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Abstract

In recent years, the Great Lakes have suffered stresses from a variety of sources, including the contamination of sediments. Toxins in lake sediments affect the health of wildlife and humans. Cleaning up sediments is costly and generally involves public funds. To determine whether such programs are efficient, it is necessary to have estimates of the value of improvements. Using a contingent valuation survey of residents of counties surrounding Lake Michigan, the authors find that the benefits of cleaning up the areas of concern in the lake outweigh the costs, providing the average household with a welfare improvement of $540.21.

Keywords: non-market valuation, contingent valuation, water quality.
JEL Classification: Q51, Q53.

Introduction

The Great Lakes Basin represents the largest surface freshwater system in the world, containing 20 percent of the world's surface fresh water. The lakes represent an important natural resource, used to provide drinking water, transportation, and numerous commercial and recreational opportunities. However, the system is currently experiencing a variety of stresses. The threats posed by invasive species such as the zebra mussel and, more recently, the Asian carp have received much attention from environmental groups, government agencies and the press. Over time, use of the lakes has also caused damage in the form of pollution. Toxins such as dioxin, arsenic and PCBs contaminate the sediments in the lakes. These contaminated sediments have been created by decades of industrial pollution, poorly treated waste water, sewer overflows, and urban and agricultural runoff.

Because less than one percent of the water flows out of the system annually, such contaminants are not easily flushed from the system. Buried contaminants posing serious human and ecological health concerns can be resuspended by storms, ship propellers, and bottom-dwelling organisms. The presence of these contaminants imposes costs to society in the form of risk to human health, decreases in or damage to wildlife habitat, reduced recreational opportunities, and reductions in commercial fishing and navigation throughout the region. The toxins may be absorbed by fish and move up the food chain. Fish such as lake trout and salmon can be unsafe to eat in some areas because of the heavy concentrations of toxic substances in their tissues, where concentrations may be up to a million times higher per weight than the concentrations in the surrounding water. Human consumption of contaminated fish, water fowl, or contaminated water can lead to increased cancer risk, central nervous system disorders, skin disorders, developmental delays of children, and negative immune system effects. These risks are particularly great for children and pregnant women (Henry, 2009).

The governments of the U.S. and Canada have committed themselves to clean up the most polluted areas of the Great Lakes. The International Joint Commission (IJC) represents the combined efforts of the national governments of Canada and the U.S., as well as state, provincial, local, and tribal authorities, to improve environmental conditions in the Great Lakes Basin. The IJC has identified 42 areas of concern (AOCs) in the Great Lakes, over 80% of which have restrictions on fish and wildlife consumption. Ten of these AOCs are located in Lake Michigan, as shown in Figure 1. The Great Lakes Water Quality Agreement, first signed in 1972, requires U.S. states and Canadian provinces to develop Remedial Action Plans to examine stresses, develop remedial actions, and monitor improvements. Efforts to clean up the areas include reductions in industrial pollution, improved waste water treatment by municipalities and the cleanup of existing contaminated sediments (International Joint Commission, 2003).

Such remediation is a costly undertaking. For proposed contaminated sediment cleanup projects for which the IJC reported cost estimates in 2003, those estimates ranged from $323,000 (the St. Claire River in Ontario) to $465 million (the upper Kalamazoo River in Michigan). The question of who should pay for cleanup is also complicated. Governments cannot bear the costs alone, but identifying those responsible for the contamination may be difficult. The contaminants often come from a number of sources over a long period of time. These sources include not only the relatively obvious point source industrial discharge, but also runoff of soils and farm chemicals from agricultural lands, municipal waste and leaching from disposal sites. Because of their large surface areas, the lakes may also absorb contaminants from the atmosphere (EPA, 2011). In many cases, part of the cost is being paid by identifiable industrial polluters. The cleanup of one hotspot of the lower Fox River, which involves the removal of 150,000 cubic yards of sediments contaminated with PCBs, is being partially financed with $30 million received by the EPA and the Wisconsin Department of Natural Resources from two paper companies, NCR Corp. and Sonoco-U.S. Mills (Brinkman, 2000). But because the sources of the pollution are diverse and not always obvious, a large percentage of the funding for cleanup will come from government sources.

In order to make good decisions concerning the allocation of scarce resources, it is important to have accurate estimates of the costs and benefits of improving water quality at each AOC. As with many environmental problems, the value of improving water quality in Lake Michigan is more difficult to measure than the cost because such improvements are not traded in markets. Fortunately, economists have developed a variety of techniques for valuing non-market goods such as environmental goods. We choose to use the contingent valuation technique rather than travel cost or hedonic models because we feel that this will allow a comprehensive estimate of the benefits of reducing contaminated sediments, including both use and nonuse values.

The CV method is a particularly versatile valuation technique that has been used extensively in all areas of nonmarket valuation. A large amount of research has been conducted using CV to estimate the value of a wide variety of goods including water quality improvements, air quality improvements, and endangered species. Early works include Rowe, dArge and Brookshire's (1980) work on air quality; Brookshire, Eubanks and Randall's (1983) work on endangered species; Desvousges, Smith, and Fisher's (1987) work on water quality improvements in the Monongahela River; and Carson and Mitchell's (1993) work on the value of boatable, fishable, and swimmable water quality. More recent works include contingent valuation work on nonpoint source pollution and water quality improvements in Lake Mendota in Wisconsin by Stumborg, Baerenklau, and Bishop (2001); Egan, Herriges, Kling, and Downing's (2009) work on using water quality measures to value improvements in water quality; and work by Adamowicz, Dupont, Krupnick, and Zhang (2011) on the value of reducing disease risk in municipal drinking water supplies.

The aim of this paper is to present the results of a contingent valuation application to estimate the value of cleaning up all 10 AOCs in Lake Michigan. In the next section we discuss the survey used to gather the data necessary to estimate the value of the cleanup.

1. The survey

The data used in this research was gathered with a contingent valuation survey of people living in the vicinity of Lake Michigan. The survey was sent to a random sample of 1,800 residents of the states of Michigan, Wisconsin, Illinois, and Indiana located in the counties that border Lake Michigan. The sample was drawn by the sampling firm, Survey Sampling International.

Standard CV methodology was used in the development of the survey (see Whitehead, 2006). The survey was developed with input from a focus group of students from Western Michigan University, who completed an early draft of the survey, and then answered a series of questions designed to identify any unclear, ambiguous or leading questions. The final survey consisted of a preamble that provided the reader with a brief discussion of the water quality issue at the 10 AOCs located in Lake Michigan, what the cleanup options are, and what is currently being done about the problem. The next section gathered information about the respondent's recreational trips taken to Lake Michigan as well as some opinion information. The respondent was then presented with the contingent valuation question, which elicited information about the respondent's willingness to pay for the creation of a Lake Michigan Cleanup fund for cleanup of contaminated sediments in all areas of concern that have been identified in Lake Michigan. The respondent's yes/no responses to the CV question are used to estimate a willingness to pay function.

An important concern in CV estimation is the issue of protest responses. Ideally, the respondent's yes/no answer can be interpreted as a statement about whether the value they place on the good is higher or lower than the dollar amount they are being asked to pay. However, the possibility exists that the respondent may answer "no" to the valuation question if they object to some other aspect of the question, such as the payment vehicle being used. In this case, the "no" answer should not be interpreted as a response to the valuation question. Identifying these protest responses is often accomplished by asking the respondent about their motivation for answering the valuation question in the manner in which they answered. When a protest answer is identified, it is eliminated from the analysis. Care must be taken to avoid biasing the valuation question in the process of eliminating protest responses (Halstead, Luloff, and Stevens, 1992; and Jorgensen, Syme, Bishop, and Nancarrow, 1999). Figure 1 shows the valuation question used in the survey as well as the follow up question used to determine protest answers.

A final section of the survey gathered socioeconomic information such as age, gender, education level, employment situation, and income. This section also included an area for respondents to list additional comments about their answers to the survey.

As noted above, the contingent valuation question was designed to allow for estimation of the total value that respondents place on cleaning up all areas of concern in Lake Michigan. The actual valuation question took the form, "Would you vote "yes" on a referendum that would create a Lake Michigan Clean-up Fund? This fund would be added to the money collected from corporations and used for cleanup of contaminated sediments in ALL areas of concern that have been identified in Lake Michigan. Residents of the states bordering Lake Michigan will participate in the referendum. If passed, the referendum will result in a one-time increase in each household's tax bill, with the increase being based on household annual income. Suppose passage of the referendum would result in a one-time increase in your tax bill of $X (payable in five $X/5 installments over a five year period)."

The value of the bid amount, *X*, was varied across respondents to allow for estimation of the willingness to pay function. The bid design took the following form: 30% of the respondents were presented with a bid of $100, 16.56% with a bid of $250, 16.64% with a bid of $500, 16.64% with a bid of $750, and 20.16% with a bid of $1,000. This bid design was a modification of the bid design used in a pre-test version of the survey, which was designed to identify any problems with the survey prior to mailing the final version of the survey. This pre-test was sent to a small, random sample of individuals living in the same region as the final survey recipients.

A modified version of the survey methodology described by Dillman (1978) was used for both the pre-test and final surveys. In particular, recipients who did not reply to the initial mailing were sent a reminder postcard. Recipients who still did not reply were sent a second copy of the survey. Those who did not reply to the second survey were not contacted further.

The valuation model we use is based on the approach taken by Cameron (1988). In particular, the respondent will answer "yes" to the dichotomous choice contingent valuation question if their willingness to pay for the good in question is greater than the bid they are presented with. We can characterize the probability of respondent i answering "yes" in the following manner

$$\Pr\left[yes_i\right] = \Pr\left[wtp_i > Bid_i\right], \quad (1)$$

where wtp_i represents respondent i's willingness to pay, and Bid_i represents the dollar bid presented to respondent *i.* A variety of functional forms can be specified for willingness to pay. We assume that the respondent's willingness to pay takes the linear form

$$wtp_i = \beta X_i + \varepsilon_i, \quad (2)$$

where β is a parameter vector, X_i is a data matrix, and ε_i is a mean zero, iid random error with standard deviation, σ. Combining (1) and (2) we get

$$\Pr\left[yes_i\right] = \Pr\left[\beta X_i + \varepsilon_i > Bid_i\right], \quad (3)$$

If ε is assumed to be normally distributed, this statement can be further modified to

$$\Pr\left[yes_i\right] = 1 - \Phi\left[\frac{Bid_i - \beta X_i}{\sigma}\right], \quad (4)$$

where $\Phi\left[\cdot\right]$ represents the cumulative density function of a standard normal distribution. Equation (4) can be used, along with an explicit specification for equation (2), to estimate the parameters of the willingness to pay function as well as the standard deviation, σ. An examination of equation (4) reveals that the maximum likelihood coefficient estimate for Bid_i is actually the reciprocal of the standard deviation of willingness to pay. This was a key insight of Cameron (1988). The coefficient estimates for the other parameters of the willingness to pay function are also confounded with the inverse of the standard deviation, and need to be adjusted in order to be interpreted correctly. In the next section, we discuss the results of maximum likelihood estimation of this model.

2. Results

The first step in estimation of the model is to specify the variables contained in equation (2). We assume that willingness to pay for the water quality improvement in Lake Michigan is a function of several variables that measure the extent to which the respondent uses the lake for recreation, the extent to which the respondent is concerned with the problem, and other sociodemographic variables. These variables are listed in Table 1 (see Appendix). The variable *Trips* represents the number of recreation trips that the respondent took to Lake Michigan in the past year. *ConcernJustified* is a variable that measures the extent to which the respondent believes that the concern about contaminants in Lake Michigan sediments is justified. *TourNavFish* is a variable designed to measure whether the respondent believes that a cleaner lake would generate more revenue from tourism, improve navigation in the Great Lakes, and/or increase opportunities for commercial fishing in the Great Lakes. *Gender*, *Age*, and *Income* are self-explanatory. The variable *QuestionOrder* was included to control for the fact that each survey included two separate valuation questions, which were randomized across respondents. We use only the data from the valuation question discussed above in this research. The final variable, *Sigma*, represents the standard error.

Table 1 contains the results of the estimation of equation (4) using maximum likelihood estimation. Five of the nine variables included in the estimation are statistically significant at the 95% confidence level. *TourNavFish* and *ConcernJustified*, both of which are designed to control for the respondent's attitudes toward the problem and its cleanup, have positive parameter estimates, although only *ConcernJustified* is statistically significant. As expected, the more concerned the respondent is over the problem, the more he is willing to pay to clean up the problem. In particular, concerned respondents are willing to pay $845 more than respondents who are not concerned. Likewise, willingness to pay is positively affected if the respondent is convinced that cleaning up the contaminated sediments will improve tourism, navigation, or commercial fishing. As expected, the parameter associated with the respondent's usage of the lake, *Trips*, is positive, though not statistically significant. The gender parameter estimate indicates that females are willing to pay $397 more than males. Age and income both have a positive impact on willingness to pay, though the income parameter is not statistically significant.

Applying maximum likelihood estimation techniques to estimate the parameters stated in equation (4) results in calculating a coefficient for the bid amount, Bid_i. As noted above, this coefficient represents the reciprocal of the standard deviation of willingness to pay. The literal interpretation of this coefficient is the sensitivity of the likelihood function to the bid amount. A statistically insignificant coefficient on the bid amount would be troubling as it suggests that the respondents are not sensitive to the bid amount. We have some validation for our survey and the bid amounts used as our estimated coefficient is statistically different from zero. This evidence suggests that the responses that we have observed are not the result of hypothetical bias, but rather that survey respondents were trading off the bid amount and disposable income when answering the valuation question.

Because the parameter estimate for sigma is statistically significant, we can form the bid function to calculate the average willingness to pay for the Lake Michigan cleanup. Table 1 indicates that average willingness to pay is $1,033, with a standard deviation of $597. Calculating a 95% confidence interval produces a range of $964-1102 for mean willingness to pay. According to the U.S. Census, there are approximately 4,860,368 households in the studied area. This leads to a value point estimate of aggregate willingness to pay of $5,020,760,144 and a 95% confidence interval of $4,685,707,652-5,355,812,636. The IJC estimates that the total cleanup cost is $2,400,000,000. On a per-household basis, with the average willingness to pay of $1,033 and the average cost per household in the region of $493.79, the welfare improvement for each household is estimated to be $540.21. Given these estimates, cleaning up contaminated sediments in Lake Michigan is clearly socially optimal.

Conclusions

The Great Lakes represent an important natural resource, providing drinking water, transportation, recreation and commercial opportunities. However, the lakes are currently at risk due to a number of negative environmental factors, including contaminated sediments. Decades of industrial pollution, sewer overflows and urban and agricultural runoff have lead to areas in which contaminants such as dioxin, arsenic and PCBs have become concentrated in sediments. These toxins are harmful to wildlife such as fish, water fowl and fish-eating birds as well as to humans.

Because of the risk associated with contaminated sediments, the governments of the U.S. and Canada have agreed to clean up these areas of concern. However, such cleanup programs are extremely costly, with costs of cleaning up individual areas in Lake Michigan ranging from $5 million to over $300 million. Although large polluters such as paper mills may be forced to pay some of these costs, they cannot be expected to bear the full cost, as they are not the only parties responsible for the pollution. As a result, public funds are needed to complete cleanup operations. It is, therefore, important to determine whether cleaning up contaminated sediments is an efficient use of public funds. Our results suggest that the lower bound of a 95% confidence interval on willingness to pay to clean up all areas of concern in Lake Michigan is almost twice the estimated cost. We conclude that funding a cleanup of sediments in Lake Michigan is economically efficient, providing the average household with a welfare improvement of $540.21.

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Appendix

Table 1. Parameter estimates

Parameter	Estimate	*t*-ratio
Intercept	-1377.36	-1.88*
Trips	151.40	0.82
ConcernJustified	845.56	2.50*
TourNavFish	2.45	1.95
Gender	397.22	1.85
Age	15.23	2.28*
Income	4.68	1.64
QuestionOrder	606.63	2.03*
Sigma	980.75	3.58*
Avg WTP	1032.85	
St. dev. WTP	596.84	

Note: * Significant at the 95% confidence level.

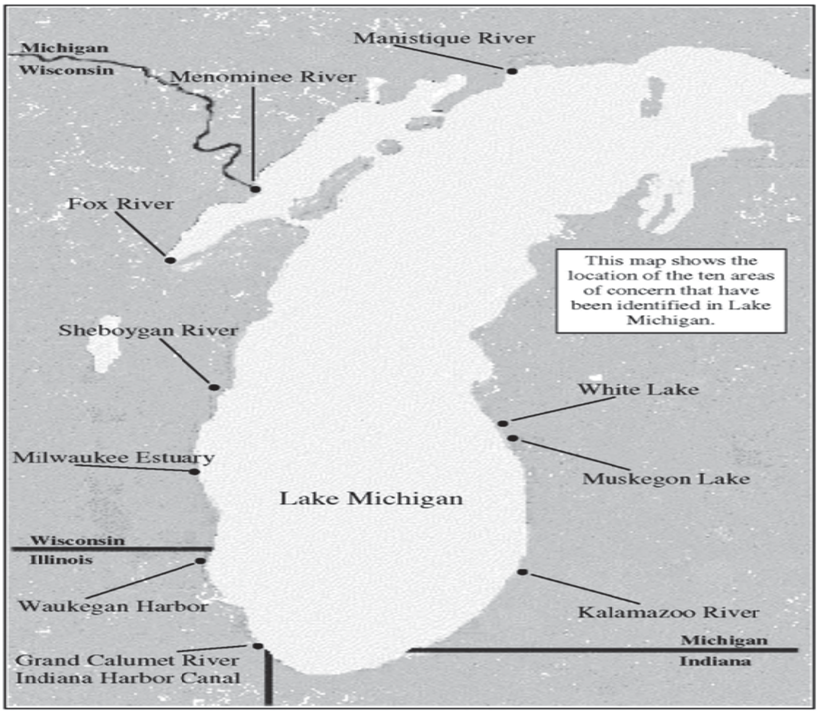

Fig. 1. Contingent valuation question

One objective of this study is to determine how valuable a cleaner Lake Michigan is to people in the region. In the next section, we will be asking you how you would vote on a special ballot regarding removal of contaminated sediments to improve water quality in Lake Michigan. While there is currenty no such ballot being implemented, the possibility is being considered. We would like you to respond *as if* you were actually voting on the referendum and, in each case, as if it were the only cleanup project available.

When you think about your answer, please keep in mind both the benefits of changes in water quality in Lake Michigan and the impact that passage of the referendum would have on your own pocketbook. Again, please answer as if this was a **real** referendum and it was the **only** project available.

Would you vote “yes” on a referendum that would create a Lake Michigan Clean-up Fund? This fund would be added to the money collected from corporations and used for cleanup of contaminated sediments in all areas of concern that have been indentified in Lake Michigan. Residents of the states bordering Lake Michigan will participate in the referendum. If passed, the referendum will result in a one-time increase in each household’s tax bill, with increase being based on household annual income. Suppose passage of the referendum would result in a one-time increase in your tax bill of $250 (payable in five $50 installments over a five year period). I would vote:

1. No
2. Yes.

To help us better understand your answer, please indicate the single most important reason for your response to the preceeding question:

1. In general, this project is *not* a good use of my money.
2. In general, this project *is* a good use of my money.
3. The plan is unclear or unrealistic.
4. I don’t believe that anything I have done has directly or indirectly damaged the lake.
5. I already contribute to environmental causes as much as I can.
6. No one should have the right to damage the lake in the first place.
7. Other.