.284	4.13	32.140	1.34
PROPERTY	-0.143	-2.43	22.519	3.07	-0.090	-1.51	5.333	0.39
NONPOINT	0.040	0.49	-4.702	-0.48	-0.012	-0.15	2.715	0.17
PFIESTER	-0.116	-1.60	10.530	1.20	-0.122	-1.59	-17.168	-1.03
WATERSHD	-0.121	-1.63	5.205	0.59	-0.175	-2.36	-2.952	-0.19
NONWHITE	-0.008	-0.09			0.018	0.30		
FEMALE	0.046	0.70			-0.059	-1.35		
AGE	0.001	0.41			0.005	2.62		
FARM	0.008	0.10			0.088	1.62		

WQRATE		-2.404	-0.49	-157.301	-2.64
σ		86.383	28.88	83.627	22.72
R^2	0.062				
Log Likelihood	-794.05	-2986.97		-2324.45	
ρ				0.800	2.643

Table 5. Willingness to Pay and Quality Models: WQDRINK

	Independent				Joint			
	WQDRINK		MAXWTP		WQDRINK		MAXWTP	
	Coeff.	t-ratio	Coeff.	t-ratio	Coeff.	t-ratio	Coeff.	t-ratio
ONE	2.374	14.43	40.546	2.41	2.303	15.49	257.185	3.95
A1	0.000	-0.58	0.303	5.46	0.000	-0.56	0.275	3.91
INCOME	0.001	1.60	0.115	1.97	0.001	1.64	0.169	2.33
RURAL	0.166	1.96	-25.340	-2.59	0.179	2.12	2.398	0.15
SEPTIC	-0.147	-1.65	14.225	1.32	-0.135	-1.50	5.213	0.34
PRIVWELL	0.419	5.97	-7.660	-0.87	0.424	5.81	32.641	2.02
PROPERTY	-0.107	-1.78	21.645	2.97	-0.100	-1.64	12.898	1.35
NONPOINT	0.045	0.55	-3.194	-0.33	0.053	0.57	9.044	0.75
PFIESTER	0.110	1.49	11.823	1.35	0.122	1.73	20.985	1.85
WATERSHD	0.010	0.14	7.235	0.82	0.012	0.17	19.394	1.66
NONWHITE	-0.159	-1.77			-0.089	-1.23		
FEMALE	-0.041	-0.62			-0.084	-1.62		
AGE	0.006	2.99			0.008	3.85		
FARM	0.323	3.825			0.258	3.477		

WQDRINK		-10.895	-2.35	-96.147	-3.89
σ		85.989	28.89	84.834	22.26
R^2	0.221				
Log Likelihood	-784.56	-2998.65		-2328.78	
ρ				0.610	3.670

Table 6. Expected Willingness to Pay: Jointly Estimated Models

	WQRATE		WQDRINK	
Water Quality	E(WTP)	t-ratio	E(WTP)	t-ratio
Poor	287.83	3.23	253.57	5.12
Fair	132.65	5.14	158.45	6.52
Good	21.67	1.73	72.92	19.78
Excellent	0.41	0.32	19.22	2.23