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Effect of Risk Perception on Willingness to Pay for Improved Water Quality

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by

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Groundwater quality improvement benefits for Nebraska were estimated using both contingent valuation (CV) and averting expenditures (AE) methods. Willingness to pay (WTP) and averting expenditures were measured based on a mail survey of 4,000 randomly selected Nebraska households that was conducted in mid October 1997. A double-bounded referendum format was used to elicit WTP for water quality improvements. The questionnaire also solicited information on the socioeconomic factors hypothesized to influence WTP and averting expenditures, including: risk perceptions, age, level of education, income, length of stay in Nebraska, source of water supply, opinions regarding who should pay for water quality programs, and presence of children as well as pregnant woman in the home. The response rate for the Dillman mail survey procedure was 35 percent, resulting in 1416 useable responses.

Respondents were asked willingness to pay questions for two water quality program, one addressing nitrate pollution only and another addressing all contaminants. In Nebraska there is nearly complete dependence on groundwater for domestic use and the dominant water quality problem is nitrates. The USEPA maximum contaminant level (MCL) for nitrate nitrogen in drinking water is 10 mg/l, yet in 1990, 17.5 percent of the domestic wells were found to contain more than 10 mg/l of nitrate (Exner and Spalding, 1990). However, the nitrate problem is not as severe as these data suggest, because approximately 82 percent of the respondents used community water systems, which meet the public health standard at least most of the time. As a result, about 72 percent lived

where there was no problem, as defined by the Nebraska Department of Public Health; three percent lived where the problem was serious and the remaining 25 percent were from areas where there were minor problems. Other contaminants sometimes found in domestic water supplies include trace amounts of agricultural pesticides, coliform bacteria and excessive dissolved solids (hardness).

This paper emphasizes the results associated with the impact of risk and risk preferences on WTP for improved water quality. Utility theory suggests that WTP for better quality of goods and services should be related to the amount and significance of the improvement being purchased. For water quality, this means that one would hypothesize a direct relationship between WTP and both the perceived seriousness of the water quality problem and the perceived consequences of poor quality, collectively called risk perception. In other words, the higher the perceived risk the more there is to be gained from purchasing improved water quality. Similarly, one would expect consumers to be willing to pay more to improve all water quality parameters than to reduce nitrates only. However, empirical results from previous CVM studies suggest that WTP is often independent of the quantity being purchased (NOAA, 1993). In this study we tested three related hypotheses: (1) WTP for water quality depends on perceived risk; (2) perceived risk is an accurate representation of actual risk; and (3) WTP for removing all water pollutants is greater than for removing nitrates only.

Comparison of Perceived and Actual Risk

On average, the subjective risk perceptions of respondents were quite different from actual or expert risk, especially concerning the number of people who perceived

there to be no problem even when they lived in areas where experts believed there was a serious problem (Table 1). Of the 187 respondents who lived in areas where the actual risk was serious or moderate, only 5 subjectively rated their situation as serious or moderate. At the other end of the distribution there was little difference in perceived versus actual risk. Of the 649 respondents who lived in areas of no or slight problems, only 5 percent perceived the problem as moderate or serious. The implications of these differences between actual and perceived risk and the reason for it will be considered after addressing the statistical results regarding factors affecting WTP for water quality.

Table 1. Perceived Risk versus Actual Risk

Perceive Risk	Actual Risk					
	Serious	Moderate	Satisfactory	Slight	None	Total
Serious	-	-	1	-	2	3
Moderate	1	4	5	2	18	30
Satisfactory	11	32	52	30	71	196
Slight	11	42	77	37	122	289
None	13	73	233	61	306	686
Total	36	151	368	130	519	1204

Willingness to Pay for Improving Water Quality

Willingness to pay for improving water quality was estimated from the double bounded CV results, using censored logistic regression as suggested by Cameron (Cameron, 1988). Three distributions (log normal, Weibull and log logistic), and two

specifications of the upper bound for yes-yes answers (infinity and reported maximum bid) were considered. The alternative distributions were evaluated using a maximum log likelihood estimation and the log normal distribution was found to fit best for both WTP for nitrates and WTP for all contaminants. Using a respondent reported maximum bid rather than infinity as the upper bound for yes-yes responses reduced the variance for the estimated mean and median values and, thus, was selected as the preferred approach.

Mean WTP for the nitrate program was estimated at $9.50 per month and mean WTP for reducing all contaminants was slightly greater at $9.72 per month (Table 2). This difference is small, but statistically significant at the five percent level. It could be argued that such a small difference is further evidence of the difficulty of differentiating between different sized programs with CVM, but on the other hand this small difference is consistent with the fact that most water quality problems in Nebraska are associated with nitrates rather than other contaminants.

Table 2. Mean and Median Willingness to Pay for Water Quality Improvements

Statistics	WTP to Reduce Nitrates ($/month)	WTP to Reduce all Contaminants ($/month)
Mean WTP	9.50	9.72
95% Confidence Interval for Mean WTP	8.95 to 10.04	9.17 to 10.27
Median WTP	7.27	7.42
95% Confidence Interval for Median WTP	6.90 to 7.64	7.05 to 7.79

From a political referendum perspective, the distribution of the WTP responses is perhaps more important than the mean. Although median WTP is slightly smaller in both cases, reflecting the fact that a few large WTP responses biases the mean upward, the distribution is not too sharply skewed. Even though the two largest cities in Nebraska both have good quality water and account for 34 percent of respondents, only about 29 percent of all respondents who were offered an initial bid of two dollars voted no-no, suggesting that their actual vote was a zero (Table 3). The tightness of the distribution was even more striking on the high end where only about seven percent voted yes-yes to the maximum initial bid of $15 per month, suggesting that very few people were willing to pay substantially more than the typical respondent.

Table 3 Distribution of Surveyed Household Classified by Bid Values for Nitrates and All Contaminants

Program Version	Initial Bid Value, $/m (# responses)	% YY	% YN	% NY	% NN
Nitrate Contamination	2 (347)	30.25	26.5	15.85	27.4
	5 (356)	22.2	28.1	20.5	29.2
	10 (361)	15.8	18.0	26.3	39.9
	15 (324)	6.8	17.9	17.3	58.0
	Total response = 1388	**18.9**	**22.7**	**20.1**	**38.3**
All Contaminants	2 (350)	29.7	24.85	16.6	28.85
	5 (354)	23.2	26.3	20.9	29.6
	10 (361)	18.6	19.1	23.5	38.8
	15 (327)	7.7	21.1	17.1	54.1
	Total response = 1392	**20.0**	**22.8**	**19.6**	**37.6**

Factors Explaining WTP for Water Quality Improvements

The variables which were hypothesized to affect WTP for water quality improvements included both continuous and dummy variables. The continuous variables were annual household income before taxes, age of respondent and years of residence in Nebraska. The dummy variables included presence of pregnant woman in the home, the presence of a baby less than six-month old, farm income categories, severity of nitrate problem, main source of household water, type of residence (city, acreage or farm), level of education, whether respondent had taken any averting action, gender of respondent, whether or not the respondent expects to be living in Nebraska five years from now, and a benevolence factor, defined as whether the expressed WTP was only for improving the respondents own water supply only or for water quality improvement for all Nebraska citizens. These factors were considered for both nitrates and all contaminants.

All of the factors considered explained 22 percent of the variance in WTP for programs to reduce nitrate contamination, as measured by the pseudo R^2. The statistically significant factors, at a 90 percent confidence level or better, were income, age, actual risk, source of water and averting actions (Tables 4 and 5). Those willing to pay the most were high income, respondents who were dependent on a public water system, lived in a high risk area and had already taken some type of averting action. The factors having the largest impact on WTP over the relevant range of the data were age, income and risk.

Of particular interest is the fact that the benevolence factor and education were

not statistically significant. The insignificance of the benevolence factor suggests that people were not willing to pay more to make the water quality programs available to others as well as themselves. The fact that none of the education categories were statistically significant was unexpected. It was hypothesized that the better educated respondents would be more aware of water quality problems and, thus, have greater WTP. One possible explanation is that all groups are aware of the general problem and consequences and, thus, have similar WTP preferences. Another possibility is that preferences are the same between education groups, but for different reasons. The highly educated may express a WTP because they understand the consequences, while the less

Table 4. Likelihood Ratio Tests for Groups of Dummy Variables Hypothesized to Affect WTP for Reducing Nitrates and All Contaminants, Using Log-Normal Distribution and Reported Maximum Bids for Yes-Yes Responses.

Dummy Variable Group (Degrees of Freedom)	Likelihood Ratio Statistic (LR Test)	
	WTP for Nitrate Reduction	WTP for All Contaminants
AG INCOME(3)	12.6[A]	18.5[A]
EDUCATION(4)	1.7	1.7
PERCEIVED RISK(4)	349.6[A]	N.A.
ACTUAL RISK(4)	7.1[C]	N.A.
RESIDENCE(2)	2.0	2.3

Note: [1] LR Test = - 2 [LnL_R - LnL_U]
where LnL_R is the max log-likelihood estimated from the restricted model, and LnL_U is the max log-likelihood estimated from the unrestricted model
[2] A = 99% significant, B = 95% significant, C = 90% significant.

Table 5. Impacts of Explanatory Factors on WTP for Nitrates and All Contaminants Using Log-Normal Distribution and Reported Maximum Bids for Yes-Yes Responses.

Variable Name	WTP for Nitrate Reduction		WTP for All Contaminants	
	Estimated Coefficient, (SE)	P-Value	Estimated Coefficient, (SE)	P-Value
INTERCEPT	0.9919 (0.5328)	0.058	1.2807 (0.4760)	0.0071
LOG INCOME	0.1078 (0.0442)	0.015	0.1045 (0.0399)	0.0089
YEARS NE.	0.0006 (0.0020)	0.710	-0.002 (0.0018)	0.2804
AGE	-0.0061 (0.0026)	0.016	-0.006 (0.0023)	0.0093
BENEVOLENCE	0.0140 (0.0559)	0.755	-0.088 (0.0511)	0.0834
ACTUAL RISK				
1 = serious	0.3683 (0.5165)	0.476		
2 = moderate	0.3771 (0.1857)	0.042		
3 = slight	0.1508 (0.0801)	0.060		
4 = satisfactory	0.0757 (0.0709)	0.286		
PERCEIVED RISK				
1 = serious	0.2761 (0.1743)	0.113		
2 = moderate	-0.0100 (0.0869)	0.908		
3 = slight	0.0229 (0.0678)	0.735		
4 = satisfactory	-0.1170 (0.0921)	0.204		
AG INCOME				
1 = none	0.2037 (0.1616)	0.208	0.1146 (0.1548)	0.458
2 = < 10%	-0.0150 (0.1840)	0.935	-0.081 (0.1757)	0.645
3 = 10%-50%	0.1902 (0.1606)	0.236	0.2751 (0.1576)	0.081
EDUCATION				
1 = < high school	-0.1393 (0.2287)	0.542	-0.130 (0.1907)	0.495
2 = high school	-0.1354 (0.1026)	0.187	-0.049 (0.0899)	0.583
3 = some college	-0.0927 (0.0942)	0.325	-0.025 (0.0822)	0.757
4 = bachelor	-0.0884 (0.0949)	0.315	0.069 (0.0824)	0.401
RESIDENCE				
1 = city or town	-0.2231 (0.1812)	0.218	-0.212 (0.1772)	0.231
2 = small acreage	-0.0487 (0.1610)	0.762	-0.027 (0.1559)	0.863
PREGNANT = 1	-7.22E-6 (0.1143)	0.999	-0.126 (0.1023)	0.216
BABY = 1	0.1415 (0.2325)	0.543	0.184 (0.2065)	0.372
WAT. SOURCE = 1	-0.2416 (0.1301)	0.063	-0.215 (0.1259)	0.088
AVERT = 1	0.1073 (0.0574)	0.062	0.0986 (0.0518)	0.057
MALE =1	0.0078 (0.0608)	0.898	-0.028 (0.0545)	0.602
PLANS to STAY	0.1712 (0.1349)	0.204	0.127 (0.1206)	0.292

educated may have a similar WTP because they fear the consequences even though they may not understand them.

The factors explaining WTP for reducing all contaminants were very similar to the results for nitrates only. The only major differences were that much less of the total variance was explained, as measured by a pseudo R^2 of 8 percent compared to 22 percent for nitrates, and the benevolence factor was significant for all contaminants, whereas it was not for nitrates only. Less of the total variance is explained, because risk data were not available for all contaminants. Why the benevolence factor is significant for all contaminants, but not for nitrates is unclear. It may be that nitrates are a much more localized problem and, thus people are less supportive of statewide programs that apply to everyone.

Effect of Risk Perceptions on WTP

Risk perceptions were a very important determinant of WTP for nitrates. Both perceived subjective risk and actual risk were statistically significant parameters, although the actual risk gave a more consistent result across risk categories and subjective risk had a larger impact on WTP. For the actual risk categories, the more serious the problem the greater the WTP, except there was no distinction between serious and moderate problem. The results for the subjective risk categories indicate that people are WTP more if the problem is serious than if it is slight, but the intermediate categories are statistically insignificant with unexpected signs. However, the maximum likelihood test (LR) for groups of categorical variables shows that the impact of the perceived risk categories on WTP is much larger than for actual risk, as evidenced by a LR value of 350 for perceived

risk versus 7.1 for actual risk.

The impact of risk perceptions is consistent with what one would expect from utility theory in that perceived risk is a measure of how much the consumer might gain from a program that reduces risk from poor water quality. However, the differences between actual and perceived risk ratings suggests imperfect consumer information with respect to actual risk. Consumers perceive the problem as less serious than the experts, as measured by USEPA public health standards, and perceptions strongly influence WTP. Hence, the WTP values for nitrates are biased downward by imperfect information.

Conclusions and Implications

These empirical results suggest that CVM can yield theoretically consistent results regarding the quantity of the good being purchased, even for complex goods which consumers are not used to valuing. Consumers expressed a higher WTP when they believed that they were purchasing a larger volume of the public good, defined as protection from nitrates only versus protection from all contaminants. They also expressed higher WTP when perceived risk was greater. On the other hand, consumer subjective risk perceptions understated actual risk, as measured by USEPA public health standards, which led to a downward bias in WTP. This suggests that public information programs may be needed before consumers will provide an optimum level of support for public goods, such as water quality programs, It also suggests that consumer purchases of private goods to avert the consequences of adverse water quality are also less than optimal.

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