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# **Valuing Groundwater Quality: Does Averting Behavior Matter?**

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## **Abstract**

Contingent valuation (CV) or defensive behavior data is often used to estimate the economic value of water quality. Although combining these data (i.e., stated and revealed preferences) mitigates the potential bias from using either type of information, the costs of collecting both could overwhelm the benefits. We attempt to find a convenient estimation method by using a proxy indicator for revealed preferences in the analysis of stated preference data. Specifically, this study explores the effect of individuals' reported defensive behavior on their stated preferences for groundwater quality. Logit models based on random utility theory were estimated using referendum CV data at household level collected in Maine, US. The results suggest that failure in accounting for defensive behavior in the valuation could result in a bias willingness to pay estimate for groundwater quality. We also found that the monetary value for groundwater quality was small, even though subsoil water constituted an important drinking water supply in the survey period. The results also revealed that respondents' averting behavior were mainly influenced by their perception of groundwater quality. Implications of our findings for welfare analysis are discussed.

**Key words:** contingent valuation, averting behavior, groundwater quality

**JEL Classification:** Q5, Q2, H23

## Introduction

Revealed Preference (RP) and Stated Preference (SP) methods are used to estimate the non-market value of environmental amenities including air and water quality. Estimates for the value of groundwater quality are mixed across studies and often depend on the chosen valuation method (Abdalla, 1994, Abdalla, et al., 1992, Stenger and Willinger, 1998). Averting defensive expenditures, an application of an indirect RP method, is used to approximate the cost of groundwater degradation (Abdalla, et al., 1992). The advantage of RP methods is that is based on actual behavior; however, they could suffer of omitted variable bias (Carson, et al., 1996). Alternatively, Contingent Valuation (CV), a direct stated preference method, can be used to elicit the respondents' willingness to pay (WTP) for hypothetical programs that improve the quality of groundwater. Nevertheless, these stated values are conditional upon the simulated scenario presented to the respondent (Portney, 1994). Even with this limitation, SP methods can allow to model the demand for new products and has favorable statistical properties (Mark and Swait, 2004).

To combine the realism of the RP data and the favorable statistical properties of the SP data, recent research pools revealed and stated preferences (Adamowicz, et al., 1994, Whitehead, 2005). Nevertheless, collecting both revealed and stated preferences data could be expensive and time consuming. Therefore, finding a convenient way to take into account revealed preferences information in the analysis of stated preferences data would make conclusions from SP data stronger.

There is much to learn with respect to the effect of averting behavior on environmental valuation in the analysis of stated preferences. Thus, the purpose of this study is to explore the effect of individuals' reported defensive behavior on their responses in the hypothetical referendum CV method and therefore their economic value for groundwater quality. About 23% of the freshwater used in the U.S. came from groundwater sources<sup>1</sup>.

The study specifically aims: (1) To assess the effect of peoples' perceptions of groundwater quality and their averting behavior (AB); and (2) to understand how their

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<sup>1</sup><http://water.usgs.gov/edu/qa-usage-gw.html>

defensive (i.e. averting) behavior relates to their value of preserving groundwater quality, which is the main contribution of our research.

To address these objectives, we use econometric models based on random utility theory and welfare analysis. Our findings show that (1) perceptions of groundwater quality affects individuals averting behavior, and (2) willingness to pay (WTP) estimates for groundwater quality are sensible to the inclusion of different measures for averting behavior. What is more important, failing to control for households' averting behavior could generate bias WTP estimates. These results add information to the literature related to methods for valuing environmental amenities and specifically associated to improve the estimation characteristics of stated preference methods for the valuation of water quality.

In the remainder of this paper, we first highlight critical literature focusing on the contrast of nonmarket valuation methods such as averting behavior and CV methods and provide a theoretical model that served as the basis for our empirical estimation. Then we present an overview of the survey, including the referendum CV question, and summarize the sample characteristics. Next we provide the empirical models to assess the value of groundwater quality and the factors that affect averting behavior and present the estimated results from the logit regressions. Finally, we end with conclusions and policy implications

## **Theoretical framework**

Revealed and Stated preference methods are non-market valuation techniques used to assess the value of environmental amenities. Revealed preference methods look for related markets in which the environmental good is implicitly traded. Information derived from observed behavior in these markets is used to determine the individual's valuation of the environmental resource. In contrast, stated preference methods have been developed to assess the value of those environmental resources that are not traded in any market (Birol, et al., 2006). The description and limitations of two non-market valuation methods that capture the value of water resources, is the subject of the following sections.

### ***Averting Behavior and Valuation of Water Quality***

Averting behavior (AB) is a revealed preference method that estimates the costs incurrent to avoid exposure to a contaminant (Abdalla, et al., 1992). However, RP techniques

are sensitive to the functional form used in the estimation and to the assumptions made in the model. Furthermore, RP methods could be subject to omitted variable bias (Carson, et al., 1996). Some important limitations of AB method are: a) individuals may take more than one form of defensive behavior in response to an environmental damage and b) averting expenditures does not measure all the costs related to pollution (Birol, et al., 2006).

In practice, AB valuation method calculates additional expenditures that would not be made if not faced with the environmental health risk. For example, the purchase of bottled water or water filters may only be made when faced with the risk of contaminated drinking water. Studies on valuation of water quality using defensive behavior methods have shown that households' knowledge of contamination, perception of risk, and presence of children affect their averting actions (Abdalla, et al., 1992, Poe and Bishop, 1999, Um, et al., 2002).

Based on Poe and Bishop (1999), we can define the model for defensive or averting behavior  $AB$  as follows:

$$AB = f(E(Q^0), K_{HLTH\ EFTS} | Z) \quad (1)$$

Where  $E(Q^0)$  is the perception of water quality (expected water quality) without program intervention;  $E(Q^0)$  is equal to  $Q^0$  when residents have perfect information about water quality without any program intervention.  $K_{HLTH\ EFTS}$  represents whether or not the respondent is aware of health effects caused by drinking water with contaminants.

### ***Contingent Valuation and Reported Averting Behavior***

Alternatively, the economic value of a change in groundwater quality can be estimated using Stated Preference (SP) methods such as Contingent Valuation (CV). The contingent valuation method is one of the most common approaches for valuing environmental quality and biodiversity (Hanemann, et al., 1991). An important reason is that the other valuation methods are unable to identify and measure passive or nonuse values of environmental amenities (Birol, et al., 2006, Nunes and van den Bergh, 2001). An additional advantage of this technique is that provides information on preferences that are otherwise impossible to disclose when actual choice behavior cannot be revealed (Commission, 2010). However, choice responses can be influenced by the design and implementation of the survey (Birol, et al., 2006, Boyle and Bishop, 1988). It is important to

note that CV estimates generally are lower than their revealed preference counterparts (Carson, et al., 1996), therefore providing conservative values for environmental amenities.

Combining revealed and stated preference information has some benefits in the estimation (Adamowicz, et al., 1994, Ben-Akiva, et al., 1994, Khattak, et al., 1996, Whitehead, et al., 2008). However, collecting both preferences could result time consuming and expensive, instead we use reported behavior with stated preference data. Specifically, we include reported defensive behavior information in the analysis of Dichotomous Choice Contingent Valuation (DC-CV) data.

A similar study by Bergstrom et al. (2001) explored the effects of subjective risk perceptions and preventing (averting) behavior on groundwater quality valuation using CV data. Different from this study, we control for perceptions about water quality using a measure that indicates whether the respondent believe or not that the program will at least maintain the quality of water (i.e. perceptions on the quality changes of water before and after the program intervention), while Bergstrom et al. used perceptions of the quality of water before the intervention. In addition, we evaluate the sensibility of the WTP estimates to different proxies for averting behavior.

### ***Theoretical model***

In order to estimate the value of groundwater we solve the household utility maximization problem as follows:

$$\max U = u(X, Q) \quad s. t. \quad P \cdot X = M \quad (2)$$

Where  $u$  is the household's utility function,  $X$  is a vector of market goods,  $P$  is a price vector of market goods,  $M$  is income, and  $Q$  is groundwater quality. Solving this optimization problem yields a set of conditional demand functions for the market goods  $x_i^*(P, Q, M)$ . Substituting  $x_i^*$  into the objective function provides us with the indirect utility function which can have two forms depending on whether or not the groundwater quality improve or at least has the same standards under a program intervention.

$$V^j = (P, Q^j, M^j | Z) \text{ where } \begin{cases} j = 1 \text{ with program} \\ j = 0 \text{ without program} \end{cases} \quad (3)$$

Where  $Z$  represents a vector of individual characteristics. Solving for income  $M^j$  from the indirect utility function, we obtain the following expenditure function:

$$M^j = e^{j*}(P, Q, u) \quad (4)$$

Assuming that individuals have rights on water quality without the protection program  $Q^0$ , and that with the program groundwater quality will improve from  $Q^0$  to  $Q^1$ , the income (expenditures) under the program implementation is defined as follows:

$$M^1 = M^0 - WTP \quad (5)$$

Solving for  $WTP$  and replacing income with the expenditure functions, we can determine  $WTP$  as follows:

$$WTP = e^{0*}(P, Q^0, u^0) - e^{1*}(P, Q^1, u^0), \quad Q^1 > Q^0 \quad (6)$$

In other words,  $WTP$  is the Compensating Surplus (CS) Hicksian economic welfare measure that represents the willingness to pay to increase or at least to maintain groundwater quality<sup>2</sup>. A graphical representation of CS measure is presented in figure 1, where  $WTP$  is shown to be the amount of money paid by the household to the government in order to implement the program. Thus, the household will receive higher quality of water and keep the same utility level  $u^0$  after the program implementation and the transfer of money (note that optimizing adjustments are not allowed). This definition can be mathematically represented as follows:

$$V(P, Q^1, M^0 - WTP|z) = V(P, Q^0, M^0|z) = u^0 \quad (7)$$

Thus, solving for  $WTP$ , we obtain the following function:

$$WTP = WTP(E(\Delta Q)|z, M) = WTP(E(Q^1 - Q^0)|z, M) \quad (8)$$

Where  $z$  represents the individual characteristics including averting behavior  $AB$  and perceptions  $PERC$ .  $E(\Delta Q)$  is the individual expectation of the change of groundwater quality as a result of the program implementation. This expected change depends on

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<sup>2</sup> Improvement or maintenance of ground water quality would be possible through a program that was explained to participants in a survey as follows: "The proposed program would protect and maintain a safe level of groundwater quality".

respondents' perception about the program effectiveness on improving or at least maintaining the level of groundwater quality in the future.

## **Empirical framework**

### ***Survey***

The study was conducted in Aroostook County, which is the largest county in Maine with an area of 6,671 square miles and a population of 71,870 habitants (US Census 2010)<sup>3</sup>. In 1995, groundwater constituted 83% of the drinking water supply; hence, efforts to protect subsoil water quality from chemical contamination are a relevant task for this county. Among the common potential sources of phreatic water pollution are: the use of fertilizers in agriculture, and human and animal sewage wastes, especially because of their high content of nitrates. The situation could become worse for the groundwater systems when sewage disposal and treatment systems are not properly implemented. Nitrate is the most common chemical contaminant in the worlds' groundwater aquifers (Spalding and Exner, 1991).

At the time of the survey, 87% of public and private groundwater met the federal safety standard of 10 milligrams of nitrate-nitrogen per liter ( $\text{NO}_3\text{-N}$  mg/L), which means that the remaining 13% of ground water supply had nitrate levels exceeding 10 mg/L. The health implications of nitrates in drinking water includes cancer (Ward, et al., 2005) and methemoglobinemia (known as blue baby syndrome) (Avery, 1999). Thus, a groundwater protection program was proposed for Aroostook County. The plan would maintain nitrate levels of groundwater at or below 10  $\text{NO}_3\text{-N}$  mg/L during 10 years if implemented. The willingness to pay of the habitants for the program was collected through a CV survey. Because drinking water supply is a relevant service of groundwater; assuming that the other conditions and services of groundwater quality are held constant, the CV questionnaire would manly capture its use value.

The mail survey was conducted from September 1996 to March 1997 (see Bergstrom, Boyle et al., 2001 for more details of the survey); a total of 1,050 households were randomly selected from a registered voter list directory of Aroostook County, Maine, US. The response

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<sup>3</sup> <http://quickfacts.census.gov/qfd/states/23/23003.html>

rate was approximately 53% of the total households selected. The survey questions were related to: (1) information on respondents' concerns and perceptions of water quality including averting behavior, (2) respondents' knowledge on the potential risk of contaminated water, (3) CV questions, and (4) respondents' characteristics.

The CV component of the survey contains a dichotomous-choice (DC) question similar to an election ballot questionnaire: it asked individuals whether or not they would support the protection program which would be sponsored by the habitants through the payment of a special tax to cover the program costs. Figure 2 shows the DC question presented to respondents. The values of the special tax used in this referendum question range from \$25 to \$500.

### ***Determinants of Averting Behavior***

In this section, we investigate the factors that affect averting behavior of the respondents to analyze whether or not this behavior is consistent with theory from previous literature, such as Poe and Bishop (1999), and therefore to evaluate whether or not reported AB is a valid indicator of respondents' revealed preferences. In addition, the model estimates allows us to better understand how AB affects CV responses in the next section. Based on equation 1, the AB model can be specified as follows:

$$AB_i = \alpha_0 + \alpha_1 SAFWAT_i + \alpha_2 K_{(HLTH\ EFTS)_i} + \alpha_3 I_{NITRAT_i} + \alpha_4 LEAKA_i + \alpha_5 LEAKC_i + Z_i' \gamma + u_i \quad (9)$$

where  $SAFWAT_i$  is the respondent's perceived water quality without program represent  $Q_i^0$ ,  $K_{(HLTH\ EFTS)_i}$  represents the level of knowledge about the health effects of contaminated water,  $I_{NITRAT_i}$  indicates whether the participant was aware of potential nitrate contamination of groundwater,  $LEAKA_i$  and  $LEAKC_i$  indicate the concern level (from 1 to 5) of water contamination from community sewage treatment plants and fertilizer leakage, respectively. The vector  $Z$  is a vector of socio-demographic variables such as respondent gender, age, presence of children under 12 years in the household, education, and household income; and  $u_i$  is the error term.

The following dependent variables are used as proxy for the averting behavior  $AB$ :  $I_{BUYWATER}$  (i.e., bought bottled water),  $I_{FILTER}$  (i.e., purchased filter to remove harmful

chemicals), *I<sub>BOILWAT</sub>* (i.e., boiled water), and *I<sub>SOFTNR</sub>* (i.e., installed a softener). Defensive behavior methods often use expenditures on bottles of water or water filters on water quality valuation (Abdalla, et al., 1992, Abrahams, et al., 2000). Because the measures for *AB* are binary variables, a logit model is used to estimate equation (14) (Greene and Hensher, 2010).

In terms of signs, it is expected for  $\alpha_1$  to have a negative sign, because an expected higher water quality would reduce averting behavior. The coefficients  $\alpha_2$  and  $\alpha_3$  are expected to be positive. The sign of  $\alpha_4$  and  $\alpha_5$  are ambiguous, although they are expected to be positive if the respondent believes that he or she can reduce the risk of drinking water with contaminants from fertilizer or sewage treatment plants leakages by taking action.

### ***Groundwater Quality Valuation***

The welfare analysis for referendum data can be computed as described in the Hanemann (1984) study. However, although this method is more widely used, it often requires a truncation point and does not allow for negative bids. In contrast, Cameron's approach allows for negative bids and direct computation of the WTP value. Likewise, it does not require integration as Hanemann (1984) approach. Therefore, this study uses Cameron (1988) approach:

$$P_i[Y_i = 1] = P_i[\text{true } WTP_i > Tax_i] = P_i[x_i\beta + \mu_i > Tax_i] = P_i\left[z_i > \frac{Tax_i - x_i\beta}{\sigma}\right] \quad (10)$$

Where  $P_i[Y_i = 1]$  is the probability that respondents choose yes to the referendum question,  $x_i\beta$  is the linear representation of estimated WTP, and  $z_i$  is the standardized error term of the model. Thus, following Cameron (1988), we estimated a logit model for the binary response  $Y_i$  as follows:

$$P_i[Y_i = 1] = \frac{1}{1 + e^{-x_i\beta}} \quad (1)$$

Because an individual's perceptions *PERC* and averting behavior *AB* are contained in the vector  $z$  of equation (2), the linear form  $x_i\beta$  can be specified as follows:

$$E(y_i) = x_i\beta = \beta_o + \beta_1 STAX_i + PERC_i'\gamma + AB_i'\theta + Z_i'\delta \quad (2)$$

Where  $i$  indicates the  $i^{\text{th}}$  respondent ( $i = 1, 2, \dots, n$ );  $STAX_i$  is the special tax in the DC question. The explanatory variables of interest are described as follows:  $PERC_i$  is a vector that represents the resident  $i$ 's perception of the effectiveness of the program in maintaining water quality, and  $AB_i$  indicates averting behavior of the respondent  $i$ . The control variables are represented by  $Z$ , which the vector of socio-demographic information as defined before. The vector of parameters corresponding to  $Z$  is represented by  $\delta$ . A more detailed description of the socio-demographic variables is presented in table 1.

Because Cameron's approach allows direct computation of the WTP, the average dollar value of consumer surplus ( $CS$ ) for an individual can be easily computed as follows:

$$CS = - \frac{\bar{x}_i \hat{\beta}}{\hat{\beta}_{LSTAX}} \quad (3)$$

Where  $\bar{x}_i$  is a vector of mean values of the explanatory variables, and  $\hat{\beta}$  is a vector of parameter estimates obtained from the logit regression in equation (9).

The expected sign of the coefficients of the explanatory variables of interest in equation (11) are as follows:  $\beta_1$  has an expected negative sign because of concavity of the utility function,  $\gamma$  is a parameter vector in which estimates are expected to have positive signs, the reason is that if respondents believe that water quality would maintain safety levels after the protection program, then they would place a higher economic value for the program,  $\theta$  is a vector of parameters predicted to be positive, because higher risk-averse individuals will be willing to pay more for a protection program that maintains safety levels of water quality. On the other hand, the signs of the coefficients corresponding to the respondent's socio-demographic information  $Z$  are unambiguous except for the coefficient of income which is expected to be positive.

Because including respondents who believed that the program should not be paid with a tax can underestimate WTP value, we exclude them from the estimation. Another potential issue is that assuming a linear relationship of the dependent variable with some of the explanatory variables might be wrong; therefore, we estimate a model with a logarithmic transformation of the income and the tax variables (11) following Bergstrom et al. (2004).

These transformations are also a convenient means of transforming a highly skewed variable in the sample (i.e., income variable) into one that is more approximately normal (figure 3).

All different model specifications include the vector  $Z$  that contain the control variables,  $LSTAX$  that is the log transformation of special tax, and  $I_{QIMPROV}$  to account for respondents' perception of the program effectiveness  $PERC$ .  $I_{QIMPROV}$ <sup>4</sup> indicates whether or not a participant believes the program will at least maintain water quality in the future.

#### *Full model*

The first model specification (equation 13), is as follows:

$$y_i = \beta_0 + \beta_1 LSTAX_i + \gamma_1 I_{QIMPROV_i} + ABconsistent'\theta + Z'\delta + u_i \quad (4)$$

where the vector  $ABconsistent$  contains all averting behavior variables that are consistent with theory of defensive expenditures and  $y_i$  is the yes/no response to the DC question that takes values 0 or 1,  $LSTAX$  is the log transformation of special tax, the vector  $Z$  contains demographic information including the log transformation of income  $LINCOME$ , and  $u_i$  is the error term.

#### *Reduced form model*

This model specifications is similar to the base model (equation 13), but we use only one indicator for averting behavior. The purpose to estimate a model with a single measure for averting behavior is to evaluate the consistency of the parameters and the WTP estimate.

#### *Simple model*

In order to check the consistency of the estimates when averting behavior is not incorporated in the analysis, the final specification estimates equation (13) without any proxy variable for AB.

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<sup>4</sup> Indicator variable that is 1 if the respondent believe that the program will at least maintain water quality in the future, and 0 otherwise.

### ***Sample Characteristics***

Table 1 shows the descriptive statistics of the respondent's socio-demographic information and the variables of interest used in the study. Overall, the average annual household income was \$27,122 in 1996. Because this variable is highly skewed to the left taking the logarithm transformation of income make this variable to look more normally distributed (Figure 3).

According to the survey responses, only 42% of the respondents believe that groundwater quality with the program would be at least as good as it is without the program. This high percentage of respondents who believe the program will not have great impact could drive down the WTP estimate. Therefore, we use an indicator variable in the model estimation to control for this characteristic of the data. Only 8% installed a filter to remove harmful chemicals, and only 11% buy bottled water because their concerns about contaminants in drinking water. These values indicate that if any concern of water safety exists, respondents do not take major action to address the potential risk of contaminated water.

### **Results and Discussion**

The models were estimated using the survey data of groundwater in Aroostook County, Maine, U.S. The results of empirical valuation model for averting behavior and for groundwater quality and are presented in table 2 and 3, respectively.

#### ***Determinants of Averting Behavior***

Table 2 shows the estimates for the averting behavior model specifications based on equation 13. We use a different proxy for defensive behavior:  $I_{FILTER}$  (column 1), and  $I_{BUYWAT}$  (column 2),  $I_{BOILWAT}$  (column 3), and  $I_{SOFNR}$  (column 4), as dependent variable in each of the four model specifications.

The perception of how safe was the water prior program  $SAFWAT$  was a statistically important variable and is negatively correlated with respondents' averting behavior related to purchasing bottled water or boiling water (columns 2 and 3). In addition, the presence of children under 12 years old in the household increases respondents' risk aversion, who choose to boil water as a preventing measure. Interestingly, according to the estimation

results, a higher concern of groundwater contamination by leakage from landfills and garbage dumps *LEACKA* intensifies averting behavior related to boiling water (column 3). However, there was not statistical significance concerning contamination by leakage from fertilizer use *LEACKC* across all model specifications. Checking for a possible correlation between *LEACKA* and *LEACKC*, we found their correlation is not high ( $\rho = 0.52$ ) and therefore collinearity should not be an issue. As a robustness check, we estimated the model in equation 14 without *LEACKC* and found similar results (See Table A1 in Appendix).

Overall, our results show that bottled water and boiled water are the only defensive behavior measures reported by the households in Aroostook County that are consistent with theory of averting expenditures (i.e., they respond to factors cited in previous research such as perceived water quality). Therefore, these reported measures can be reliable indicators for revealed preferences and can provide insightful information about the value of groundwater quality estimated in the next section using CV data.

### ***Groundwater Quality Valuation***

In this section, we evaluated if the program could be sponsored by the habitants of Aroostook County by assessing respondents' WTP for the program, which is calculated using the parameter estimates from the logit model specifications (table 3). All specifications use the CV response (1 if respondents accept to pay the special tax to cover the program costs, 0 otherwise) as the dependent variable. Models in columns 1 to 3 account for consistent individuals' averting behavior AB (i.e., boiled water, purchased bottled water), while models in columns 4 and 5 account for averting measures that were shown to be inconsistent with theory (i.e., installed filters, bought softener). Finally, model of column 6 does not include any indicator of AB.

According to our results, the special tax was significant and negative across all models which is consistent with the concave shape of our general utility function. This means that, on average, people decreases its inclination for the program when the tax becomes higher. Income was significant and positive for models in columns 1 and 3. This means that households with higher income level would place a higher value for the program (that would

keep safe levels of water quality) than lower income households, everything else hold constant.

The impact of purchasing bottled water  $I_{BUYWAT}$  on the support for the program is positive and statistically significant (column 2). This means that people that buy bottled water could be more concerned about nitrate contamination of groundwater and therefore they would be more inclined to pay the tax to support the program. On the other hand, the defensive measure boiled water  $I_{BOILWAT}$  is not statistically significant in the model. According to CDC (2015), heating or boiling water will not remove nitrate levels of water<sup>5</sup>. Therefore, one would expect that boiling water will not influence the respondents' decision to support the program that would maintain safe nitrate levels of water. Likewise, installing a filter  $I_{FILTER}$  or a softener  $I_{SOFTNR}$  was not statistically significant (columns 4 and 5). One reason that could explain the lack of statistical significance of these variables is that they were not consistent with theory (i.e., they were not related to perceptions of water quality) as it was discussed in the previous section. As a whole, the results provide support for the use of bottled water purchases  $I_{BUYWAT}$  in defensive behavior valuation methods for groundwater valuation. In contrast, the other actions undertaken to reduce any risk of contaminated water: installation of filter  $I_{FILTER}$ , installation of softener  $I_{SOFTNR}$ , boiling water  $I_{BOILWAT}$  did not show any statistical effect on the support of the protection program.

The mean WTP estimates for each model specifications were computed using equation 12. The results show that not accounting for averting behavior would not drastically affect the mean WTP under the model with logarithmic transformations of income and special tax variables. However, under the linear model, when averting behavior is omitted, the (negative) WTP estimate was much higher, yet no statistical differences were found (Table A2 in Appendix). Similarly, Bergstrom, et al. (2001) obtained negative WTP estimates when they used the same data with a linear specification. The negative WTP estimates under the linear model specifications apparently indicate that overall residents in Aroostook County do not favor the protection program. However, a non-trivial percentage of respondents (42%) accepted to pay the special tax in the CV question. Therefore, these

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<sup>5</sup> <http://www.cdc.gov/healthywater/drinking/private/wells/disease/nitrate.html>

negative estimates of WTP under linear model should be interpreted with caution. Furthermore, as discussed before the model specifications in table 3 with log transformations of skewed variables such as respondents' income are more appropriate in this case.

Even though there were not statistical differences of the mean WTP estimates across the model specifications in table 3. It appears that omitting information of defensive behavior in the analysis of stated preferences, would slightly increase the mean WTP estimate (i.e., WTP of column 6 is \$0.35 higher than WTP of column 1). Similarly, including reported averting behavior information that are not consistent with theory (i.e., *ISOFTNR* and *IFILTER* in columns 4 and 5, respectively) will affect the WTP value in a similar manner as omitting averting information (i.e. WTP of columns 4 and 5 are higher than WTP of columns 1, 2, and 3).

These results point out that including consistent individuals' characteristics of averting behavior in valuation analysis of water quality might be important. The implication of not including averting behavior or include inconsistent measures could cause upward bias estimates and overstate the economic benefits of a program. The estimated WTP when controlling for consistent averting behavior (columns 1, 2, and 3) at the mean values of the explanatory variables ranges from \$2.51 to \$2.77<sup>6</sup> per year during 10 years of program implementation which is much lower than the lowest annual special tax value presented in the DC question (\$25). Our mean WTP estimate for a 10-year protection program of groundwater quality in Maine is at least \$25 which is a little more than half of the value estimated by Bergstrom, et al. (2004) using pooled CV data of Maine and Georgia (i.e., which was \$48)<sup>7</sup>. Our estimated WTP indicates that a 10-year protection program was worth at least 0.1 % of the annual household income (before taxes) of 1995, which seems low considering that groundwater contributed 83% of drinking water supply at the survey period.

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<sup>6</sup> These are WTP estimates of 1997. In 2015 dollar values the WTP is \$3.77 and \$4.16, respectively.

<sup>7</sup> The value for a groundwater protection Georgia was higher than in Maine, making the pooled estimate of Georgia & Maine together higher.

## **Conclusions**

Defensive expenditures (or Averting Behavior AB) is a revealed preference method, used to estimate value of water quality by approximating the costs of water degradation. However, the estimates are dependent on the model assumptions made by the researcher. A more common valuation approach is Contingent Valuation (CV), a stated preference method that has better statistical properties than stated preference methods. Nevertheless, the CV estimates are sensible to the survey methodology. Ideally, one would like to combine CV and AB information to value water quality; however, collecting both preferences could be expensive. To find a convenient way to use both CV and AB information that provide robust results, this study uses reported averting behavior and evaluates how it affects the value of a protection program of groundwater quality using data from a Dichotomous Choice Contingent Valuation (DC-CV) method. The logit estimates revealed that people's averting measures related to boiling water and buying bottled water were mainly influenced by their perception of water quality. This study also found that bottled water purchases were the only measure of defensive behavior that influenced respondents' decision to support the protection program that would maintain or improve groundwater quality. More importantly, our results show that ignoring defensive measures or using inconsistent indicators of AB could overstate the economic benefits of a program. The last result corroborates previous evidence that averting costs estimates are sensible to model assumptions (i.e., in our study respondents' WTP was sensible to the chosen averting behavior indicator). Overall, our findings have implications on the selection of the valuation method and the corresponding model assumptions to estimate the welfare impact of a policy decision.

## **Limitations and Future Research Needs**

Although the study explores how CV estimates are dependent to the effect of alternative measures of averting behavior showing the sensibility of the estimates to researcher's assumptions when implementing averting behavior AB methods, this study did not directly compare estimates from CV and AB techniques because of data limitations. It would be important to compare the estimates obtained from averting expenditures such as expenditures on bottles of water (which were consistent measures in this study) with CV

estimates in Maine. In addition, because the survey was conducted in 1997, conditions and services of groundwater as well as individuals' preferences and perceptions have probably changed; therefore, estimates from this study should not be used in benefits-costs analysis for current policy evaluation. A new study using alternative stated preference methods such as choice experiments combined with reported behavior would allow a better understanding of preferences, and therefore provide deeper information for policy evaluation.

## Tables

Table 1. Means of explanatory variables used in the AB and DC question models

Variable		Mean	Standard Deviation
<u>Socio-Demographic Information</u>			
MALE	=1 if Male	0.64	0.48
HHAGE	Age (years)	39.48	17.08
I_UNDER12	=1 if children under 12 years old	0.03	0.17
EDU	Education Level	3.47	1.54
INCOME	Household Income level (\$)	27122	21710
<u>Averting Behavior Variables</u>			
IFILTER	=1 if installed a filter to remove harmful chemicals	0.08	0.27
IBUYWAT	=1 if buy bottled water	0.11	0.31
ISOFTNR	=1 if installed a softener	0.20	0.40
IBOILWAT	=1 if boil water	0.08	0.27
<u>Perception and Knowledge Variables</u>			
IQIMPROV	=1 if belief water would be at least as good as without 10-year program	0.42	0.49
SAFWAT	Perception of how safe is the water prior program (0-100)	74.65	25.51
INITRAT12	=1 if concerns of nitrate contamination of water	0.43	0.50
KHLTH_EFTS	Knowledge of the relationship of nitrates in drinking water and “blue baby syndrome” and cancer forms (0-2)	0.40	0.63
LEAKC	Concern level about groundwater contamination by leakage from fertilizer (1-5)	3.82	1.23
LEAKA	Concern level about ground water contamination by leakage from landfills and garbage dumps (1-5)	3.40	1.41

Table 2. Logit Estimates for Averting Behavior Model

VARIABLES	(1) I <sub>FILTER</sub>	(2) I <sub>BUYWAT</sub>	(3) I <sub>BOILWAT</sub>	(4) I <sub>SOFTNR</sub>
MALE	0.497 (0.728)	-0.337 (0.563)	0.525 (0.947)	1.214** (0.552)
HHAGE	0.0342* (0.0198)	0.00612 (0.0192)	-0.0212 (0.0302)	-0.00362 (0.0143)
I <sub>UNDER12</sub>		1.300 (1.217)	3.332** (1.650)	
EDU	0.312 (0.227)	-0.241 (0.223)	0.326 (0.337)	0.145 (0.155)
LINCOME	-0.128 (0.235)	0.376 (0.411)	-0.758 (0.627)	-0.0770 (0.194)
SAFWAT	-0.00263 (0.0111)	-0.0353*** (0.00906)	-0.0381** (0.0158)	-0.0126 (0.00903)
I <sub>NITRAT12</sub>	0.465 (0.618)	-0.343 (0.597)	-0.494 (0.890)	-0.210 (0.452)
K <sub>H<sub>L</sub>TH EFTS</sub>	-0.785 (0.583)	0.226 (0.424)	0.532 (0.557)	0.144 (0.345)
LEAKA	-0.0630 (0.245)	0.389 (0.242)	0.789* (0.435)	-0.00528 (0.165)
LEAKC	-0.0275 (0.262)	-0.120 (0.262)	-0.649 (0.443)	-0.0389 (0.193)
Constant	-3.579 (2.747)	-3.516 (3.380)	6.187 (5.311)	-0.569 (2.062)
Observations	178	183	140	153

Standard errors in parentheses \*\*\* p&lt;0.01, \*\* p&lt;0.05, \* p&lt;0.1

Table 3. Logit estimates for DC-CV response under different averting behavior measures.

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
LSPTAX	-0.556** (0.225)	-0.589*** (0.202)	-0.565** (0.223)	-0.601*** (0.200)	-0.544*** (0.205)	-0.591*** (0.199)
IBUYWAT	0.871 (0.613)	1.080** (0.509)				
IBoilWAT	-0.343 (0.912)		0.167 (0.806)			
IFILTER				0.677 (0.634)		
ISOFTNR					0.156 (0.439)	
IQIMPROV	0.0192 (0.445)	0.199 (0.387)	0.0645 (0.438)	0.242 (0.382)	0.190 (0.388)	0.309 (0.376)
MALE	-0.672 (0.482)	-0.119 (0.420)	-0.744 (0.474)	-0.257 (0.414)	-0.311 (0.426)	-0.207 (0.408)
HHAGE	-0.000233 (0.0150)	-0.00106 (0.0131)	0.00363 (0.0146)	-0.00112 (0.0131)	0.00273 (0.0134)	0.000806 (0.0128)
IUNDER12	0.0817 (1.299)	-0.414 (1.200)	0.0966 (1.287)	-0.0477 (1.187)	0.129 (1.230)	-0.184 (1.177)
EDU	-0.00574 (0.175)	0.0940 (0.151)	-0.0135 (0.173)	0.0335 (0.150)	0.0385 (0.146)	0.0580 (0.147)
LINCOME	0.608* (0.363)	0.234 (0.237)	0.603* (0.357)	0.261 (0.241)	0.113 (0.204)	0.245 (0.232)
Constant	-4.192 (3.492)	-1.079 (2.396)	-4.094 (3.444)	-0.887 (2.428)	0.367 (2.168)	-0.947 (2.358)
WTP (per year)	2.51	2.77	2.61	2.91	3.02	2.86
Observations	132	169	132	169	148	169

Standard errors in parentheses \*\*\* p&lt;0.01, \*\* p&lt;0.05, \* p&lt;0.1

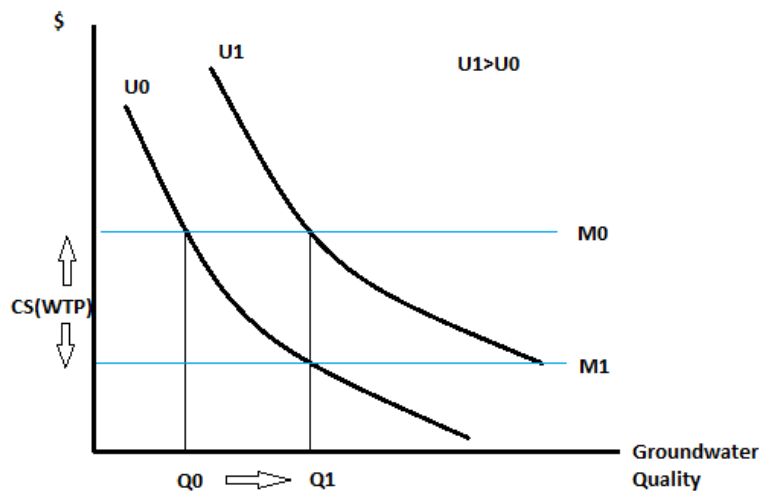


Figure 1. Compensating Surplus (CS) for Groundwater Quality Increase

*If the program of providing technical and financial assistance to individuals and groups interesting in protecting groundwater from potential nitrate contamination were place on the next election ballot, would you vote for the program if the special tax needed to fund the program cost your household \$ \_\_\_ per year for 10 years? (Circle on number)*

1 Yes

2 No

Figure 2. DC-CV question

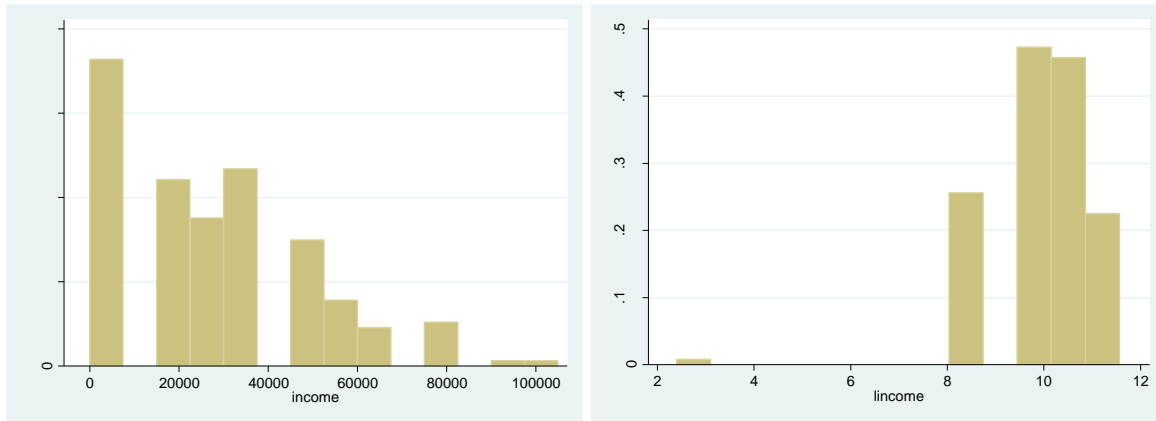


Figure 3. Histogram of income [left] and log (income) [right]

## Appendix

Table A1. Logit Estimates for Averting Behavior Model without LEAKC

VARIABLES	(1) IFILTER	(2) IBUYWAT	(3) IBOILWAT	(4) ISOFTNR
MALE	0.504 (0.724)	-0.297 (0.554)	1.003 (0.927)	1.229** (0.547)
HHAGE	0.0343* (0.0198)	0.00623 (0.0193)	-0.0171 (0.0307)	-0.00351 (0.0144)
IUNDER12		1.274 (1.207)	2.708* (1.482)	
EDU	0.310 (0.227)	-0.237 (0.222)	0.382 (0.348)	0.144 (0.155)
INCOME	-0.127 (0.234)	0.357 (0.404)	-0.857 (0.620)	-0.0739 (0.194)
SAFWAT	-0.00264 (0.0111)	-0.0359*** (0.00906)	-0.0424*** (0.0163)	-0.0126 (0.00902)
INITRAT12	0.465 (0.617)	-0.377 (0.591)	-0.645 (0.874)	-0.213 (0.452)
KHLTHEFTS	-0.794 (0.577)	0.200 (0.420)	0.411 (0.545)	0.133 (0.340)
LEAKA	-0.0727 (0.226)	0.319* (0.183)	0.397 (0.298)	-0.0169 (0.154)
Constant	-3.664 (2.629)	-3.509 (3.337)	5.967 (5.303)	-0.711 (1.938)
Observations	178	183	140	153

Table A2. Logit estimates for DC-CV response under different averting behavior measures  
(Linear Model)

VARIABLES	(1) y	(2) y	(3) y	(4) y	(5) y	(6) y
SPTAX	-0.00301** (0.00148)	-0.00334** (0.00134)	-0.00297** (0.00146)	-0.00341** (0.00135)	-0.00284** (0.00136)	-0.00326** (0.00133)
IBUYWAT	1.004* (0.589)	1.139** (0.494)				
IBoilWAT	-0.534 (0.848)		0.0204 (0.749)			
IFILTER				0.675 (0.623)		
ISOFTNR					0.0254 (0.422)	
Iqimprov	0.137 (0.413)	0.182 (0.365)	0.192 (0.405)	0.227 (0.361)	0.244 (0.364)	0.294 (0.354)
MALE	-0.360 (0.441)	-0.0860 (0.395)	-0.425 (0.434)	-0.192 (0.390)	-0.254 (0.399)	-0.152 (0.386)
HHAGE	-0.00293 (0.0137)	-0.00525 (0.0124)	0.00165 (0.0133)	-0.00419 (0.0123)	-0.00356 (0.0126)	-0.00248 (0.0121)
IUNDER12	-0.319 (1.221)	-0.680 (1.197)	-0.386 (1.211)	-0.377 (1.172)	-0.361 (1.190)	-0.511 (1.162)
EDU	0.0868 (0.158)	0.0295 (0.139)	0.0830 (0.155)	-0.0125 (0.138)	-0.0169 (0.139)	0.00801 (0.136)
INCOME	1.28e-05 (1.01e-05)	1.91e-05** (9.20e-06)	1.25e-05 (9.93e-06)	1.91e-05** (9.09e-06)	1.34e-05 (9.18e-06)	1.88e-05** (9.06e-06)
Constant	-0.952 (0.761)	-1.100* (0.656)	-0.993 (0.750)	-0.829 (0.662)	-0.524 (0.689)	-0.983 (0.646)
\$WTP (per year)	-182	-176	-176	-157	-161	-174
Observations	146	188	146	188	163	188

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