Essays on the Economics of Drinking Water Quality and Infrastructure

Eftila Tanellari

Dissertation submitted to the faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of

Doctor of Philosophy
In
Agricultural and Applied Economics

Darrell Bosch, Chair
Kevin Boyle
Bradford Mills
Christopher Parmeter
James Pease

April 29, 2010
Blacksburg, Virginia

Keywords: Willingness-To-Pay, Drinking Water Quality, Drinking Water Infrastructure, Averting Behavior

Essays on the Economics of Drinking Water Quality and Infrastructure

Eftila Tanellari

ABSTRACT

This dissertation consists of three essays that examine consumer behavior with respect to drinking water quality issues. The first essay uses contingent valuation method to explore consumers' willingness to pay (WTP) for a hypothetical material in home drinking water infrastructure that will remain leak free. Willingness to pay is investigated using both dichotomous choice and dichotomous choice with follow-up formats using a national telephone survey of consumers. Our results indicate that consumers' concerns about future system failures and income positively affect their WTP for an improved material while satisfaction with the water quality, education and the bid amount asked negatively affect their WTP for an improved material. There are no significant differences in the determinants of WTP between respondents who have experienced problems with home water infrastructure and respondents who have not. Furthermore, the estimated mean WTP does not change significantly between the dichotomous choice questioning format and the dichotomous choice with follow-up format

The second essay investigates the determinants of consumers' willingness to accept improvement programs for three drinking water issues: water quality, pinhole leaks in home plumbing infrastructure and aging public infrastructure. The research is based on a mail survey of consumers in Northern Virginia and the Maryland suburbs of Washington D.C. The analysis

focuses on the relationship between information, risk perceptions and willingness to pay. Results indicate that the choice to support any of the programs is negatively affected by the cost of the proposed improvement. Consumers' risk perceptions, the external information provided in the survey and whether they read the annual report from their water utility affect their choices for investment in improvement programs.

The third essay examines the effect of risk perceptions about tap water, general risk aversion and consumers' characteristics on their decision to avert drinking water risks and related expenditures. Results are based on the same survey data from the second study. The risk aversion measure is elicited using the sequence of questions employed in the National Panel Study of Income Dynamics. Results indicate that consumers' risk perceptions affect both the decision to avert and the amount spent on averting activities. However, we do not find a significant impact of risk aversion on averting behavior. In addition we find that respondents were more likely to use water treatments if they were unsatisfied with their tap water or had problems or concerns with water odor and particles.

AKNOWLEDGEMENTS

Looking back at the path leading to this degree, I realize that it would have not been possible without the support and encouragement of numerous people that stood beside me during this challenging but rewarding journey.

I am deeply grateful to Dr. Darrell Bosch, the chair of my advisory committee, and Dr. Kevin Boyle. Thank you for your guidance, mentoring and support throughout my graduate research studies.

Many thanks go to my committee members, Dr. Bradford Mills, Dr. Christopher Parmeter and Dr. James Pease who provided insights and constructive suggestions towards the completion of this dissertation and Marilyn Echols for her help and support. Special thanks go to my friends and colleagues Dr. Elton Mykerezi and Dr. Gentian Kostandini for their advice, suggestions and invaluable friendship.

I would like to thank AWWARF for funding the National Drinking Water Survey and NSF for funding and supporting my research under Grant No. 0329474. I would also like to thank Susan Willis-Walton, director of the Virginia Tech Center for Survey Research for her valuable help in designing and conducting the national drinking water survey.

Finally, many thanks go to my family and friends for their support and encouragement. In particular, I would like to thank my father, Jorgji, my brother, Kristi and my dear Davide for their continuous love and support. I am fortunate to have such remarkable and considerate people in my life.

TABLE OF CONTENTS

LIST OF TABLES

ESSAY 1

ESSAY 2

ESSAY 3

INTRODUCTION

Recently the failure rate of public and home infrastructure has increased dramatically resulting in water service interruptions, contamination, degraded water quality and property damages. The causes of such problems are the aging and deteriorating public infrastructure, pinhole leaks that are caused by copper corrosion as well as incidents of lead in the water, chloride leaching from pipes and contamination cases. These problems with the public water service have raised concern among consumers and policymakers as they threaten the safety and quality of drinking water. Consequently, there is a need for improvements and investments in the drinking water distribution systems. Such investments need to reflect the values that consumers place on improvements as well as their demand and support for public policy changes and protection plans to ensure safe drinking water as required by the Safe Drinking Water Act.

The first paper entitled “Willingness to Pay for Improvements in Home Drinking Water Infrastructure” focuses on the copper corrosion in home drinking water plumbing. The study estimates consumers’ willingness to pay for an improved piping material that will remain leak free and examines the determinants that affect their willingness to pay. The analysis is based on a national household survey in the US. Consumers’ willingness to pay was elicited using contingent valuation and utilizing two response formats: dichotomous choice and dichotomous choice with follow-up. The data is analyzed using a logistic regression in the case of dichotomous choice responses and a seemingly unrelated bivariate probit model in the case of the dichotomous choice with follow-up.

The second essay is entitled “On Consumers' Attitudes and Willingness to Pay for Improved Drinking Water Quality and Infrastructure.” The objective of this paper is to examine the determinants that affect consumers' behavior and willingness to pay for improved water quality and related infrastructure. More specifically, we evaluate consumers' support for three improvement programs, a water quality improvement program, a pinhole leak damage insurance program and a water utility infrastructure upgrade program. In addition, the effect of the information and consumers' perceptions on willingness to pay is explored. The analysis is based on a mail survey send to 5,200 households in the Northern Virginia and Maryland suburbs of Washington DC. The data is analyzed using a multinomial logit model where probability of each program being chosen is evaluated against the choice of no program at all.

The third essay is entitled "Risk Measures and Averting Behavior for Drinking Water Quality." This study examines the effects of consumers' risk perceptions about the quality of tap water, experiences and their characteristics on treatment decisions and expenditures using the same data source as the second essay. We consider averting choices consumers make in terms of bottled water and treatment devices for ensuring the safety of their drinking water. In addition, the analysis accounts for two types of risk measures, perceived risk regarding tap water and a general risk aversion measure as used in the U.S. Panel Study of Income Dynamics (PSID). Consumers' expenditures on treatment methods are modeled using a Heckman selection framework where the decision to avert is modeled first and then the expenditures are analyzed conditional on this choice.

Essay 1

Willingness to Pay for Improvements in Home Drinking Water Infrastructure

Introduction

In recent years there have been an increasing number of reported leaks in copper drinking water pipes in the United States due to corrosion. These leaks, called pinhole leaks, appear as small holes in pipes and are mainly caused by copper corrosion. They affect the drinking water supply in private residences and commercial properties resulting in loss of potable water resource, high costs to repair and replace degraded pipes and potential damage to private property and personal valuables. Leaks may go undetected for some time if they occur in the walls or basement causing further damage. Direct damages to private property due to leaks are estimated to range from $600 to $30,000 per residence (Scardina et al., 2008). Potential health and environmental issues have attracted significant regulatory attention. Health problems include allergic reactions such as irritation of eyes, skin, nose, throat and lungs related to mold and mildew exposures as well as diseases such as asthma and gastrointestinal upsets. Other problems resulting from leaks include discolored water, tastes, odors and water damage costs. The interaction of water-related physical and chemical parameters is the cause of corrosion problems in most cases (Edwards et al., 1994; Schock, 1999; Farooqi et al., 2008). Differences in water chemistry and elements in the water over the US may explain why some areas of the country have much higher reported rates of leaks. A national survey of homeowners in 2006 revealed that on average 11 percent of respondents reported problems with rates as high as 23 percent in some areas (Scardina et al., 2008).

The recent outbreaks of pinhole leaks in consumers' plumbing systems have drawn the attention of authorities to take the necessary action to protect the existing investment in plumbing materials. Local environmental agencies, water utilities and the EPA are taking measures to address public concerns about environmental and drinking water problems. In order to establish effective policies and regulations, it is important that environmental agencies, policymakers and water utilities have information on consumer demand for alternatives to reduce corrosion. In particular, these agencies and policymakers need to know how the pinhole leak problem is perceived by consumers and their willingness to pay for alternative solutions. While research in the area of pinhole leaks has focused on its causes, less research has been conducted to determine how such information would be used in the household decision process regarding solutions to pinhole leaks, and what factors shape consumers' willingness to pay (WTP) for improved home drinking water infrastructure. Prior empirical studies that assess water quality and improvements in water quality have focused on ground water quality and drinking water supply (Mitchell and Carson, 1981; Desvousges et al., 1987; Jordan and Elnagheeb, 1993; Powell et al., 1994; and Poe and Bishop, 1999). Little is known about consumer willingness to pay for potential solutions to problems of drinking water infrastructure and the associated health risks. There is a need for research on improvements in private infrastructure and the value that consumers place on reducing or avoiding pinhole leak incidents in the future. Policy makers' understanding of the public's knowledge and support on this issue can assist them in formulating policies affecting water infrastructure and public health. The estimated WTP values will assist in establishing policy actions that will benefit consumers by improving or protecting private infrastructure nationwide. Corrosion in public infrastructure exposes consumers to similar risks, thus the results may provide insights in the determinants of willingness to pay for public drinking water infrastructure improvements including water storage, treatment and conveyance.

We report results of a study that elicits consumer preferences for improved drinking water infrastructure in their homes. The study is part of an interdisciplinary study concerning copper corrosion in home drinking water plumbing (Dietrich et al., 2003). Survey results shed light on how respondents perceive the problem of corrosion, estimate how much they are willing to pay for improved materials and infrastructure and examine the factors that influence the willingness to pay. In addition, we report WTP estimates from two questioning formats, dichotomous choice contingent valuation (DC) and dichotomous choice with follow-up (DCF). Several studies (Hanemann et al., 1991; Herriges and Shrogren, 1996; Cameron and Quiggin, 1994; Kanninen, 1995; McFadden and Leonard, 1993) have examined the statistical properties of the estimators and the estimates from DC and DCF questions. Hanemann, et al. (1991) proved that the follow-up question in dichotomous choice contingent valuation increases the asymptotic efficiency[1] of the model. The DCF method generates estimates with narrower confidence intervals around the mean or median WTP. Although dichotomous choice with follow-up estimates are more efficient, it is still unclear whether point estimates are less biased when compared to the single question format. Hanemann et al. (1991) argue that the follow-up question improves the choice of the initial bid therefore resulting in less biased estimators. However, the follow-up questions may introduce bias in value estimates due the anchoring effect[2]. There is no conclusive finding that either questioning format is preferred to the other. Furthermore, Hanemann et al. (1991), Herriges and Shrogren (1996) and McFadden and Leonard

[1] The limit of the estimator's efficiency as the sample size grows.

[2] Propensity to accept higher or lower bid amounts than the true WTP value. It usually occurs when respondents interpret bids as indicators of quality or value.

(1993) show that the central tendency measures of WTP using DC and DCF can be quite different. Consequently, we use both methods in estimating WTP to account for any discrepancies or added insight brought by the follow-up questions.

The rest of the paper is organized as follows. Section two provides a description of the conceptual framework. The data and the survey design are described in section three. An overview of the models is presented in section four and the results and conclusions are discussed in section five.

Conceptual Framework

This study uses contingent valuation to elicit respondents' willingness to pay to improve home drinking water infrastructure and ensure that it will remain leak free for a period of 50 years. Contingent valuation, a survey-based method, is used to elicit values that people place on environmental and recreational goods and services when markets are missing (Boyle, 2003). According to the NOAA Panel (1993) contingent valuation can be a useful technique in providing estimates for Hicksian surplus to inform policymakers (Boyle, 2003) and is a reliable method in estimating non-use values, that is, values people place on goods for reasons other than direct use or purchase (Mitchell and Carson, 1989). In fact, contingent valuation is the only method that considers non-use values in an economic analysis such as altruistic, bequest or existence values (Mitchell and Carson, 1989). Applications of contingent valuation are extensive in the literature with a significant contribution made from Cummings, Brookshire, and Schultze (1986), Mitchell and Carson (1989) and the NOAA panel report (1993).

An important component of a contingent valuation study is the choice of the response format to elicit WTP. The primary questioning formats for contingent valuation questions are open-ended, payment card and dichotomous choice. Open-ended questions have been used since the early applications of contingent valuation (Alberini and Cooper, 2000). This method asks respondents how much they would be willing to pay for an improvement in an environmental good. Although this format has persisted, it is argued that respondents have difficulty in answering as they find it hard to come up with specific dollar amounts for the value of a good. However, this format has the desirable feature that it yields continuous values thus increasing statistical efficiency and avoiding anchoring on bid amounts.

In the payment card format, respondents are presented with a range of values and are asked to choose the highest value they are willing to pay for the change in the environmental good. Their true WTP then lies in the interval between the chosen value and the next highest bid. Payment card questions are easier for respondents compared to the open-ended format as they can choose among a given set of values. Although payment cards avoid the starting point bias, there should be careful consideration when choosing the bid design as it might affect welfare estimates (Boyle, 2003).

Dichotomous choice questions ask respondents to answer yes or no to whether they are willing to pay $X for a good or service. X, the bid amount, is randomly varied over different respondents to avoid starting point bias. The method imitates real markets where consumers see the price offered for a good and either purchase the good or not (Mitchell and Carson, 1989). Since respondents are faced with a familiar scenario, the response rate is generally improved and response distortions are minimized compared to other question formats. Although it is an easy to answer method for respondents, dichotomous choice format does not allow direct observations of willingness to pay. Instead, the format provides an estimate of whether a respondent's willingness to pay is greater or less than the bid amount. Potential problems with dichotomous choice questions are anchoring and yeah-saying. Anchoring is the respondents' propensity to accept higher or lower bid amounts than their true WTP value because they gravitate toward or 'anchor' on an initial value that is suggested to them (Boyle, 2003). Anchoring can cause bias in value estimates. The bias can be negative or positive based on whether the initial bids are low or high, respectively. Yeah–saying is the respondents' propensity to answer yes to any bid amount presented to them (Boyle, 2003). Respondents tend to answer "yes" to any bid amount, in which case, their bids may not signal quality or value for the good in question. The result is positively biased estimates of WTP values. The discrete nature of the dichotomous choice questioning format can cause reduced statistical efficiency therefore increasing the variance of estimates and the need for large sample sizes. This is because dichotomous choice questions collect less information from each respondent compared to the open-ended format and elicit information only on whether WTP lies above or below the bid value instead of an actual WTP value. Although dichotomous choice is not short of criticism, it has become a common method in contingent valuation studies considering the recommendations received by the NOAA panel report (NOAA, 1993).

Dichotomous choice questions with follow-up are a variation of dichotomous choice format where respondents are asked a second question. Respondents receive a second round of bids in which they are asked whether they would pay a higher or lower amount depending on their answer to the initial bid. Adding a follow-up question may improve the efficiency of the welfare estimates since the additional information obtained may yield more precise estimates (Hanemann et al., 1991). However, the additional question may introduce response bias due to the anchoring effect where consumers may make adjustments based on the additional information provided (Greene et al., 1998). In this study both the original dichotomous choice

(DC) and the dichotomous choice with follow-up (DCF) responses are utilized to estimate WTP values.

Data and Survey Design

The analysis in this study was based on a national household survey in the US conducted in November 2006. The survey was intended to collect data on households' perceptions and experiences related to corrosion and their willingness to pay to prevent pinhole leaks in the future. Surveys were conducted via telephone by the Virginia Tech Center for Survey Research (CSR). A random-digit dialing was employed for the administration of the survey. In addition, the sampling design entailed a stratified sampling component in which certain areas identified to have pinhole leaks were over-sampled. Respondents were screened based on whether they currently owned or were purchasing a home and whether the home was a detached, single family residence. Screening was done because homeowners of single family residences were estimated to be more likely to have knowledge regarding their residential drinking water pipes and therefore occurrence of leaks. Calls were made and completed to 327 randomly selected households (109 calls in each area) in a Midwest county, a Southeast county and a multi-county area in the West. These areas were identified as being among the most problematic areas according to a survey of experts familiar with pinhole leak problems in the United States (Scardina et al., 2008). In addition, 453 calls were completed for households in the rest of the United States. The response rate for the survey was 28 percent excluding the ineligible pool of sample members. Specifically, 85 usable responses were obtained from the Southeast county, 87 from the Midwest county, 92 from the multi-county area in the West and 358 from the rest of the United States.

Consumers' willingness to pay was elicited by asking the following contingent valuation question:

> *If you had to replace all the plumbing in your home, would you be willing to pay more for a pipe material that would remain leak free for the next 50 years? Would you be willing to pay X dollars to ensure the material would remain leak free?*

where X was randomly selected from $500, $600, $700, $800, $1,200, $2,000 and $4,000[3], to avoid starting point bias. Depending on the answers to the initial offer, the next lower or higher value was asked of all respondents. The set of answers to the first WTP question constitute the DC responses and answers to both the first and the second WTP question constitute the DCF responses. It is assumed that the willingness to pay of respondent is zero if the answer to the WTP question was negative for the lowest cost amount of $500. Other questions in the survey collected information regarding consumer perceptions of their drinking water and corrosion issues, experiences with pinhole leaks and concerns about corrosion problems in the future. The survey also collected a variety of socioeconomic characteristics of the respondents such as income, gender, education and age. Multivariate models are then estimated to relate WTP to a number of covariates of interest that may be related to willingness to pay. These covariates include the respondents' number of years at the current residence, satisfaction with their water quality, source of water at residence and concerns about leaks in the future.

Descriptive statistics for the threshold values asked in the contingent valuation question as well as a summary of the responses from the consumers are presented in table 1. The average threshold value for the first question, that is the first suggested payment for leak-free plumbing, is $1,372. The average threshold value for the second question, the follow-up suggested payment

[3] These amounts are based on costs incurred by consumers to fix corrosion problems as well as damages to private property. The cost estimates are obtained from Scardina et al. (2008).

after the first response, is \$1,156. The average threshold value for the second question is lower than the value of the first question due to more negative responses to the initial offer than positive responses, resulting in a lower bid offer for the follow-up question. The standard deviation is lower when the second question is asked compared to just the first question. This indicates a narrower confidence interval around mean WTP and improved efficiency of WTP estimate. I_i is an indicator variable that takes values of 1 if the respondent agrees to the suggested payment and 0 otherwise. The means of I_1 and I_2 represent the proportion of the sample with a positive response to the initial and follow-up questions, respectively. From the sample, 22.8 percent accepted both the first and the follow-up suggested payments, 23.1 percent accepted the first but not the follow-up, 7.3 percent did not accept the initial but accepted the follow-up payment and 46.7 percent did not accept either payment. Distributions of willingness to pay are presented in table 2.

WTP is specified as a function of the payment offer (EXOG_BID), household income (INCOME), gender (MALE), education (EDUCATION), age (AGE), concern of developing leaks in the future (CONCERN), satisfaction with water quality (SATISFACTION), number of years that respondent has been living at the current residence (YEARS_RESIDENCE) and source of water, utility or well (UTILITY_WATER). Descriptive statistics for the variables are presented in table 3. The average annual household income in the sample is slightly over \$68 thousand. The sample consists of 40.9 percent male respondents. On average respondents were 55 years of age and had 14.5 years of schooling. Seventeen percent of respondents were concerned about corrosion problems in the future while 84 percent of them were satisfied with the quality of their tap water. Respondents have been living at the current residence for an average of almost 15 years. Seventy-nine percent of respondents get their water from a water utility, the rest use or have private wells.

Among the socioeconomic variables used in the analysis, income was the one with the most missing observations with 156 missing values. In order to increase the number of completed observations, we imputed income by regressing it on education, age, gender and race. The imputed values were inserted for the missing values. Considering the imputed income values and discarding observations with missing values for non-income variables, 622 completed observations were utilized in the analysis of this paper. More specifically, 85 completed observations were utilized from the Southeast county, 87 from the Midwest county, 92 from the multi-county area in the West and 358 from the rest of the United States.

Estimating Willingness to Pay

For a nonmarket good, willingness to pay represents the dollar amount that the respondent is willing to give up in exchange for the good in order to remain indifferent. The j^{th} respondent's true willingness to pay is expressed as:

$$WTP_j = X_j\beta + \varepsilon_j \quad (1)$$

where WTP_j is the true latent willingness to pay of the jth respondent, X_j is a vector of observed explanatory variables, β is a vector of parameters and ε_j is the error term that contains all the unobserved determinants of WTP. Equation 1 is a latent regression because the values of WTP cannot be directly observed and the regression cannot be estimated as it stands. However, we can observe different levels associated with willingness to pay and represent them by using an indicator variable I, which takes values of one if the answer to the contingent valuation is positive and zero otherwise.

In the case of the dichotomous choice format, we adopt the censored econometric model proposed by Cameron (1988), which allows for the direct estimation of parameters and the standard errors of WTP. The observed WTP can take the following values depending on whether the answer to the contingent valuation question is "yes" or "no":

(2)

$$\text{WTP} \geq t_j \qquad \text{if the response is yes } (I_j = 1)$$

$$\text{WTP} < t_j \qquad \text{if the response is no } (I_j = 0)$$

where t_j is the bid offer for respondent j. For a given sample of observations, the log likelihood function takes the following form:

(3)

$$\log L = \sum_j (1 - I_j)\left[\left(t_j - x_j\beta\right)/k\right] - log\left\{1 + exp\left[\left(t_j - x_j\beta\right)/k\right]\right\}$$

Maximization of the above log likelihood function allows for the identification of κ and β separately due to the presence of the bid amount t_j (see Cameron, 1988).

For the dichotomous choice with follow-up question, there are four possible answers for the valuation questions which bound respondents' WTP in one of the following categories:

(4)

$$t_{1j} \leq \text{WTP} < t_{2j} \qquad \text{if the response is yes-no } (I_{1j} = 1, I_{2j} = 0)$$

$$t_{1j} > \text{WTP} \geq t_{2j} \qquad \text{if the response is no-yes } (I_{1j} = 0, I_{2j} = 1)$$

$$\text{WTP} \geq t_{2j} \qquad \text{if the response is yes-yes } (I_{1j} = 1, I_{2j} = 1)$$

$$\text{WTP} < t_{2j} \qquad \text{if the response is no-no } (I_{1j} = 0, I_{2j} = 0)$$

where t_{1j} is the first bid offer and t_{2j} is the second bid offer for each respondent. Since the probability that a respondent will receive a lower (higher) bid in the second question is equal to the probability of him/her responding "no" ("yes") to the first bid value, it is clear that the second question is endogenous and depends on the information revealed from the answer to the first question. To correct for this endogeneity, Cameron and Quiggin (1994) suggest the use of simultaneous equation systems. The dependent variables in the system of equations are discrete and represented by the indicator variable *I* which takes values as shown in equation 4. Normality is preferred in estimating the joint distribution of discrete variables since the bivariate normal distributions are the most familiar and have well-understood properties. Additionally, the bivariate normal distribution is preferred because it allows for non-zero correlation unlike the logistic distribution (Cameron and Quiggin, 1994). Using equation 1 and 4 the probability that a respondent will answer yes – no is given by:

$$\Pr(yes, no) = \Pr\left(WTP_{1j} \geq t_{1j}, WTP_{2j} < t_{2j}\right) = Pr\left(\frac{\varepsilon_{1j}}{\sigma_{1j}} \geq \frac{(t_{1j} - x_{1j}\beta}{\sigma_{1j}}, \frac{\varepsilon_{2j}}{\sigma_{2j}} < \frac{(t_{2j} - x_{2j}\beta}{\sigma_{2j}}\right) \tag{5}$$

The other combination of responses (yes-yes, no-yes and no-no) can be formulated in a similar way. Following Cameron and Quiggin (1994) the log-likelihood function for the DCF format takes the form:

(6)

$$\log L = \sum_i \Big\{ (I_1 I_2) log \left[\int_{(t_1 - X'_1\beta_1)/\sigma_1}^{\infty} \int_{(t_2 - X'_2\beta_2)/\sigma_2}^{\infty} g(z_1, z_2) dz_2 dz_1 \right]$$

$$+ (1 - I_1)(I_2) log \left[\int_{-\infty}^{(t_1 - X'_1\beta_1)/\sigma_1} \int_{(t_2 - X'_2\beta_2)/\sigma_2}^{\infty} g(z_1, z_2) dz_2 dz_1 \right]$$

$$+ (1 - I_1)(1 - I_2) log \left[\int_{-\infty}^{(t_1 - X'_1\beta_1)/\sigma_1} \int_{-\infty}^{(t_2 - X'_2\beta_2)/\sigma_2} g(z_1, z_2) dz_2 dz_1 \right]$$

$$+ (I_1)(1 - I_2) log \left[\int_{(t_1 - X'_1\beta_1)/\sigma_1}^{\infty} \int_{-\infty}^{(t_2 - X'_2\beta_2)/\sigma_2} g(z_1, z_2) dz_2 dz_1 \right] \Big\}$$

The parameters to be estimated from the maximization of the log likelihood function are β_1, β_2, σ_1, σ_2, and ρ where β_1 and β_2 are the regression coefficients, σ_1 and σ_2 are the dispersion parameters and ρ is the correlation coefficient of the error terms.

Empirical Results

Estimation results are presented in table 4. Marginal effects measure the impact that changes to exogenous variables would have on the probability that the respondent answers "yes" to the DC question and "yes" to both WTP questions in the DCF format (or $I_1 = 1$and $I_2 = 1$; see table 1). Consumers concerned about having pipe failures in the future (CONCERN) were more willing to pay for improvements in pipe materials. Also, consumers who were satisfied with their water quality (SATISFACTION) were less likely to be willing to pay the amount they were asked. The coefficient on income is positive ($p=0.05$) indicating that willingness to pay increases with income. Younger respondents were more willing to pay for improvements in pipe material in the DC model while older respondents were more willing to pay in the DCF model. A negative relationship with age was also found by Hamilton (1985) who studied public attitudes towards water contamination. Education is also an important factor in explaining WTP, with more educated consumers showing decreased willingness to pay for the suggested improvements.

The coefficient of exogenous threshold (the random bid amount asked) is negative and significant for both the DC and DCF indicating that not varying the bid amount randomly in the survey would lead to starting point bias. Respondents were more willing to pay for the proposed improvements as the amount of the initial bid decreased. The coefficients on gender, years living in that residence and source of water were not significant. ρ, the correlation coefficient of the error terms, is different from zero indicating that the error terms are positively correlated and the information revealed by the answer to the second bid offer depends on the answer to the first bid offer. Therefore, the bivariate probability model is the appropriate model for the data.

Two estimates of willingness to pay are presented; the mean WTP and the conditional mean WTP (table 5). The mean WTP is simply the sample mean of the stated willingness to pay amount. The conditional mean is the expected WTP conditional on the fact that respondents' true WTP lies between the amount they were willing to pay and the next higher bid value. Respondents' mean willingness to pay was about four hundred dollars when the analysis was limited to just their first response (DC) and $536 when respondents' answers to the initial and the follow-up questions were considered (DCF). This difference may be due to the systematic bias in responses because of the introduction of a follow-up question in DCF where the second question increases the likelihood that respondents will engage in yeah-saying. However, the conditional and the unconditional means are similar for both the DC and the DCF questioning formats because the differences between these estimates are not significant.

Additional Specifications and Robustness

It is possible that the determinants of the willingness to pay might differ between respondents who had experienced leaks and some subsequent financial and emotional costs and respondents who had not. Thus, we ran two separate regressions, one for respondents who had experienced leaks and one for respondents who had not. Results showed no significant differences in the determinants of consumers' willingness to pay.

Respondents in our sample received their water either from water utilities or private wells. Given that the sources of water are different from one another, the water quality and its properties might also differ among these sources. Furthermore, the preferences of households whose primary water source is not the local utility company, but rather a private well, may be substantially different from respondents who get their water from a utility company. As a result, respondents' WTP as well as the determinants of their WTP might be different depending on the source of water and therefore deserve separate treatment. We present additional specifications of the multivariate models that only focus on households whose water comes from the local utility. Results presented in table 6 indicate that estimates do not change when well water users are excluded from the analysis (compared to table 4). This result may be due to the small proportion of respondents that gets their water from private wells, a total of 130 respondents. Models that only use the subset of households that have private wells indicate that the WTP is not affected by education, income or the bid amount.

Additionally, we also present results that focus primarily on the subsample of households living in the most problematic areas according to number of leaks (also referred to as hotspot areas) located in the Midwest County, the Southeast County and the multi-county area in the

West (table 7). These models indicate that both the mean and the conditional WTP are higher for the hotspot areas when the dichotomous choice format is used. In the overall model, previous experience with leaks did not affect willingness to pay for improvements while being in a hotspot area does affect results. Perhaps, being in a hotspot area exposes consumers to more media coverage about the problem which may affect their willingness to pay. In contrast to the rest of the US, WTP of respondents located in these problematic areas is not affected by their education level, satisfaction with their water quality and the number of years they have been living in the current residence.

Finally, to test the sensitivity of the results to outliers and inconsistent answers we excluded outliers as suggested by Mitchell and Carson (1989). The authors considered as outliers responses of WTP that exceeded 10 percent of respondents' income. Results indicate no significant changes in estimates of WTP and its determinants, suggesting that the findings are robust to the existence of outliers.

Conclusions

Results show that the determinants of willingness to pay for improved home drinking water infrastructure include income, education, age of respondent, concerns for leaks in the future and satisfaction with water quality. There are no significant differences in the determinants of consumers' willingness to pay for respondents who had experienced leaks and the ones who had not. We also find evidence that the initial bid amount is negatively related with the stated WTP, therefore it is important to carefully choose an optimal bid design to avoid biased results. The conditional and unconditional means of WTP reported from the DC format are not significantly different from the respective means using the DCF format.

Economists will find results interesting as the study represents an extension of willingness to pay methods beyond conventional environmental and resource economics applications. The results are of interest to firms providing plumbing materials and services as they indicate potential consumer demand for product improvements. Consumers are willing to pay about $400 for a pipe material that would remain leak free in the next 50 years. This figure constitutes 45 percent of the cost of materials needed for a complete replumbing of an average size house using copper pipes, according to a 2006 national telephone survey to plumbers. Results are also important in deciding whether new policies and programs are needed to ensure that drinking water fulfills requirements under the Safe Drinking Water Act and protect public health. Estimated WTP is a good measurement of benefits to consumers from improvements in water infrastructure. In addition, estimates can be used to predict whether certain water policies and protection plans will be accepted by the public or evaluate if public officials are investing accordingly in drinking water protection plans. Policymakers and water utility managers may use information on private demand for improved water quality and reduced health hazards to infer such demand for public projects. Our findings suggest that efforts should be made to find the causes of pinhole leaks and provide solutions to drinking water corrosion.

References

Alberini, A., Cooper, J., 2000. "Applications of the Contingent Valuation Method in Developing Countries." *Rome: Food and Agriculture Organization of the United Nations, Economic and Social Development Paper* 146.

Boyle, K. J., 2003. Contingent Valuation in Practice. in *A Primer on Nonmarket Valuation*. Edited by Champ P. A., Boyle K. J. & Brown T. C. Kluwer Academic Publishers.

Cameron, T. A., 1988. "A New Paradigm for Valuing Non-market Goods Using Referendum Data: Maximum Likelihood Estimation by Censored Logistic Regression." *Journal of Environmental Economics and Management* 15, 355-379.

Cameron, T. A., Quiggin, J., 1994. "Estimation Using Contingent Valuation Data from a 'Dichotomous Choice with Follow-up' Questionnaire." *Journal of Environmental Economics and Management* 27(3), 218–234.

Cameron, T. A., Huppert D. D., 1989. "OLS vs. ML Estimation of Non-Market Resource Values with Payment Card Interval Data." *Journal of Environmental Economics and Management* 17, 230-246.

Cummings, R. G., Brookshire D. S., Schulze W. D. (eds.), 1986. *Valuing Environmental Goods: An Assessment of the Contingent Valuation Method*, Totowa, NJ: Rowman & Allanheld.

Desvousges, W. H., Smith V. K., Fischer A., 1987. "Option Price Estimates for Water Quality Improvements: A Contingent Valuation Study for the Monongahela River." *Journal of Environmental Economics and Management* 14, 248-267.

Dietrich, A.M., Edwards M.A., Duncan S., Dwyer S., Loganathan G.V., Camper A., Bosch D., 2003. "Toward Sustainable Materials for Drinking Water Infrastructure." Grant funded by National Science Foundation. Virginia Tech, Blacksburg, Virginia.

Edwards, M., Ferguson, J.F., Reiber, S.H., 1994. "The Pitting Corrosion of Copper." *Journal of American Water Works Association* 86(7), 74.

Farooqi, O. E., Loganathan, G. V. (Late), Lee, J., Edwards, M. A., Scardina, P., and Bosch, D., 2009. "Copper Pinhole Failures: Plumbing Susceptibility and Management." *Journal of Water Resources Planning and Management* 135(4), 227.

Greene, D., K. E. Jacowitz, D. Kahneman, and D. McFadden, 1998. "Referendum Contingent Valuation, Anchoring, and Willingness-to-Pay for Public Goods." *Resource and Energy Economics* 20, 85-116.

Hamilton, L. C., 1985. "Who Cares About Water Pollution? Opinions in Small-Town Crisis." *Sociological Inquiry* 55, 170-181.

Hanemann, W. M., Loomis J., Kanninen B.J., 1991. "Statistical Efficiency of Double-Bounded Dichotomous Choice Contingent Valuation." *American Journal of Agricultural Economics* 73, 1255-1263.

Herriges, J. A., Shogren J. F., 1996. "Starting Point Bias in Dichotomous Choice Valuation with Follow-up Questioning." *Journal of Environmental Economics and Management* 30, 112-131.

Jordan, J., Elnagheeb A. H., 1993. "Willingness-To-Pay for Improvements in Drinking Water Quality." *Water Resources Research* 29(2), 237-245.

Kanninen, B. J., 1995. "Bias in Discrete Response Contingent Valuation." *Journal of Environmental Economics and Management* 28, 114-125.

Maddala, G. S., 1983. *Limited-Dependent and Qualitative Variables in Econometrics*. Cambridge University Press, Cambridge.

McFadden, D., Leonard G., 1993. Issues in the Contingent Valuation of Environmental Goods: Methodologies for Data Collection and Analysis. in *Contingent Valuation: a Critical Assessment*. Edited by J. Hausman, North-Holland, Amsterdam, 165-208.

Mitchell, R. C., Carson R. T., 1981. *An Experiment in Determining Willingness to Pay for National Water Quality Improvements*. Unpublished Report, Resources for the Future, Washington, DC.

Mitchell, R. C., Carson R. T., 1989. *Using Surveys to Value Public Goods: the Contingent Valuation Method.* Washington, DC: Resources for the Future.

National Oceanic and Atmospheric Administration (NOAA). 1993. Natural Resource Damage Assessments under the Oil Pollution Act of 1990. *Federal Register* 58, 4601-4614.

Poe, G. L., Bishop R. C., 1999. "Valuing the Incremental Benefits of Groundwater Protection When Exposure Levels are Known." *Environmental and Resource Economics* 13(3), 347-373.

Powell, J. R., Allee D. S., McClintook C., 1994. "Groundwater Protection Benefits and Local Government Planning. Impact of Contingent Valuation Information." *American Journal of Agricultural Economics* 76(5), 1068-1075.

Scardina, P., Edwards M., Bosch D., Loganathan G. V., Dwyer S. K., 2008. Assessment of Non-Uniform Corrosion in Copper Piping. Final Report for American Water Works Association Research Foundation, Denver, Colorado.

Schock M.R., 1999. "Water Quality and Treatment," in *Internal Corrosion and Deposition Control*, American Water Works Association, McGraw Hill, Chapter 17.

Table 1 – Descriptive Statistics of Threshold Values and Responses

	Description	Mean	Standard Deviation
t_1	Threshold value for first question*	$1371.61	$1150.87
t_2	Threshold values for second question*	$1156.42	$832.33
I_1	Discrete response for first question**	0.46	
I_2	Discrete response for second question**	0.30	
Joint frequencies of discrete responses			
I_1=1 I_2=1		0.23	
I_1=1 I_2=0		0.23	
I_1=0 I_2=1		0.07	
I_1=0 I_2=0		0.47	

*First suggested payment for leak-free plumbing. Second question refers to the follow-up suggested payment after the first response.
** 1 = yes and 0 = no

Table 2 – Distributions of Willingness to Pay

First Bid (Second Bids)	YY	YN	NY	NN	n
$500 (600)	34 (61.8%)[a]	21 (38.2%)	0	0	55
$600 (700/500)	34 (34.7%)	27 (27.5%)	3 (3.1%)	34 (34.7%)	98
$700 (800/600)	35 (30.2%)	26 (22.4%)	10 (8.6%)	45 (38.8%)	116
$800 (1200/700)	20 (18.9%)	27 (25.5%)	5 (4.7%)	54 (50.9%)	106
$1200 (2000/800)	14 (14.6%)	18 (18.7%)	13 (13.5%)	51 (53.1%)	96
$2000 (4000/1200)	7 (7.5%)	27 (29.0%)	9 (9.7%)	50 (53.8%)	93
$4000 (2000)	0	0	6 (9.0%)	61 (91.0%)	67
Overall	144 (22.8%)	146 (23.1%)	46 (7.3%)	295 (46.7%)	631

[a] Numbers in parentheses are percentages of the total number of respondents for that threshold category who gave the indicated sequence of responses.

Table 3 – Variable Definition and Summary Statistics

Variable	Description	Mean
INCOME	Household income (midpoint of the reported interval in thousands of dollars)	68.134 (37.765)[a]
MALE	Gender of respondents (1 if male and 0 if female)	0.409 (0.492)
EDUCATION	Number of years of schooling	14.527 (2.462)
AGE	Age of respondents	55.079 (16.044)
CONCERN	Respondents' concern of developing leaks in the future (1 if very concerned or somewhat concerned and 0 otherwise)	0.173 (0.378)
SATISFACTION	Satisfaction with the water quality (1 if very satisfied or somewhat satisfied and 0 otherwise)	0.843 (0.364)
YEARS_RESIDENCE	Number of years that respondents have been living at the current residence	14.823 (14.862)
UTILITY_WATER	Source of water (1 if water comes from a water utility and 0 otherwise)	0.786 (0.410)
EXOG_BID	Exogenous bid amount asked in the first WTP question	1371.612 (1150.866)

[a] Numbers in parenthesis are standard deviations of estimates

Table 4 – Estimation Results for DC and DCF

	DC		DCF	
Variable	**Marginal Effects**	**P-Values**	**Marginal Effects** [a]	**P-Values**
INCOME ($1k)	0.0027	0.000**	0.0019	0.000**
	(0.0007)[a]		(0.0004)	
MALE	-0.0493	0.282	-0.0350	0.192
	(0.0459)		(0.0268)	
EDUCATION	-0.0241	0.022**	-0.0103	0.093*
	(0.0105)		(0.0061)	
AGE	-0.0061	0.001**	0.0036	0.001**
	(0.0018)		(0.0011)	
CONCERN	0.1346	0.031**	0.0870	0.034**
	(0.0623)		(0.0411)	
SATISFACTION	-0.1752	0.007**	-0.0857	0.047**
	(0.0644)		(0.0431)	
YEARS_RESIDENCE	-0.0020	0.318	0.0002	0.860
	(0.0020)		(0.0012)	
UTILITY_WATER	0.0416	0.441	0.0305	0.325
	(0.0539)		(0.0310)	
EXOG_BID	-0.0003	0.000**	-0.0001	0.000**
	(0.0000)		(0.0000)	
ρ			0.4941	
			(0.0625)	
log L			-660.07	

*Indicates significance at the 10% level ** Indicates significance at the 5% level
[a] Numbers in parenthesis are standard errors of estimates
Note: Marginal effects are computed on the probability that the respondent answers each of the dichotomous choice questions in the affirmative. In the case of discrete variables, the marginal effects show the probability for a discrete change of the variable from 0 to 1.

Table 5 – Estimates of Willingness to Pay

	DC	DCF
Mean WTP	397.46 (21.16)[a]	536.45 (27.36)
Conditional Mean WTP	400.64 (7.76)	518.22 (12.13)

[a] Numbers in parenthesis are standard errors of estimated mean WTP.

Table 6 – Results by Source of Water

	Users of Water from Local Utility (n=492)				Users of Water from Private Wells (n=130)			
	DC		DCF		DC		DCF	
Variable	Marginal Effects	P-Values	Marginal Effects	P-Values	Marginal Effects	P-Values	Marginal Effects	P-Values
INCOME ($1k)	0.0035	0.000**	0.0025	0.000**	0.0001	0.936	-0.0004	0.616
	(0.0008)[a]		(0.0005)		(0.0015)		(0.0009)	
MALE	-0.0664	0.197	-0.0423	0.160	0.0504	0.629	0.0374	0.544
	(0.0515)		(0.0301)		(0.1043)		(0.0616)	
EDUCATION	-0.0359	0.003**	-0.0158	0.024*	0.0203	0.380	0.0086	0.523
	(0.0120)		(0.007)		(0.0231)		(0.0135)	
AGE	-0.0051	0.011**	0.0033	0.005**	-0.0142	0.004**	0.0059	0.039**
	(0.0019)		(0.0012)		(0.0049)		(0.0028)	
CONCERN	0.0979	0.169	0.0883	0.062*	0.2813	0.048**	0.0867	0.308
	(0.0712)		(0.0473)		(0.1423)		(0.0849)	
SATISFACTION	-0.1494	0.037**	-0.0729	0.121	-0.3996	0.017**	-0.1413	0.209
	(0.0715)		(0.047)		(0.1668)		(0.1124)	
YEARS_RESIDENCE	-0.0024	0.270	0.0000	0.998	-0.0028	0.585	0.0017	0.565
	(0.0021)		(0.0013)		(0.0051)		(0.003)	
EXOG_BID	-0.0002	0.000**	-0.0001	0.000**	-0.0006	0.000**	-0.0002	0.616
	(0.0000)		(0.0004)		(0.0001)		(0.0009)	
ρ			0.4926				0.5722	
			(0.0705)				(0.1432)	
log L			-514.85				-131.84	
Mean WTP	402.20		541.32		379.23		517.69	
	(17.97)		(31.32)		(43.11)		(55.54)	
Conditional Mean WTP	396.88		517.37		414.90		521.43	
	(8.49)		(13.42)		(18.60)		(28.20)	

*Indicates significance at the 10% level ** Indicates significance at the 5% level

[a] Numbers in parenthesis are standard errors of estimates

Table 7 – Results by Location

	Hotspot Locations				Rest of the US			
	DC		DCF		DC		DCF	
Variable	**Marginal Effects**	**P-Values**	**Marginal Effects**	**P-Values**	**Marginal Effects**	**P-Values**	**Marginal Effects**	**P-Values**
INCOME($1k)	0.0038	0.000**	0.0020	0.003**	0.0015	0.061*	0.0017	0.002**
	(0.0011)[a]		(0.0007)		(0.0008)		(0.0005)	
MALE	-0.0655	0.307	-0.0398	0.352	-0.0465	0.396	-0.0300	0.389
	(0.0642)		(0.0427)		(0.0547)		(0.0349)	
EDUCATION	-0.0175	0.228	0.0009	0.931	-0.0212	0.084*	-0.0178	0.024**
	(0.0145)		(0.01)		(0.0123)		(0.0079)	
AGE	-0.0054	0.015**	-0.0037	0.016**	-0.0053	0.021**	-0.0036	0.019**
	(0.0022)		(0.0015)		(0.0023)		(0.0015)	
CONCERN	0.1291	0.089*	0.1247	0.035**	0.143	0.080*	0.0334	0.559
	(0.0760)		(0.0591)		(0.0816)		(0.0571)	
SATISFACTION	-0.0545	0.496	-0.0721	0.236	-0.1803	0.033**	-0.0851	0.177
	(0.08)		(0.0608)		(0.0844)		(0.0630)	
YEARS_RESIDENCE	-0.0007	0.765	0.0009	0.683	-0.0046	0.052*	-0.0003	0.856
	(0.0025)		(0.0018)		(0.0024)		(0.0016)	
SOURCE_WATER	-0.0233	0.798	0.0234	0.683	0.0487	0.416	0.0318	0.397
	(0.0911)		(0.0573)		(0.06)		(0.0376)	
EXOG_BID	-0.0000	0.029**	-0.0002	0.000**	-0.0001	0.000**	-0.0001	0.000**
	(0.0000)		(0.0007)		(0.0000)		(0.0005)	
ρ			0.5125				0.5860	
			(0.1245)				(0.1143)	
log L			-278.68				-375.07	
Mean WTP	603.70		496.31		475.19		472.95	
	(57.17)		(39.30)		(40.93)		(33.22)	
Conditional Mean WTP	593.86		527.97		471.46		511.03	
	(27.98)		(19.81)		(14.72)		(15.70)	

*Indicates significance at the 10% level ** Indicates significance at the 5% level
[a] Numbers in parenthesis are standard errors of estimates

Essay 2

On Consumers' Attitudes and Willingness to Pay for Improved Drinking Water Quality and Infrastructure

Introduction

The water infrastructure in the US is in immediate need for investment (Clark et. al., 1999). A survey conducted by the Environmental Protection Agency (US EPA, 2009) determined that nationwide, community and non-community water systems will need to invest an estimated $334.8 billion between 2007 and 2027 in water infrastructure to protect from contaminants that might create serious health risks and to assure continued compliance with the Safe Drinking Water Act. Such investment will finance installation, upgrades or replacement of equipment, treatment technologies and distribution infrastructure. In addition, Brongers (2002) finds that in the US alone 10-32% of the public drinking water infrastructure is lost to corrosion, costing approximately $22 billion per year. The cost is nearly twice that for corrosion to private drinking water infrastructure including residential, commercial, and school buildings (Edwards, 2003).

Problems with drinking water infrastructure, whether public or private, threaten the safety, quality and health values of drinking water for the public. Recently the failure rate of home infrastructure has increased in certain areas (Bosch et. al., 2006), causing consumer concerns. Consumers have reported an increasing number of leaks in drinking water pipes due to copper corrosion as well as breaks in the water main due to aging and deteriorating public infrastructure that affect water quality and water service. These failures have been geographically uneven with certain areas facing significantly higher incidence of problems.

Leaks in water mains and household water systems may result in increased public health risks such as water-borne disease in addition to degraded water taste, odor, and/or appearance. A national survey by the Water Quality Association (2001), determined that 86 percent of Americans are concerned about their home water supply while 32 percent believe their tap water is not as safe as it should be. Additionally, the survey found that 41 percent use water treatment devices in their homes or bottled water or both. Preventive measures are necessary to avoid water contamination and leakage that may result in serious health risks associated with medical costs.

Efficient investments in public infrastructure need to reflect the value that the users of such infrastructure place on the resulting improvements. Previous research has mainly focused on water quality improvements, in particular on reductions of contamination of groundwater from agricultural activities (Desvousges et. al., 1987, Jordan and Elnagheeb, 1993, Powell et. al., 1994, and Poe and Bishop, 1999). Research has been done on issues regarding water infrastructure in the US but the main scope has been to examine its condition and estimate the costs of maintenance and new investments necessary. To our knowledge little research is conducted on consumers' willingness to pay for improvements in drinking water infrastructure and/or water quality, even though the maintenance and replacement of public infrastructure is considered to be one of the major challenges related to drinking water in the 21st century (Clark et. al., 1999). In addition, little empirical research has focused on examining consumers' perceptions and attitudes regarding drinking water.

The objective of this paper is to examine the determinants that affect consumers' behavior and willingness to pay for improved water quality and related infrastructure improvements. More specifically, the analysis links consumers' attitudes and perceptions towards drinking water quality and infrastructure to their willingness to pay for improvement programs based on data from a survey of Northern Virginia and Maryland suburbs of Washington DC. Three improvement alternatives are evaluated, a water quality improvement program, a pinhole leak damage insurance program and a water utility infrastructure upgrade. These programs are interesting and relevant for the area being surveyed because of the high number of problems reported related to breaks in public water mains and other infrastructure, damage to private infrastructure from pinhole leaks, and quality of drinking water. Results will provide insightful information to policy makers regarding consumers' perceptions and willingness to support programs aimed at improving drinking water quality and infrastructure. Moreover, the analysis will link information and consumers' risk perceptions to the valuation framework.

Conceptual Framework

Theory suggests that consumers' attitudes and perceptions may affect consumer behavior and the choices they make. A theoretical model that describes the consumer decision process was developed by Engel, Kollat and Blackwell (EKB) in 1968 and later revised by Engel, Blackwell and Miniard (EBM) in 1986. This model is traditionally used in studies of market behavior and consumer choices. It describes consumer behavior in five main stages consisting of (1) problem recognition, (2) information searching, (3) information processing and perceptions, (4) evaluation of alternatives and (5) making a choice. Using the EKB model as the theoretical foundation, Huang (1993) estimates consumer risk perceptions, attitudes and willingness to pay for residue free produce. The study uses a simultaneous equation model to analyze the relationship between risk perceptions, attitudes and behavioral intentions. According to Huang (1993), information searching includes knowledge and information obtained by consumers via the search process. Perceptions represent the formation of an individual's state of mental awareness once knowledge and information is acquired (Huang, 1993). Perceptions can change continuously over time due to personal, social and economic factors. Attitude is a predisposition to respond to an object or concept based on experience and it influences behavior (Engel, et al., 1986). Consumer perceptions are an example of the cognitive component of attitudes. Behavior intentions represent consumers' mental construct in connection with their knowledge, information, perceptions and attitudes. Once the behavioral intentions are formed, the consumer makes a choice among the available alternatives.

The literature reviewed above indicates that information affects behavior through risk perceptions. In order to test whether this finding applies to our study, we regress risk perceptions on information and respondents demographic characteristics. We find that in our case information that respondents obtain does not affect their risk perceptions directly. Therefore, we proceed to assume that information and risk perceptions affect consumers' willingness to pay jointly.

The model assumes that the information consumers accumulate about drinking water affects the choices they make. Consumer choices are also affected by their perceptions and beliefs regarding water quality as well as socioeconomic factors. Since consumers' actual choices are unobservable, this study will consider consumer behavioral intentions (willingness to pay for improvements) which are observed using survey techniques. The conceptual model is as follows:

$$\text{WTP}_t = f\ (\text{INFO, RP, C, SE}) + \varepsilon_t \tag{1}$$

where WTP_t indicates consumers' *t* willingness to pay for improvements in drinking water quality and infrastructure, INFO represents consumers' knowledge and information searching regarding water quality and infrastructure, RP stands for consumers' risk perceptions and attitudes towards drinking water, SE represents socioeconomic characteristics that may be correlated with consumer's behavior and ε_t is an error term.

Empirical Framework

The respondents will choose an improvement program among the water quality improvement, the pinhole leak damage insurance and the water utility infrastructure upgrade based on the given alternatives. The choice they make is mutually exclusive and the responses have no natural ordering. The appropriate model for unordered responses is the multinomial logit as suggested by Davidson and MacKinnon (2004). The consumers will choose alternative j if the utility from that alternative is higher than the utility they get from the status quo (not choosing any improvement program at all). Although we cannot observe the utility of the consumer, we observe the choices that the consumers make. The probability that a particular choice is observed is given by:

$$\Pr(y_t = l) = \frac{\exp\,(W_{tl}\beta^l)}{\sum_{j=0}^{J} exp(W_{tl}\beta^l)} \qquad for\ l = 0, \dots \dots, J. \tag{2}$$

where W_{tj} denotes a row vector of observations on variables of interest for alternative j and β^j is a vector of parameters, usually different for each j=0,…,J. The parameters of the multinomial logit are estimated using the maximum likelihood procedure. The loglikelihood function can be written as:

$$\sum_{t=1}^{n}\left(\sum_{j=0}^{J} I(y_t = j)W_{tj}\beta^j - log\left(\sum_{j=0}^{J} \exp\,(W_{tj}\beta^j)\right)\right) \tag{3}$$

where I(.) is the indicator function of the alternative chosen. Each observation contributes two terms to the loglikelihood function: the first is $W_{tj}\beta^j$ where $y_t = j$ and the second is the negative logarithm of the denominator in equation (2) (Davidson and MacKinnon, 2004).

When choosing which program to support, respondents take into consideration all the characteristics of each of the programs. As a result, the probability that a program is chosen will depend on the same set of characteristics and the explanatory variables W_t will be the same for each choice j.

An important property of the multinomial logit model is the independence of irrelevant alternatives or IIA property. It states that the ratio of the probabilities of any two responses depends solely on the explanatory variables and the parameters associated with those responses (Davidson and MacKinnon, 2004). Therefore the inclusion or exclusion of a category should not affect the relative risk of the other options or categories.

Data and Variable Description

The data for this paper were collected through a mail survey sent to the Northern Virginia and Maryland suburbs of Washington DC area in the winter of 2007. This study area was chosen due to the high number of reported failures in public (Clark et. al., 1999) and private plumbing systems (WSSC, 2007), its aging infrastructure and relatively high incidence of other water quality issues such as lead in the water and microbial contamination (Edwards et al., 2009). The pool of participants was a randomly selected group from the zip codes that are serviced by the Fairfax Water Utility Authority and the Washington Suburban Sanitary Commission (WSSC). The sample consisted of 5,200 households and was provided by the Survey Sampling International (SSI). The design method for the survey followed the format for mail surveys suggested by Dillman (1978) to ensure a high response rate. The survey process consisted of an initial survey which was followed by a reminder card and a second survey sent approximately three and six weeks after the first mailing, respectively. The total number of surveys returned was 1,232, constituting a response rate of 24 percent. Only 866 responses were included in the analyses. Observations with missing information on certain variables were deleted from the sample.

Information

One of the goals of this study is to examine how respondents obtain and use information, and how this information shapes their willingness to pay for drinking water. To accomplish this, the sample was randomly split into three different subsamples with each subsample receiving a different information set regarding drinking water at the beginning of the survey. The first group did not receive any additional drinking water information in the survey. The second group received general information on the water quality in their homes including ways the water is treated, how often it is tested, what is it tested for and whether it complies with the EPA standards of drinking water. The information reads as follows:

> *Water that is treated by drinking water utilities in the Washington D.C. metropolitan area goes through several treatment processes. Utilities monitor for over 120 contaminants in the drinking water. The water is typically tested at least 240 times a day. Treated drinking water is in compliance with all State and Federal regulations.*

The third group also received information related to water quality but, in contrast to the second group, this information was somewhat negative. Respondents received a description of some of the problems that had occurred and current issues with water quality in the area where they reside. This group received the following information:

> *Water utility infrastructure in the Washington D.C. metropolitan area is aging and deteriorating. Leaks and breaks in water mains that interrupt services to water utility customers are occurring more often and for longer periods. Such interruptions cause inconvenience and, in some cases, property damages to customers.*

Respondents were also asked how often they read the Annual Water Quality Report/Consumer Confidence Report that they receive from their water utility. The report provides information about where the water comes from and what it contains, levels of any contaminants present and EPA health-based standards for comparison, potential health effects of any contaminant that is detected as well as general educational information and compliance rules. Whether respondents read the report (INFO) serves as an indicator of the information they acquired about the quality of their tap water.

Risk Perceptions

Part of our analysis focuses on consumer risk perceptions and attitudes towards water quality and infrastructure and their willingness to pay for improvements. A series of questions was asked to reveal respondents' perceived risk and risk related behavior with regards to their tap water. More specifically, respondents were asked about their tap water use: whether they use their water for all households needs or if they restrict the use to not include drinking and/or cooking. Respondents were also asked whether they use bottled water and/or other water treatment methods because they want to improve the safety of their water. In order to capture consumers' risk perceptions from responses of several questions, we have constructed an index that incorporates all responses and serves as a composite measure of risk (RISKINDEX). The risk index reflects respondents' true perceived risk as it is based on consumer's actual behavior and beliefs regarding water safety issues. The risk index variable was constructed based on whether consumers use bottled water for safety reasons, whether they use water treatment methods for safety reasons and usage of tap water (all household needs, all needs except drinking, all needs except drinking and cooking). Each of the responses to these questions was standardized to a range of 0 to 1 and then added together to construct the risk index variable. In addition, we include a measure of risk aversion (RISKAVERSION) we elicit from respondents based on a sequence of questions developed by Barsky et al. (1997) and used in the U.S. Panel Study of Income Dynamics (PSID). This allows us to explore the implications of interpersonal differences in risk aversion for willingness to pay.

Consumers were also asked if they had any problems with pinhole leaks or breaks in the water main, if they use bottled water and/or other water treatment methods and the reasons why they do so. Based on responses to these questions, several other indexes were constructed to capture consumer experiences and perceptions that may incline them to support a particular program. A palatability index (PALATABILITY) captures consumer concerns about the taste, smell and color/clarity of tap water. This index is based on whether taste is important in the decision to purchase bottled water and if treatment methods are used for the purpose of improving the taste, the smell or the color/clarity of the tap water. A leak index (LEAKS) captures respondents' experiences and concerns about leaks and it includes responses to whether they have had pinhole leaks in the water pipes at the current residence or whether they use water treatment methods in order to protect the plumbing system. A reliability index (RELIABILITY) accounts for whether respondents had water service interruptions or problems because of breaks in the water main or if they use bottled water for convenience. All indexes were standardized to the same range of 0 to 1 to reduce variability relative to other indexes.

Willingness to Pay

Respondents' willingness to pay for improvements in water quality and infrastructure is elicited using the contingent valuation method. Participants were asked to evaluate three water improvement programs. The first program is targeted to further improve the quality of water including taste, odor, color and safety. The second program described an insurance program to cover all future costs of pinhole leak damage and repairs including collateral damage to home and personal property. The third program proposes an upgrade to the public water distribution infrastructure. Each program would cost respondents a certain amount in addition to the water bill per quarterly billing cycle. The three programs were incorporated in one question in order to avoid bias based on the order in which programs were presented (see Appendix). The values for the costs were randomly selected from $40, $70, $85, $105 and $180. These payments were based on water bill values for residents in the study area. More specifically, these values are the

20th, 40th, 50th, 60th and 80th percentiles of the distribution of the 2007 quarterly water bill values[4] which include water and sewer. A fractional factorial design was used to generate the cost values for the programs. The costs were allowed to be the same for two of the programs and different for the third one, resulting in 60 different combinations. The number of combinations was generated using the following formula:

$$2n^{(k-1)} + n^2 - 3n \tag{4}$$

where n is the number of possible cost values available which in this case is 5 and k is the number of cost values that is chosen for the valuation question which is 3 for the three programs, with one value being randomly assigned to each program. Respondents were given the choice to accept payment for one of the programs or choose not to support any of the programs and not pay anything. Seventeen percent of respondents chose to support the water quality program, 9 percent voted for the pinhole leak program and 29 percent voted for the public infrastructure program (table 1). The rest of the respondents, about 44 percent, were not willing to pay anything and did not support any of the programs. The mean willingness to pay was \$85.07 for the water quality improvement program, 80.69 for the pinhole leak damage insurance program and \$87.64 for the water utility infrastructure upgrade (table 2). The public infrastructure upgrade program had the largest share of votes and the highest mean willingness to pay compared to the other programs.

In addition, respondents were asked whether they were homeowners (OWNHOUSE). We hypothesize that individuals who own the house/apartment they reside in are more likely to accept water improvement programs compared to individuals who rent. About 92 percent of participants were homeowners (table 3). It is expected that respondents will also be more likely

[4] Water bill values are of customers serviced by the Fairfax Water Utility Authority and WSSC.

to accept an improvement program if a child under the age of 18 is present in the household (CHILDREN) to avert any perceived risks. About 36 percent of the sample had a child under the age of 18. Finally, a series of socioeconomic questions were included at the end of the survey. Respondents were asked about their age (AGE), gender (MALE), race (WHITE) and education (COLLEGE). The mean age of participants was 54 years of age with 62 percent of them being male and 79 percent of them being white. About 77 percent of the respondents had an education level of four years of college or above.

Empirical Results

Estimation results from the multinomial logit model indicate that the cost of the program is an important determinant in the decision to support a program (table 4). The presence of children under the age of 18 in the household makes respondents more likely to support the water quality improvement program. Similar results are found by previous research indicating that parents are willing to protect their children from possible health risks (Dickie and Gerking, 2007). The risk index coefficient has a positive and significant effect on supporting the water quality improvement program. As individuals become more wary of their tap water, their willingness to pay to avoid any risks increases and vice versa. Other important determinants of willingness to improve water quality are the safety information message included at the beginning of the survey (SAFETYINFO decreases the likelihood of accepting program), whether respondents own the house they live in (homeowners are less willing to pay to improve water quality) and race (whites are less likely to support the program).

The safety information (SAFETYINFO) and the infrastructure information (INFRASTRUCINFO) have a positive effect on the willingness to accept the pinhole leak insurance. Information provided to consumers affects their decisions regarding pinhole leak problems. Consumers that are made aware of problems with infrastructure are more likely to invest in protective programs. The leaks index (LEAKS) and the reliability index (RELIABILITY) are positive determinants in the decision to support the pinhole leak insurance program. Consumers who had prior problems with pinhole leaks and those who use treatment methods to protect against leaks are more likely to choose the pinhole leak insurance program. Also, consumers that had breaks in the water main (RELIABILITY) were more likely to support this program. This supports the hypothesis that the insurance program is perceived as a way to avoid any problems with the water infrastructure. Among the socioeconomic variables, race was the only significant determinant showing that whites are less willing to pay for the pinhole leak insurance program.

With regards to the water infrastructure upgrade program, consumers who read the annual reports sent by the utilities (INFO) are less likely to support this program. The reason for this finding might be that the report serves as a reassurance from the water authority. Respondents who had problems with breaks in the water main in their residence, were willing to pay for the infrastructure upgrade program (coefficient of reliability index is positive and significant) indicating that past experience is an important in valuation decisions. In addition, age and education are significant determinants of the choice to accept the infrastructure upgrade. Younger consumers with a four year college degree are more willing to pay for public infrastructure.

The estimates from the multinomial logit are expressed in terms of relative risk ration in table 5. They are obtained by exponentiating the multinomial logit coefficients in table 4. Relative risk ratios show by how much the relative risk of choosing one of the programs over no program (the base outcome) changes for a unit change in the predictor variable. The results indicate that a one dollar increase in the cost of program j decreases the relative risk of voting for program j relative to no program at all by a factor of 0.99, given all the other variables in the model are kept constant. The other coefficients can be interpreted similarly.

Conclusions

The determinants of willingness to pay for the proposed improvement programs differ among the three choices. Consumer risk perceptions affect their willingness to pay to improve the water quality but not the leaks insurance program or the infrastructure upgrade. Information given to consumers affects their behavior which implies that there is potential for information campaigns to gather public support for expenditures in water infrastructure. On the other hand, information regarding water quality and EPA compliance may affect consumers' confidence about their tap water and therefore their decisions regarding investments in improvement programs. The results indicate stronger support for public infrastructure improvements, which suggests that public decision makers' efforts to provide consumers with information about water infrastructure will affect consumers' support for infrastructure improvement programs. In addition, this study supports previous findings regarding the link between information, risk perceptions and individuals' valuation decisions.

References

Barsky, R. B., F. T. Juster, M. S. Kimball and M. D. Shapiro, 1997. "Preference Parameters and Behavioral Heterogeneity: An Experimental Approach in the Health and Retirement Study." *The Quarterly Journal of Economics* 112(2), 537-579.

Bosch, D., Sarver E., Tanellari E., Dwyer S., Willis-Walton S., Loganathan G.V., Farooqi O., and Lee. J., (2006). *National Pinhole Leak Costs and Willingness to Pay for Improved Plumbing Materials*. AWWARF Report. Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

Boyle, K. J., 2003. Contingent Valuation in Practice in *A Primer on Nonmarket Valuation*. edited by P. A. Champ, K. J. Boyle and T. C. Brown. Kluwer Academic Publishers.

Brongers M.P.H., 2002. Appendix K. Drinking Water and Sewer Systems *in Corrosion Costs and Preventative Strategies in the United States*. Report FHWA-RD-01-156. U.S. Department of Transportation Federal Highway Administration.

Clark, R. M., Rizzo G. S., Belknap J. A., and Cochranes C., 1999. "Water Quality and the Replacement and Repair of Drinking Water Infrastructure: The Washington DC Case Study." *Aqua* 48(3), 106-114.

Davidson, R., and MacKinnon, J. D., 2004. *Econometric Theory and Methods.* Oxford University Press.

Desvousges, W. H., Smith V. K., and Fischer A., 1987. "Option Price Estimates for Water Quality Improvements: A Contingent Valuation Study for the Monongahela River." *Journal of Environmental Economics and Management* 14, 248-267.

Dickie, M., and Gerking, S., 2007. "Altruism and Environmental Risks to Health of Parents and their Children." *Journal of Environmental Economics and Management* 53, 323-341.

Dillman, D. A., 1978. *Mail and Telephone Surveys: The Total Design Method*, New York: John Wiley and Sons.

Donkers, B., Melenberg B., and Van Soest A., 2001. "Estimating Risk Attitudes using Lotteries: A Large Sample Approach." The Journal of Risk and Uncertainty 22(2), 165-195.

Edwards M., S. Triantafyllidou, and D. Best, 2009. Elevated Blood Lead in Young Children Due to Lead-Contaminated Drinking Water: Washington, DC, 2001−2004. *Environmental Science and Technology* 43(5), 1618–1623

Edwards, M., 2003. "Controlling Corrosion in Drinking Water Distribution Systems: A Grand Challenge for the 21st Century." *Water Science and Technology*, in press.

Engel, J. F., Blackwell R. D., and Miniard P. W., 1986. *Consumer Behavior*, 5th ed. Holt, Rinehart and Winston.

Huang, C. L., 1993. "Simultaneous-Equation Model for Estimating Consumer Risk Perceptions, Attitudes, and Willingness to Pay for Residue-Free Produce." *The Journal of Consumer Affairs* 27(2), 377-396.

Jordan, J., and Elnagheeb A. H., 1993. "Willingness-To-Pay for Improvements in Drinking Water Quality." *Water Resources Research* 29(2), 237-245.

Luoh, M., and Stafford F., 2007. Estimating Risk Tolerance from the 1996 PSID. Available on-line at: http://psidonline.isr.umich.edu/Data/Documentation/Cbks/Support.html.

Poe, G. L., and Bishop R. C., 1999. "Valuing the Incremental Benefits of Groundwater Protection When Exposure Levels are Known." *Environmental and Resource Economics* 13(3), 347-373.

Powell, J. R., Allee D. S., and McClintook C., 1994. "Groundwater Protection Benefits and Local Government Planning. Impact of Contingent Valuation Information." *American Journal of Agricultural Economics* 76(5), 1068-1075.

US Environmental Protection Agency. 2009. *Drinking Water Infrastructure Needs Survey and Assessment, Fourth Report to Congress.* Office of Water, Washington DC.

Washington Suburban Sanitary Commission (WSSC). 2007. http://www.wsscwater.com/index.cfm.

Water Quality Association. 2001. *2001 National Consumer Water Quality Survey*. Available by request at www.wqa.org.

Table 1. Descriptive Statistics of Choice of Improvement Program

Improvement Program	Frequency	Percentage	Cumulative Frequency
No Program	384	44.34	44.34
Water Quality Improvement	150	17.32	61.66
Pinhole Leak Damage Insurance	80	9.24	70.90
Water Quality Infrastructure Upgrade	252	29.10	100.00
Total	**866**	**100.00**	

Table 2. Mean Willingness to Pay for Improvement Programs

Improvement Program	Mean WTP	Standard Deviation
Water Quality Improvement	85.07	43.59
Pinhole Leak Damage Insurance	80.69	44.11
Water Quality Infrastructure Upgrade	87.64	44.49

Table 3. Variable Definitions and Summary Statistics

Variable	Definition	Mean (n=866)	Standard Deviation
INFO	1 if respondent read the annual report from the water utility almost always or sometimes, 0 otherwise	0.670	0.471
SAFETYINFO	1 if a safety information blog about tap water was included in the survey, 0 otherwise	0.323	0.468
INFRASTRUCINFO	1 if an information blog about the current situation of public water infrastructure was included in the survey, 0 otherwise	0.329	0.470
RISKINDEX	Risk index coefficient, range from 0 to 1	0.366	0.241
RISKAVERSION	Risk aversion coefficient	0.684	1.389
PALATABILITY	Palatability index, whether respondents use bottled water to improve the taste of water or use treatment devices to improve clarity, taste or smell, range from 0 to 1	0.308	0.263
LEAKS	Leak index, whether respondents have experienced leaks or if they treat their water to protect their plumbing system, range from 0 to 1	0.088	0.194
RELIABILITY	Reliability index, whether respondents water service was interrupted because of breaks in the water main or if they use bottled water for convenience, range from 0 to 1	0.371	0.305
COST1	Cost of the first program in the WTP question, takes random values from $40, $70, $85, $105 or $180	97.604	46.724
COST2	Cost of the second program in the WTP question, takes random values from $40, $70, $85, $105 or $180	97.338	47.672
COST3	Cost of the third program in the WTP question, takes random values from $40, $70, $85, $105 or $180	96.282	46.777
OWNHOUSE	1 if respondent owns the house they live in, 0 otherwise	0.927	0.260
CHILDREN	1 if children under 18 are present in the household, 0 otherwise	0.357	0.479
AGE	Respondent's age	53.978	13.611
MALE	1 if respondent is male, 0 otherwise	0.618	0.486
WHITE	1 if respondent is white, 0 otherwise	0.789	0.408
COLLEGE	1 if the education level of the respondent is college or above, 0 otherwise	0.772	0.419

Table 4. Maximum Likelihood Estimates of Multinomial Logit Model

	Water Quality Improvement	
Variable	Estimated Parameter	Standard Error
INFO	-0.2205	0.2159
SAFETYINFO	-0.4803*	0.2562
INFRASTRUCINFO	-0.0220	0.2385
RISKINDEX	2.2323**	0.4829
RISKAVERSION	-0.0075	0.0679
PALATABILITY	-0.2155	0.4549
LEAKS	-0.2493	0.5531
RELIABILITY	0.4085	0.3559
COST1	-0.0087**	0.0025
COST2	0.0012	0.0023
COST3	0.0003	0.0022
OWNHOUSE	-0.7095*	0.3717
CHILDREN	0.4365*	0.2431
AGE	0.0035	0.0095
MALE	-0.2475	0.2135
WHITE	-0.6145**	0.2546
COLLEGE	0.1779	0.2475
CONSTANT	-0.1389	0.7749
	Pinhole Leak Damage Insurance	
INFO	-0.4102	0.2712
SAFETYINFO	0.6376*	0.3274
INFRASTRUCINFO	0.5475*	0.3284
RISKINDEX	-0.1364	0.6472
RISKAVERSION	-0.1037	0.1104
PALATABILITY	-0.2360	0.5829
LEAKS	1.5615**	0.5571
RELIABILITY	1.0240**	0.4234
COST1	0.0001	0.0029
COST2	-0.0080**	0.0033
COST3	0.0001	0.0029
OWNHOUSE	1.1949	0.7900
CHILDREN	-0.0352	0.3178
AGE	-0.0004	0.0117
MALE	-0.1716	0.2759
WHITE	-1.1895**	0.3099
COLLEGE	-0.1101	0.3002
CONSTANT	-1.4810	1.1393

Continued

Variable	Water Utility Infrastructure Update	
	Estimated Parameter	Standard Error
INFO	-0.2977*	0.1795
SAFETYINFO	-0.0765	0.2053
INFRASTRUCINFO	-0.1163	0.2080
RISKINDEX	0.6465	0.4223
RISKAVERSION	-0.0305	0.0646
PALATABILITY	-0.1718	0.3816
LEAKS	-0.4992	0.4710
RELIABILITY	0.5131	0.2945
COST1	0.0027	0.0018
COST2	0.0072**	0.0018
COST3	-0.0081**	0.0019
OWNHOUSE	-0.5517	0.3393
CHILDREN	0.0577	0.2037
AGE	-0.0127*	0.0077
MALE	-0.0897	0.1802
WHITE	-0.2172	0.2334
COLLEGE	0.5330**	0.2208
CONSTANT	0.2945	0.6519

*Indicates significance at the 10% level
** Indicates significance at the 5% level

Table 5. Relative Risk Ratios for the Multinomial Logit Model

Variable	RRR[a]	Standard Error
	Water Quality Improvement	
INFO	0.8021	0.1732
SAFETYINFO	0.6186*	0.1585
INFRASTRUCINFO	0.9783	0.2333
RISKINDEX	9.3214**	4.5014
RISKAVERSION	0.9925	0.0674
PALATABILITY	0.8061	0.3667
LEAKS	0.7793	0.4310
RELIABILITY	1.5046	0.5356
COST1	0.9914**	0.0025
COST2	1.0012	0.0023
COST3	1.0003	0.0022
OWNHOUSE	0.4919*	0.1828
CHILDREN	1.5474*	0.3762
AGE	1.0036	0.0095
MALE	0.7808	0.1667
WHITE	0.5409**	0.1377
COLLEGE	1.1948	0.2957
	Pinhole Leak Damage Insurance	
INFO	0.6635	0.1800
SAFETYINFO	1.8919*	0.6195
INFRASTRUCINFO	1.7289*	0.5679
RISKINDEX	0.8725	0.5646
RISKAVERSION	0.9015	0.0995
PALATABILITY	0.7897	0.4604
LEAKS	4.7661**	2.6550
RELIABILITY	2.7844**	1.1791
COST1	1.0001	0.0029
COST2	0.9920**	0.0032
COST3	1.0001	0.0029
OWNHOUSE	3.3031	2.6096
CHILDREN	0.9654	0.3068
AGE	0.9996	0.0117
MALE	0.8423	0.2324
WHITE	0.3044**	0.0943
COLLEGE	0.8957	0.2689

Continued

Variable	Water Utility Infrastructure Update	
	RRR	Standard Error
INFO	0.7425*	0.1333
SAFETYINFO	0.9264	0.1902
INFRASTRUCINFO	0.8902	0.1852
RISKINDEX	1.9089	0.8061
RISKAVERSION	0.9699	0.0627
PALATABILITY	0.8421	0.3213
LEAKS	0.6070	0.2859
RELIABILITY	1.6704*	0.4920
COST1	1.0027	0.0018
COST2	1.0073**	0.0018
COST3	0.9919**	0.0019
OWNHOUSE	0.5760	0.1954
CHILDREN	1.0594	0.2158
AGE	0.9873*	0.0076
MALE	0.9142	0.1648
WHITE	0.8048	0.1879
COLLEGE	1.7040**	0.3762

*Indicates significance at the 10% level

** Indicates significance at the 5% level

[a] Relative risk ratios represent the transformed estimated coefficients so that exp(β) is displayed instead of β.

Appendix

Willingness to Pay Question

1. Suppose your water utility is considering three improvement programs:

Program 1

Your water utility tests the water multiple times a day and your water is of high quality. Suppose there is a program to further improve the quality (taste, odor, color and safety) of your tap water supply. The cost of this program per quarterly billing cycle is shown in the table below. This cost would be in addition to your current water bill.

Program 2

Consider the current condition of the drinking water plumbing system in your house. Nationwide, about 8 percent of homeowners have reported pinhole leaks. Suppose you can stay with your current plumbing system, fixing any problems which may arise or replacing the plumbing system if necessary. Or, as another alternative, there is an insurance program to cover all future costs of pinhole leak damage and repairs including collateral damage to home and personal property. The cost of this program per quarterly billing cycle is shown in the table below. This cost would be in addition to your current water bill.

Program 3

Consider the quality and reliability of water services from your utility. Suppose a program were proposed to upgrade water distribution infrastructure in your utility service area. Fees collected for such a program would be entirely dedicated to replacing aged water distribution infrastructure. The cost of this program per quarterly billing cycle is shown in the table below. This cost would be in addition to your current water bill.

Program	1. Water Quality Improvement	2. Pinhole Leak Damage Insurance	3 Water Utility Infrastructure Upgrade
Cost per quarterly billing cycle	$70	$105	$105

Which program would you support? (CIRCLE ONE NUMBER)

1. Program 1
2. Program 2
3. Program 3
4. None 0

Essay 3

Risk Measures and Averting Behavior for Drinking Water Quality

Introduction

A possible consumer response to environmental or health threats is to engage in defensive behavior to minimize exposure. Similarly, problems with water quality and water related issues may compel consumers to take measures to protect themselves from potential risks. Despite regulations from the Environmental Protection Agency (EPA) under the Safe Drinking Water Act to control contaminants in drinking water, research shows that roughly one in ten Americans has been exposed to drinking water that contains dangerous chemicals or fails to comply with the federal health rules (Duhigg, 2009). If informed of the exposure to contaminants in their water, consumers may update their perceptions and take action to minimize risks by purchasing bottled water or treating their water. However, consumers are not always aware of the problems with drinking water quality (Abdalla, Roach and Epp, 1992). As a result, their behavior may be based simply on their perceptions and beliefs about the quality of water, rather than objective assessments. In addition, consumer behavior is likely to be affected by their general attitude towards risk and risky situations. Consumers may respond differently to adverse situations and some may be more willing to avoid risks than others. Previous research has addressed the role of consumers' risk perceptions in influencing their averting decisions (Abdalla, Roach and Epp, 1992; Whitehead, Hoban and Van Houtven, 1998; Abrahams, Hubbell and Jordan, 2000). However, to our knowledge, no studies have considered the effect of consumers' risk aversion measures on their decision to treat drinking water.

Consumers' averting behavior in response to water pollution and contamination is well documented in the literature. Previous research has looked at different forms of averting behaviors such as purchases of bottled water, water treatment, water filters, or boiling of tap water. However, many studies do not include measures of consumer's risk perceptions (Larson and Gnedenko, 1999; McConnell and Rosado, 2000) or were not able to make a connection between risk perceptions and averting behavior (Smith and Desvousges, 1986).

Other existing studies provide evidence that consumers' perceived risks from tap water have a significant impact on their decision to avert. Abdalla, Roach and Epp (1992) use averting expenditures to approximate the economic costs of groundwater contamination to households. They use a point scale measure of risk from exposure to contamination and find that averting actions are positively affected by perceived risk.

Abrahams, Hubbell and Jordan (2000) estimate a model of averting behavior in response to water contamination risks for Georgia residents. The model examines consumer choices between bottled water, filtered water and unfiltered tap water. A measure of risk that captures respondents' perceptions about the safety of their tap water is included in the model in the form of a binary variable that takes values of 0 if the respondent considers the tap water safe or very safe and 1 if the respondent considers tap water somewhat unsafe or unsafe. Their results indicate that perceived risk is an important determinant in the selection of averting behaviors, specifically, purchases of bottled water and water treatment.

Cai, Shaw and Wu (2008) model consumers averting behavior using drinking water treatment expenditures and elicited subjective mortality risks of arsenic. They create a weighted risk measure based on individual's prior sense of arsenic risk, information received that may update their risks and individual's socioeconomic characteristics that relate to their behavior. They conclude that consumer's perceived risk influences their expenditures on water treatment.

A more recent study by Jakus et al. (2009) examines the role of the perceived risk of tap water from arsenic contamination on purchases of bottled water. The authors elicit a probability-based measure of perceived risk that can be evaluated against mortality risk measures developed by scientists. They conclude that the perceived risk measure is a significant determinant of expenditures for bottled water.

This study examines the effects of consumer risk perceptions about tap water quality on treatment decisions and expenditures. We consider averting choices consumers make in terms of bottled water or treatment methods and averting expenditures and provide estimates of determinants that affect consumer decisions by using a Heckman selection model. The analysis accounts for both perceived risk related to water and risk aversion in general. We use the risk aversion sequence of questions developed by Barsky et al. (1997) and elicited for a nationally representative sample in the U.S. Panel Study of Income Dynamics (PSID), to generate measures of risk aversion. This allows us to explore the implications of interpersonal differences in risk aversion for averting behavior. The risk measures as well as awareness of problems, satisfaction, concerns and problems about tap water and demographic characteristics of respondents are incorporated into the model that predicts averting decisions.

The rest of the paper is organized as follows. Section two provides an overview of the conceptual framework. The data and statistical analysis are described in section three. The empirical model is presented in section four and the results and conclusions are discussed in section five.

Conceptual Framework

Averting Behavior

Averting behavior refers to a “safety” action that people undertake to reduce any undesirable attributes of environmental amenities or avoid health hazards. Averting behaviors may include protective or preventive behaviors such as wearing a seat belt, a safety helmet, installing a fire alarm, not smoking cigarettes, getting a gym membership, preventative doctor’s visits, etc. (Blomquist, 2004). Similarly, preventative or protective behaviors regarding tap water may include purchasing bottled water, filtering or treating the water, boiling, etc. Consumers would not spend money on preventive behaviors if a risk was not posed or if they believed they would not benefit from these behaviors.

Assume that the quality of the tap water (untreated water) and the quality of the bottled/treated water are represented by Q^0 and Q^1, respectively. Let annual household income be given by *Y* and consumer’s cost of averting by *C*. Respondents perceive risk from tap water of *r*. The consumer’s indirect utility before any averting action can then be written as:

$$V^0 = U(Q^0, Y, r, S) \tag{1}$$

where *S* is a vector of socioeconomic characteristics of respondents. If consumers decide to engage in averting behaviors, they would incur treatment costs of *C* and reduce their perceived risks by *r*. The indirect utility function then takes the form:

$$V^1 = U(Q^1, Y - C, S) \tag{2}$$

Consumers will choose to use bottled water and/or treatment methods if the benefits from these actions (eliminating perceived risks *r*) outweigh the cost of treatment (income loss). In other words, they will avert if:

$$U(Q^1, Y - C, S) > U(Q^0, Y, r, S) \tag{3}$$

Based on the reasoning above, consumers who decide not to use bottled water and/or treatment methods have expenditures of zero while those who decide to do so have expenditures greater than zero. Hence, expenditures are conditional on the decision to avert which can be empirically modeled using the Heckman selection model.

Risk Measures

Previous drinking water research uses two main measures for risk, perceived or subjective risk measures and science-based risks. Perceived risk measures are usually based on the construction of proxy variables from safety perceptions of consumers. Some researchers have used rating scales to measure risk (Abdalla, Roach and Epp, 1992) while others simply ask consumers whether they believe their tap water is safe to drink (Abrahams, Hubbell, and Jordan 2000). Science-based risk or objective risk is estimated in terms of probabilities of health outcomes given exposure and then compared to the risk specified by scientists. Although some researchers have found that science-based risks may be quite different from perceived risks (Slovic, 1987), others find little evidence that expert judgment of risk is different from that of the public (Rowe and Wright, 2001).

Although consumers' risk perceptions may or may not be different from scientific-based measures, previous research has established that perceived risk plays an important role in consumers' decisions regarding drinking water. However, how much risk one perceives is only one determinant of averting behavior. Consumers' disposition toward risk can also play an important role in everyday choices by determining how one reacts to any level of exposure to risk (Chavas, 2004). We hypothesize that individuals that are more cautious or risk averse will try to minimize the risks or health concerns related to drinking water by choosing to avert while others may be less willing to avoid such risks at any level of exposure. Using common practice we measure consumers' perceived risk by asking them if they believe their tap water is safe to drink or not.

Our analysis of risk aversion is based on the study by Barsky et al. (1997) who report measures of preference parameters relating to risk tolerance, time preference and intertemporal substitution. Their analysis is based on survey responses from the Health and Retirement Study (HRS) to hypothetical situations about willingness to gamble on lifetime income. The authors find that the risk tolerance coefficient does predict risky behaviors and that measured preference parameters are related to consumer behavior.

The risk aversion measure was elicited using the series of questions developed by Barsky et al. (1997) and used in the U.S. Panel Study of Income Dynamics (PSID) to quantify individual risk tolerance. Respondents were asked a series of questions that involve situations where their income (from what they consider their primary source of household income) was increased or cut with a certain probability. The answers to these questions were used to classify respondents as risk averse or risk tolerant.

An alternative way to elicit risk aversion is via questions involving lottery choices depending on different payoff-risk scenarios. The reason for using income questions is that decisions regarding actual income choices are more similar to decisions regarding water treatment, than are hypothetical gambles. The disadvantage of the income choice questions to evaluate risk aversion is that the questions are somewhat hard to follow and respondents have to skip from one question to another. Although lottery type questions may be easier to follow, they are not as relevant to drinking water quality and related decisions.

Empirical Model

We are ultimately interested in estimating the monetary expenditure response to perceived risk associated with the household's water supply. As is evident from the theoretical model however, this expenditure will be zero if the indirect utility of the status quo (no treatment methods or bottled water) exceeds that under treatment. For individuals that do not avert, the choice of the optimal level of averting expenditures is censored at zero. Hence we first model the choice to avert at all and then we analyze expenditures conditional on this choice in a Heckman selection framework. Clearly, households self select into engagement in averting behavior based on the costs and benefits of such behaviors, though such selection may be fully captured by the observables we control for. However if there are unobserved confounders that affect both the decision to avert and the actual expenditures, least squares estimates of the impact of risk on expenditures would yield inconsistent estimates (Davidson and Mackinnon, 2004). The Heckman selection model involves a procedure where the expenditure equation is modeled conditional on the choice to avert. The dependent variable (expenditures) is not always observed; it is observed when consumers choose to engage in some sort of averting behavior. Let equation (4) be the regression equation for the variable of interest which is treatment expenditures:

(4)

$$\widetilde{y_t} = X_t\beta + u_t$$

and the selection equation which is the decision to treat is given by:

(5)

$$\widetilde{z_t} = W_t\gamma + v_t$$

where:

$$u_t \sim N(0, \sigma)$$

$$v_t \sim N(0, 1)$$

$$corr\ (u_t, v_t) = \rho$$

X_t and W_t are vectors of observations on exogenous variables, β and γ are unknown parameter vectors, σ is the standard deviation of u_t and ρ is the correlation between u_t and v_t. Following Davidson and Mackinnon (2004), the actual variables observed are y_t and z_t, which are defined as follows: (6)

$$y_t = \widetilde{y_t}\ if\ \widetilde{z_t} > 0;\ y_t\ unobserved\ otherwise$$

$$z_t = 1\ if\ \widetilde{z_t} > 0;\ z_t = 0\ otherwise$$

When we observe $z_t = 1$, we also observe $y_t = \widetilde{y_t}$ together with X_t and W_t. When $z_t = 0$, the only variable observed is W_t. More specifically, consumers' expenditures on bottled water or treatment methods are observed only when they choose to purchase bottled water or to use a treatment method. The loglikelihood function can then be written as:

(7)

$$\sum_{z_t=0} \log Pr(z_t = 0) + \sum_{z_t=1} \log\big(\Pr(z_t = 1) f\ (\widetilde{y_t} | z_t = 1)\big)$$

The first term of equation 7 represents observations for which $z_t = 0$ and the second term represents observations for which $z_t = 1$. $f(\widetilde{y_t}|z_t = 1)$ is the density of $\widetilde{y_t}$ conditional on $z_t = 1$. Factoring the joint density function and rewriting v_t in terms of u_t in equation 5, the loglikelihood function becomes:

$$\sum_{z_t=0} log\Phi(-W_t\gamma) + \sum_{z_t=1} log\left(\frac{1}{\sigma}\phi((y_t - X_t\beta)/\sigma)\right) + \sum_{z_t=1} \log\Phi\left(\frac{W_t\gamma + \rho(y_t - X_t\beta)/\sigma}{(1-\rho^2)^{1/2}}\right) \tag{8}$$

The first term of equation 8 corresponds to a standard probit model and the second term corresponds to the loglikelihood function of a linear regression. The third term forces the model to estimate equations 4 and 5 simultaneously. If ρ (correlation between the error terms v_t and u_t) is zero then the probit model and the regression model can be estimated separately.

An important issue in the Heckman selection model is the identification of the parameters in the model. This is a nonlinear model with specific distributional and functional form assumptions so identification can come from nonlinearities that are included in one equation but not the other. It is, however, desirable to impose exclusion restrictions such that at least one of the regressors in the selection equation (equation 5) is excluded from the regression equation (equation 4) (Cameron and Trivedi, 2005). The variable used to identify the model in this analysis is the risk aversion coefficient.

Data and Statistical Analysis

The data for this study were collected through a mail survey conducted in Northern Virginia and Maryland suburbs of Washington DC during late 2007 using a random sampling approach. This area was selected due to the high number of reported failures in public (Clark et. al., 1999) and private plumbing systems (WSSC, 2007), its aging infrastructure and relatively high incidence of other water quality issues such as lead in the water and microbial contamination, relative to the rest of the US. The pool of participants was a randomly selected group from the zip codes that are serviced by the Fairfax Water Utility Authority and the Washington Suburban Sanitary Commission (WSSC). The sample consisted of 5,200 households and was provided by the Survey Sampling International (SSI). The design method for the survey followed the format for mail surveys suggested by Dillman (1978) in order to ensure a high response rate. The survey process consisted of an initial survey which was followed by a reminder card and a second survey sent approximately three and six weeks after the first mailing, respectively. The total number of surveys returned was 1,232, constituting a response rate of 24 percent. The sample size for estimation was reduced to 1113 observations, due to item non-response and incomplete data.

Data from the survey were used to examine averting behaviors and expenditures of participants to avoid any safety or health issues related to tap water in their homes. Data were collected on satisfaction, experiences with drinking water problems, and perceptions of drinking water safety. Participants were also asked whether they use bottled water or any treatment method for their tap water and the reason they do so. In addition, respondents who indicated that they use bottled water or treat their water were asked about their monthly expenditures on bottled water and their annual expenditures on maintaining water treatment devices. Variable definitions and descriptive statistics are presented in table 1.

Consumers' averting decisions were based on whether they use bottled water and/or treatment methods to reduce water related risks. Since consumers may use bottled or treated water for reasons other than safety (such as convenience, taste, odor, appearance, etc), we identify consumers' true averting behavior by further asking them about the reasons they do so. The variable AVERT takes values of 1 if the respondents use bottled water and treatment methods to make sure that their drinking water is safe. AVERT is 0 if the respondents use bottled water and treatment methods for reasons other than safety or if they do not take any action. Of the 1113 respondents, 43 percent use bottled water and/or treatment methods to increase safety and reduce risks of drinking water.

Averting behavior is specified as a function of satisfaction with the tap water quality (SATISFACTION), whether respondents believe their tap water is safe to drink (SAFE), consumers' risk aversion coefficient (table 2), respondents' awareness of problems with water in their neighborhood (PROBLEMS), problems or concerns regarding taste (TASTE), odor (ODOR), color (COLOR) and particles (PARTICLES), presence of children under 18 in the household (CHILDREN) and a series of demographics variables including age (AGE), gender (GENDER), race (RACE), income (INCOME) and education (EDUCATION). Eighty-six percent of respondents are satisfied with their water quality and 84 percent think that their tap water is safe to drink. Only about 8 percent of respondents are aware of water problems in their neighborhood. In addition, 36 percent of respondents reported having problems or concerns with the taste of their tap water, 25 percent with the odor of water, 13 percent with the color of water and 11 percent with particles in the tap water. The sample consists of 61.3 percent male respondents and 78.7 percent white respondents. On average, respondents were 54 years of age with 76.8 percent of them having earned a four year college degree or higher. Thirty-five percent of respondents had a child under the age of 18 living in the household. The average annual household income in the sample is slightly below $129 thousand.

Based on whether consumers engage in averting activities, they were asked about their expenditures on bottled water and/or treatment methods. We assume that respondents who did not report using bottled water or water treatments incur expenditures that are equal to 0. On average consumers reported spending $161 a year on bottled water, water treatment methods or a combination of the two. Consumers' expenditures are assumed to be a function of their safety perceptions for the tap water (SAFE), whether bottled water and/or treatment was used to improve the palatability of water (PALATABILITY), whether children under 18 are present in the household (CHILDREN) and respondents' demographic characteristics.

Risk Aversion

The risk aversion measure is an empirical measure developed by Barsky et al. (1997) and used in the national survey of Panel Study of Income Dynamics (Luoh and Stafford, 2007). Respondents were asked a series of questions about their willingness to take jobs that offer a 50-50 percent chance of doubling their income or cutting it with a certain proportion. If respondents accept the job, a second job was offered that either doubles their income or cuts it by a higher proportion than the first offer. If they reject the first job, the second job offered doubles their income or cuts it by a lower proportion than the first offer, with a 50-50 chance.[5] A third job option was then offered whose income depended on the response to the second offer. Based on answers to these questions, respondents were arranged in six main groups of risk tolerance and another four groups with wider range of risk tolerance because of item non-response or incomplete answers to some of the questions (table 2). Answers to the income questions were then converted to a risk tolerance index.

Following Luoh and Stafford (2007), we assume the utility function is given by $U(c) = (1/(1-1/\theta))c^{1-1/\theta}$ where θ is the risk tolerance. Also assume that θ is log-normally

[5]The complete range of the questions asked is presented in the appendix.

distributed such that $X=ln(\theta)$ is normally distributed. X is not directly observed, instead we observe X^* and the category it falls in.

$$X^* \text{ in group i, if } B_{i-1} < X < B_i \tag{9}$$

where B_i is the cutoff point of X determined from the survey questions that makes the individual indifferent between two income risk choices. The likelihood function can be written as the product of the probabilities of being in a particular group. Maximizing the likelihood function yields estimates of the mean and standard deviation. The conditional mean of θ can then be estimated for each group as presented in table 2. The higher the value of θ, the more risk tolerant the individual is. No parametric assumptions are made about the distribution of the risk aversion measure. The risk aversion variable is included in the decision equation in the form of binary variables corresponding to each category of risk (see table 2).

Estimation Results

The results of the Heckman selection model are presented in table 3. The first step models the decision to avert because of safety concerns (selection model) and the second step models the total costs of averting expenditures (expenditure model). The perceived risk measure (SAFE) is significant in both the decision to avert and the expenditure model. Respondents who perceive their tap water as not safe are more likely to use bottled water and/or treatment methods and more likely to spend more on such averting behaviors. Similar results about perceived risks for tap water were also found by Abrahams, Hubbell and Jordan (2000). In the selection equation, the risk aversion variables are not significant with the exception of the extreme risk categories. RISK11 (very risk tolerant) and RISK66 (very risk averse) are significant but not with the expected sign. These findings may imply several things. Individuals may not respond in the same way to all risky situations such as financial, social or health risks; risk behaviors may be different in different circumstances. Therefore measuring risk tolerance using gambles over lifetime income may not be a good predictor for risk averting behavior regarding drinking water. Another implication is that respondents may value their current jobs because of attributes other than the income they get. As a result, they may be unwilling to accept any of the hypothetical situations and answer negatively to all the questions. Due to the nature of the survey questions, there may be problems of whether respondents are giving accurate answers. Administering these questions in person may be a better but more costly survey method.

We find that the decision to avert is significantly affected by whether respondents were satisfied with their tap water (SATISFACTION). Respondents who were satisfied were less likely to demonstrate averting behavior. Being aware of problems related to tap water in the neighborhood (PROBLEMS) or having had problems or concerns with odor (ODOR) or particles (PARTICLES) in the water positively influence the decision to engage in averting behavior. Also, males (MALE), whites (WHITE) and older respondents (AGE) were less likely to treat their water or use bottled water. Presence of children under 18 in the household is not significant in the decision to buy bottled water or use treatment devices.

The expenditures for bottled water and treatment methods are significantly affected by the measure of perceived risk and income. Consumers' perceived risk (SAFE) negatively affects the amount spent on treatment of water. Respondents who perceive tap water as unsafe are more likely to increase spending on safer alternatives. PALATABILITY is positive and significant in consumer spending decisions suggesting that expenditures increase if consumers use bottled water and treatments to improve the taste, smell or clarity of water. In addition, respondents with higher household income (INCOME) are more likely to spend more on treating tap water or using bottled water.

Conclusions

This paper investigates the effect of risk perception measures on averting behaviors and expenditures for improved drinking water quality in Northern Virginia and Maryland suburbs of Washington DC. Results show that respondents' perceptions of water safety together with their awareness, concerns and problems with attributes of tap water are important determinants in the decision to undertake averting behaviors. These findings indicate that efforts by policymakers to communicate effectively to the public information on current problems can alter the public's usage of tap water. We find that consumers' general attitudes towards risk as measured by the risk aversion coefficients do not affect the decision to avert. Measures of perceived risk in terms of perceived safety about the tap water are better predictors of consumers' averting decisions and expenditures. There is a need for future research in designing measures of risk preferences that may apply to health risk situations and better explain consumer behavior regarding drinking water.

References

Abdalla, C.W., B.A. Roach and D.J. Epp, 1992. "Valuing Environmental Quality Changes Using Averting Expenditures: An Application to Groundwater Contamination." *Land Economics* 68(2), 163-69.

Abrahams, N. A., B. J. Hubbell and J. L. Jordan, 2000. "Joint Production and Averting Expenditure Measures of Willingness to Pay: Do Water Expenditures Really Measure Avoidance Costs?" *American Journal of Agricultural Economics* 82(2), 427-437.

Barsky, R. B., F. T. Juster, M. S. Kimball and M. D. Shapiro, 1997. "Preference Parameters and Behavioral Heterogeneity: An Experimental Approach in the Health and Retirement Study." *The Quarterly Journal of Economics* 112(2), 537-579.

Blomquist, Glenn C., 2004. "Self Protection and Averting Behavior, Values of Statistical Lives, and Benefit Cost Analysis of Environmental Policy." *Review of Economics of the Household* 2(1), 89-110.

Cai, Y., W. D. Shaw and X. Wu, 2008. "Risk Perception and Altruistic Averting Behavior: Removing Arsenic in Drinking Water." Paper Presented at AAEA Annual Meeting, Orlando, Florida.

Cameron, A.C. and P. Trivedi, 2005 *Microeconometrics: Methods & Applications*. Cambridge University Press.

Chavas, J.P., 2004. *Risk Analysis in Theory and Practice*. Academic Press (Elsevier), New York.

Clark, R. M., G. S. Rizzo, J. A. Belknap and C. Cochranes. 1999. "Water Quality and the Replacement and Repair of Drinking Water Infrastructure: The Washington DC Case Study." *Aqua* 48(3), 106-114.

Davidson, R. and J. D. MacKinnon, 2004. *Econometric Theory and Methods*. Oxford University Press.

Dillman, D. A. 1978. *Mail and Telephone Surveys: The Total Design Method*. New York: John Wiley and Sons.

Duhigg, C., 2009. "Toxic Waters: Clean Water Laws are Neglected, at a Cost in Suffering." *New York Times*, September 13, 2009.

Heckman, J. J., 1979. "Sample Selection Bias as a Specification Error." *Econometrica* 47(1), 153-161.

Jakus, P.M., D.W Shaw, T.N. Nguyen and M. Walker, 2009. "Risk Perceptions of Arsenic in Tap Water and Consumption of Bottled Water." *Water Resources Research* 45, W05405.

Larson, B.A. and E.D. Gnedenko, 1999. "Avoiding Health Risks from Drinking Water In Moscow: An Empirical Analysis." *Environmental and Development Economics* 4, 565-581.

Luoh, M. and F. Stafford, 2007. "Estimating Risk Tolerance from the 1996 PSID." Available on-line at: http://psidonline.isr.umich.edu/Data/Documentation/Cbks/Support.html.

McConnell, K.E. and M.A. Rosado. 2000. "Valuing Discrete Improvements in Drinking Water Quality Through Revealed Preferences." *Water Resources Research* 36, 1575-1582.

Poe, G. L. and R. C. Bishop, 1999. "Valuing the Incremental Benefits of Groundwater Protection When Exposure Levels are Known." *Environmental and Resource Economics* 13(3), 347-373.

Rowe, G. and G. Wright, 2001. "Differences in Expert and Lay Judgments of Risk: Myth or Reality?" *Risk Analysis* 21(2), 341-356.

Slovic, P., 1987. “Perception of Risk.” *Science* 236, 280-285.

Smith, V.K. and W.H. Desvousges, 1986. “Averting Behavior: Does It Exist?” *Economics Letters* 20, 291-96.

Washington Suburban Sanitary Commission (WSSC). 2007. http://www.wsscwater.com/index.cfm.

Whitehead, J. C., T. J. Hoban and G. Van Houtven, 1998. “Willingness to Pay and Drinking Water Quality: An Examination of the Averting Behavior Approach.” 68th Annual Conference of the Southern Economic Association in Baltimore, Maryland.

Table 1. Variable Definitions and Summary Statistics

Variable	Definition	Mean (n=1113)	Standard Deviation
TCOST	Total annual cost of water treatment devices and bottled water use	161.464	178.342
PALATABILITY	Palatability index of whether respondents use bottled water to improve the taste of water or use treatment devices to improve clarity, taste or smell, range from 0 to 1	0.309	0.263
CHILDREN	1 if children under 18 are present in the household, 0 otherwise	0.351	0.478
COLLEGE	1 if the education level of the respondent is college or above, 0 otherwise	0.768	0.422
AGE	Respondent's age	54.251	13.586
INCOME*	Respondent's annual income, $1000	128.935	81.055
WHITE	1 if respondent is white, 0 otherwise	0.787	0.410
MALE	1 if respondent is male, 0 otherwise	0.613	0.487
AVERT	1 if respondents engage in any type of averting behavior because of safety issues, 0 otherwise	0.430	0.495
SATISFACTION	1 if respondents are very satisfied or somewhat satisfied with the quality of their tap water, 0 otherwise	0.861	0.346
PROBLEMS	1 if the respondents are aware of problems with the drinking water in their neighborhood, 0 otherwise	0.079	0.270
SAFE	1 if respondents think their tap water is safe to drink, 0 otherwise	0.841	0.366
TASTE	1 if respondents had any problems or concerns with the taste of their tap water, 0 otherwise	0.356	0.479
ODOR	1 if respondents had any problems or concerns with the odor of their tap water, 0 otherwise	0.251	0.434
COLOR	1 if respondents had any problems or concerns with the color of their tap water, 0 otherwise	0.130	0.336
PARTICLES	1 if respondents had any problems or concerns with particles in their tap water, 0 otherwise	0.106	0.308

*Missing income values are imputed

Table 2. Risk Aversion Statistics

Group	Sample	Percent	Accept[a]	Reject[b]	E(θ | X*)
RISK11	25	2.52	3/4	None	8.295
RISK22	59	5.94	1/2	3/4	1.758
RISK33	140	14.10	1/3	1/2	0.711
RISK44	195	19.64	1/5	1/3	0.369
RISK55	178	17.93	1/10	1/5	0.193
RISK66	129	12.99	None	1/10	0.062
RISK12	18	1.81	1/2	--	3.619
RISK13	21	2.11	1/3	--	2.424
RISK46	158	15.91	--	1/3	0.171
RISK56	70	7.05	--	1/5	0.107

Source: Luoh and Stafford, 2007

Note: [a] Accept income being reduced by this proportion

[b] Reject income being reduced by this proportion

Table 3. Estimation Results from the Heckman Two-Step Model

Variable	Coefficient	Standard Error
Expenditure Model		
CONSTANT	220.197**	54.032
SAFE	-59.403**	26.730
PALATABILITY	97.699**	35.328
CHILDREN	29.207	21.043
AGE	-0.433	0.821
WHITE	15.934	23.446
COLLEGE	13.555	21.779
MALE	-5.642	18.655
INCOME	0.001**	0.001
Selection Model		
CONSTANT	2.030**	0.297
SATISFACTION	-0.490**	0.138
PROBLEMS	0.283*	0.155
SAFE	-0.743**	0.124
TASTE	-0.091	0.101
ODOR	0.201**	0.102
COLOR	0.008	0.132
PARTICLES	0.328**	0.147
CHILDREN	-0.076	0.100
AGE	-0.012**	0.004
WHITE	-0.567**	0.108
COLLEGE	0.008	0.102
MALE	-0.143*	0.085
INCOME	1.02e-08	5.81e-07
RISK11	0.527*	0.305
RISK22	0.006	0.206
RISK33	-0.138	0.155
RISK44	-0.129	0.143
RISK66	-0.591*	0.307
RISK56	-0.097	0.196
RISK46	-0.029	0.152
RISK13	0.181	0.317
RISK12	0.432	0.366
MISSINGRISK	-0.187	0.152

*Indicates significance at the 10% level
** Indicates significance at the 5% level

Appendix

Risk Questions from the Mail Survey

People make decisions everyday that involve risk. For example, every time someone drives a car there is a chance they could have an auto accident. The following questions are designed to assess your willingness to take risks.

1. Consider a job that guarantees you income for life equal to your current total income. Assume that this is your/your family's only source of income. Now suppose you are given the opportunity to take an equally good job with a 50 percent chance that it would **double your/your family income** for life. But there is a 50 percent chance that it would **cut your income by a third**. Would you take the new job? (CIRCLE ONE NUMBER)

    1. Yes, I would take the new job
    2. No, I would stay with the job that guarantees my income
    3. Don't know

If you answered "No" or "Don't know", please go to question 3.

2. Now, suppose the chances are 50 percent that the new job would **double your/your family income**, and 50 percent that it would **cut it in half**. Would you still take the new job? (CIRCLE ONE NUMBER)

    1. Yes, I would take the new job
    2. No, I would stay with the job that guarantees my income
    3. Don't know

If you answered "Yes", please go to question 5.

If you answered "No" or "Don't know", please go to the next round of questions.

3. Now, suppose the chances are 50 percent that the new job would **double your/your family income**, and 50 percent that it would **cut it by 20 percent**. Then, would you take the new job? (CIRCLE ONE NUMBER)

   1. Yes, I would take the new job
   2. No, I would stay with the job that guarantees my income
   3. Don't know

If you answered "Yes", please go to the next round of questions.

4. Now, suppose that the chances are 50 percent that the new job would **double your/your family income**, and 50 percent that it would **cut it by 10 percent**. Then, would you take the new job? (CIRCLE ONE NUMBER)

   1. Yes, I would take the new job
   2. No, I would stay with the job that guarantees my income
   3. Don't know

Please go to question the next round of questions.

5. Now, suppose that the chances were 50 percent that the new job would **double your/your family income**, and 50 percent that it would **cut it by 75 percent**. Would you still take the new job? (CIRCLE ONE NUMBER)

1. Yes, I would take the new job
2. No, I would stay with the job that guarantees my income
3. Don't know

CONCLUSION

Problems with drinking water have been reported recently in different parts of the country. For instance, there has been an increasing number of leaks in the drinking water pipes of private residences due to copper corrosion (Bosch et. al., 2006). In addition, failures in public water infrastructure due to aging cause breaks in the water main and are worrisome for consumers (Brongers, 2002). In certain areas, there have also been problems with lead in the water and microbial contamination that affect the general quality and safety of drinking water (Edwards et al., 2009). These problems have attracted the regulatory attention of water management and policymakers. Although causes of such problems are being investigated, there is a lack of information on consumer demand for solutions to these problems and consumers' support for improvements in the public water system. Public officials need to know the value consumers place on improvements in order to devise new policies and investment programs to insure compliance with the Safe Drinking Water Act. Consumers' perceptions and attitudes about public water, information, satisfaction, concerns and awareness, experiences, costs of improvements and socioeconomic characteristics may all play a role in consumers' demand for better public water supply.

The first paper entitled "Willingness to Pay for Improvements in Home Drinking Water Infrastructure" estimated consumers' willingness to pay for an improved piping material that will remain leak free and the determinants that affect their decision. Damages to private property from pinhole leaks are estimated to range from $600 to $30,000 per residence. In addition, pinhole leaks are associated with potential health and environmental issues and can alter the attributes of drinking water such as the taste, color and odor. In a national survey to homeowners we found that on average 11 percent of respondents were affected by pinhole leaks with rates as high as 23 percent. These outbreaks have attracted the attention of authorities to take measures to address consumer concerns and find solutions to corrosion problems. However there is a lack of information on consumers' demand for improvements in piping materials as well as willingness to pay to support investments. We find that the determinant of willingness to pay include the bid amount, income, education, age, concerns for leaks in the future and satisfaction with the water quality. There is no significant difference in the determinants of willingness to pay of respondents who had experienced leaks and those who had not. Our analysis also suggests that consumers are willing to pay on average $400 to $536 for a material that will remain leak free and to avoid the risk of getting pinhole leaks in their residence in the future. These results indicate that there is a strong demand for improved products. Companies and research corporations can benefit consumers and themselves by investing in the development of new products or improvement of existing ones. Policymakers and regulatory agencies can use this information to invest accordingly in water infrastructure in order to ensure compliance with the Safe Drinking Water Act. Estimated willingness to pay is a good measurement of potential support in investment from the public.

The second essay is entitled "On Consumers' Attitudes and Willingness to Pay for Improved Drinking Water Quality and Infrastructure." Reported failures in the drinking water system have increased recently in certain areas. These failures may come as a result of problems and breaks in the public water infrastructure because of aging, leaks in the home plumbing because of corrosion in copper pipes or other issues with drinking water such as lead, contamination, arsenic, etc that affect the quality of drinking water. Such failures have prompted the attention of water management and authorities for needed action to address problems. Investments in water infrastructure enhancement and compliance with regulations need to account for consumers' demand for such improvements. This study investigated the determinants of consumers' willingness to pay for three specific programs: a water quality improvement program, a pinhole leak damage insurance program and a water utility infrastructure upgrade. A multinomial logit framework is used to model consumers' willingness to pay for needed improvements. Since consumers evaluate all three programs and the respective costs and characteristics simultaneously, the same set of explanatory variables is used for each choice of program. We also investigate the effect of information and risk perceptions on the decision to support a program. We find that information given to consumers and cost of the program affect willingness to pay for improvements. This suggests that policymakers' efforts to better inform consumers of current problems and investment needs for water distribution systems will be rewarded as consumers will use the information to make appropriate decisions or support public actions to address the issues. Results also show that consumers are the most supportive of programs that will improve public water infrastructure. This result suggests that drinking water policymakers and program managers aim more of their efforts toward investments in public infrastructure, which will receive more support from consumers.

The third essay is entitled "Risk Measures and Averting Behavior for Drinking Water Quality." Problems with the quality of drinking water prompt consumers to take action to protect themselves from adverse effects and potential risks. The two previous studies have established that there is a consumer demand for improvements in public water supply. Besides the demand for improved public water supply, consumers may address the need for improved services by investing in treatment methods for their water or by consuming bottled water. This essay investigates the factors that affect consumers' decisions to treat their water and/or use bottled water and the consequent expenditures associated with their averting decisions. Particular consideration is given to the role of consumers' risk perceptions and their general attitudes towards risk. Results show that the decision to avert is affected by consumers' satisfaction with water quality, previous problems, awareness of problems in their neighborhood and socioeconomic characteristics. Spending on treatment methods and bottled water increased with consumers' income and water palatability problems. In addition, we find that consumers' perceptions about the safety of drinking water play an important role in their decision to treat drinking water as well as their spending on drinking water treatments. Water authorities can provide information and educate consumers about the quality of public water to assist them in the decision about usage of tap water. Expenditures on alternatives to public water supply such as water treatment and bottled water convey information on consumers' willingness to pay for improved quality. These estimates provide a measure for the demand for improvements to public officials that may predict public support for future investments.

Results of this dissertation provide valuable information on consumers demand for improvements in drinking water quality and infrastructure and on the extent of consumer support for investment programs. Results can be useful for policy makers and regulatory agencies in designing protection plans and investment programs that will ensure a safe drinking water supply. In addition, these studies represent an extension of conventional valuation methods to public and private drinking water infrastructure.