Environ Resource Econ (2012) 52:23–48
DOI 10.1007/s10640-011-9517-3

Heterogeneity in Values of Morbidity Risks from Drinking Water

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Accepted: 4 September 2011 / Published online: 1 October 2011

Abstract This paper reports the stated preference values for reducing the morbidity risks from drinking water estimated using a nationally representative U.S. sample of 3,585 households. Based on the average annual gastrointestinal (GI) illness risk in the U.S. from drinking water of about 5 illnesses per 100 population, eliminating the GI risk has a median annual value per household of $219. The considerable heterogeneity in the values arises largely from differences in attitudes towards risk and price sensitivity. Using interval regressions, we find that valuations are greater for those who perceive a high personal risk, consume a large quantity of tap water, or are environmentalists. The paper explores several methodological issues pertaining to the iterative choice format involving a choice between two policies characterized by their cost and GI risk. The analysis adjusts for starting point effects by basing valuations on the tradeoffs that are estimated to prevail at the "equitable tradeoff rate," which is the starting cost-water quality tradeoff rate that produces a 50–50 split in the initial policy choice between policies with greater tradeoff rates and policies with lower tradeoff rates. The heterogeneity in valuations is also explored by examining quantile regression results and the determinants of the unbounded valuation amounts at the low and high extremes.

Keywords Drinking water · Gastrointestinal illness · Morbidity risk · Stated preference survey · Willingness to pay · Starting point bias

Abbreviations

GI	Gastrointestinal
KN	Knowledge Networks
EPA	U.S. Environmental Protection Agency

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1 Introduction

Drinking water is one of the most fundamental economic commodities. Public entities, usually municipalities, supply the product, and the quality of drinking water in the U.S. is subject to U.S. Environmental Protection Agency (EPA) regulations that limit risks to very low levels. As a consequence, drinking water is often characterized as being "safe," with little communication to the public about the existence of any possible risks.

Nevertheless, drinking water in the United States is not risk-free.[1] There is substantial evidence that some municipal water supplies are often not in compliance with federal standards.[2] There are also gaps in the regulatory structure, as there is little national regulation of community wells, and private wells are not regulated at all. As a result, drinking water may pose some risks, with the health hazards ranging from minor temporary discomfort to cancer. These shortcomings in drinking water quality have led to proposals by the EPA to overhaul the enforcement of drinking water laws and the Clean Water Act more generally. The focus of this article is on acute gastrointestinal (GI) illness, which is the most prevalent health risk posed by contaminated drinking water. The annual individual risk of acute gastrointestinal illness from drinking water is about 1 in 20 in the U.S., so experiencing such ill effects is not a rare event.[3]

While drinking water is a universal commodity, the preferences for drinking water safety are not uniform. People differ widely in their adverse experiences with drinking water, their fears concerning such hazards, and their risk beliefs. We will show that these variables affect how much a person values reducing the risks posed by drinking water. Similarly, we will show that valuations rise in response to the total risk exposure with the total volume of drinking water consumed. Thus, we will demonstrate that valuations of risk reduction are responsive to perceived and actual risk levels.[4]

To examine the public's valuation of reducing the risks of drinking water illnesses, we use an original, nationally representative, stated preference survey, which is described in Sect. 2. With a sample of 3,585 households, whose characteristics are described in Sect. 3, our results provide national representation of drinking water conditions while providing information of the diverse populations who consume it. As the analysis in Sect. 4 indicates, valuations of drinking water illnesses vary considerably, but in a manner that is related to the differences in perceived and actual personal risks.

Risk factors, rather than conventional economic variables, appear to be most influential. The annual value of eliminating the average risks of acute gastrointestinal illnesses (GI) from drinking water is right-skewed, with a median of \$219 and a \$525 mean. Applying these estimates nationally, if GI risks from drinking water were completely eliminated, the total benefit to U.S. households would be \$59 billion annually.[5]

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[1] Charles Duhigg, "Millions in U.S. Drink Dirty Water," *New York Times*, Dec. 8, 2009, and Charles Duhigg, "That Tap Water Is Legal but May Be Unhealthy," *New York Times*, Dec. 17, 2009.

[2] See Duhigg, *supra* note 1, and Rahman et al. (2010).

[3] Colford et al. (2006) estimate that the total number of acute GI cases annually in the U.S. is 4.26–11.69 million, which corresponds to a risk range of 1.4 to 3.4%. Messner et al. (2006) estimate a mean number of acute gastrointestinal illness cases of 16.4 million, which corresponds to an annual risk of 6%, with an estimated range from 2 to 12%. Also see United States Environmental Protection Agency (1994–2002)

[4] Previous studies have established the substantial value of safe water both in the United States as well as in other countries. See Harrington et al. (1989), Freeman (2000), Innes and Cory (2001), McConnell and Rosado (2000), Hensher et al. (2005) and Olmstead (2010).

[5] This estimate is constructed using the annual number of cases of GI illness in Messner et al. (2006), and 2008 Census figures for number of households.

Our examination of the valuations implied by the iterative choice survey results leads to an examination in Sect. 5 of a series of methodological issues pertaining to the survey structure. The potential influence of starting point effects arising from the initial water quality-cost tradeoff rate presented to respondents is taken into account through the initial tradeoffs used, generating explicit controls for starting point effects in the regression analysis, and determination of the valuations based on what is termed the "equitable tradeoff rate," which is the initial tradeoff rate that produces a 50–50 split between choices favoring higher valuations and choices favoring lower valuations among respondents. The heterogeneity of responses is also explored using quantile regression analysis and determinants of whether the respondent reaches the upper or lower bound of the permitted tradeoff rate in the iterative choice task.

2 Survey Structure

The general research approach involved the use of a stated preference survey administered to a nationally representative Web-based panel. This research extends the survey and analytic methodology developed in Viscusi et al. (2008). That survey dealt with the recreational value of water quality in lakes and rivers, but explicitly excluded drinking water. By contrast, this survey deals exclusively on the value of reducing risk from drinking water. In addition, the choice task is quite different from that in Viscusi et al. (2008), which involved the decision to move to a different region, while this survey pertains to policy choices involving one's current region.

The survey engaged the respondents in the general topic area before introducing information on the hazards from drinking water. This introduction instructed respondents to answer the survey on behalf of themselves as well as any family members living in their household, then probed them with respect to how much they spend getting water to their homes, how much water they drink, their usage of bottled water and water filters, their experiences with unpleasant or smelly water, and risk beliefs pertaining to water.

The survey focused respondent attention on the main morbidity effect that would be considered in the survey:

> The most common sickness caused by drinking contamination is called Gastrointestinal (GI) illness. Contaminants in water can cause nausea and vomiting, diarrhea, stomach pain, and sometimes a fever. Such illnesses usually last from 2 to 14 days, but average about a week before all symptoms end.

This generic language was intentionally inclusive of a range of acute but limited GI illnesses related to water while avoiding technical or medical terminology. Longer term risks, such as cancer, were not included in questions concerning morbidity outcomes.

The survey inquired about whether the respondent had experienced acute GI illness symptoms from food or drink, the length of each of the illnesses, and whether they thought the illness was due to drinking contaminated water. Thus, the first aspect of the benefit valuation task was to ensure that respondents had a firm understanding of the health outcome and its effect on their welfare. As will be shown later, these experiences did not significantly affect valuations, whereas fears of these outcomes did.

After completing the characterization of the health outcome, the survey described the broader context of GI disease in the United States. Respondents learned the annual number of GI illnesses in the U.S. and that children under the age of 10, the elderly, and those

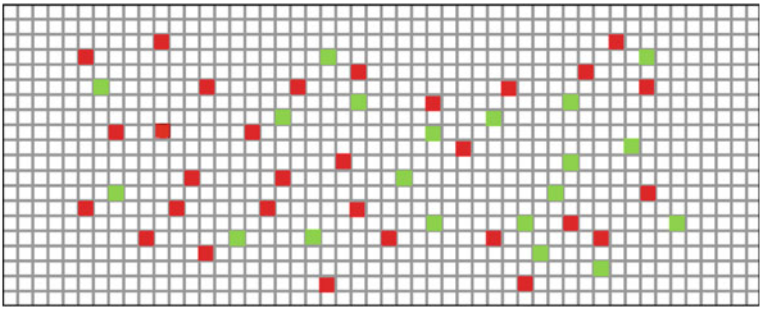


Fig. 1 Sample survey text for the treatment choice question

with compromised immune systems generally face greater risks.[6] Throughout the study the information presented to respondents accorded with scientific estimates of the actual risk levels.

The survey focused on the value of reductions in the GI risk of drinking water. Rather than conveying risk information in terms of an average probability of GI illness, the survey framed that statistic in terms of the number of annual cases per year in a population per 1,000 people. The use of frequencies rather than probabilities is less abstract and can assist respondents in conceptualizing the risk.[7] The denominator of 1,000 was used rather than 100 to permit greater variation in the magnitudes of the risk reduction that could be presented to respondents in the survey questions.

Inclusion of concrete information about the denominator avoids what Viscusi and Zeckhauser (2004) have called the “denominator blindness effect.” Their experimental studies showed that when people are not told the denominator for the frequency information that they tend to overestimate the risk levels associated with a larger numerator. Our presentation of the risk information addresses the denominator blindness effect in three ways that differ from the Viscusi and Zeckhauser (2004) experimental scenarios. Respondents (i) are given explicit information on the numerical value of the denominator in the frequency calculation, where this denominator value of 1,000 is held constant for all choices, (ii) are presented with a grid of 1,000 squares equal to the risk denominator that is then used to characterize the risk probability, and (iii) are given a risk ladder in terms of relative risk levels for a denominator of 1,000 to put the probability value in perspective.

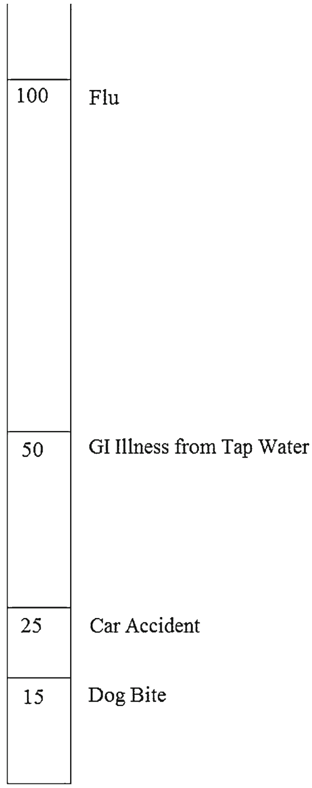
In addition to limiting distortions from the denominator blindness effect, the presentation of visual aids assists respondents generally in their understanding of the meaning of a change in the probability of getting the illness.[8] Respondents were presented with a grid of 1,000 squares. Respondents then learned about the baseline risk level for the decision with the frequency of red squares on a grid, while a reduction in that risk was illustrated with green squares. As shown in Fig. 1, a baseline risk of 50 that was reduced to 30 was represented by 50 red squares randomly placed in a grid of 1,000 squares, 20 of which turned green to indicate the risk change.

6 The 15 million GI illness figure that subjects were told is a compromise between the 16.4 million estimate in Messner et al. (2006) and the lower estimate in Colford et al. (2006) of between 4.3 million and 11.7 million illnesses.

7 See Gigerenzer and Hoffrage (1995).

8 Corso et al. (2001) examine the benefits of using such visual aids.

Fig. 2 Survey text for the risk ladder



Respondents also received relative risk information that was displayed both visually and numerically using a risk ladder. To better ensure that respondents had a context for the magnitude of risks being discussed, they were given information regarding three other risks of approximately the same magnitude: being bitten by a dog, involvement in a traffic accident, and catching the flu. The relative annual risks of these events were compared to the risk of GI illness using a risk ladder as shown in Fig. 2, with lower risks placed below GI illness, and the greater risk above.

The main valuation task asked respondents to indicate whether they would be willing to pay for a policy value that would reduce their risk level. In this pairwise choice task, one policy option is the status quo, whereas the other policy option reduces the GI risk but at increased costs. This framework differs from that in Magat et al. (2000) and Viscusi et al. (2008), which involved a choice to move to one of two regions, neither of which was the respondent's current region. The survey approach involving policies for one's current region consequently imposes fewer cognitive demands in that it does not require that respondents envision the characteristics of two hypothetical regions to which they might relocate. Neither of the regional choices in the previous studies involved the respondent's current home, whereas all the choices in this study pertain to the current home situation, with one option being the respondent's current water quality-cost levels. This framing has additional ramifications as well, as indifference in this drinking water survey is with respect to the respondent's preference for or against a policy that reduces the risk at greater costs, whereas indifference in a regional choice pairing task requires assessment of two different risk levels and two different cost amounts. The regional choice comparison structure consequently requires that respondents consider twice as many parameters in formulating a preference compared to the policy choice structure used here.

The structure of the policy question used in our survey is not only linked to the respondent's current region but also takes into account specific aspects of their water supply situation, in particular, whether they are on municipal water supplies or obtain their water from a well. Well users read the following text instead of the first sentence in Fig. 1: "Imagine that you could purchase a new treatment for the water that comes to your home faucet. This treatment would increase the yearly cost for your tap water and also reduce the risk of GI illness." Additionally, for those on municipal water supplies, respondents were told in preceding questions that risk could be reduced through improved treatment methods: "More expensive methods, using additional rounds of filtering or disinfecting, employing more expensive filter material, or employing new technologies might remove more contaminants." Those on well water systems likewise received information about water treatment options that would reduce their risk levels: "Carbon filters can be used to remove contaminants, a process called reverse osmosis can be used to remove impurities, and even ultraviolet light can be used to destroy harmful organisms in water." Respondents were given the option of staying with their current treatment regime or paying a higher water bill for those on municipal treatment or paying a higher yearly cost for treatment of their well water for respondents on well water. The cost increases in the initial choice in the different surveys ranged from \$20 to \$120 per year.[9]

Following the first choice, a series of iterative pairwise comparisons served to isolate the individual's tradeoff rate between water treatment costs and risk. Respondents considered a choice between their current treatment and a new lower risk, higher cost treatment option. After indicating a preference, the iteration process continued until subjects reached a point of indifference between the options or until they switched their choice. The indifference responses were then used to estimate the tradeoff levels between risk and cost, as discussed below.

Figure 1 illustrates a possible choice for a respondent on municipal water supplies. In this example, with no new treatment the GI illness risk is 50 per 1,000, but with new treatment the GI risk is 30 per 1,000 at an additional annual cost of \$100. Thus, \$100 is pitted against a 20/1,000 reduction in the likelihood of avoiding illness in the household, reflecting a starting trade-off ratio of \$5 per 1/1,000 risk. The respondent has the option of choosing the new treatment, no new treatment, or indicating indifference. For those indicating indifference to the pair of choices shown in Fig. 1, the risk reduction of 20/1,000 is worth \$100, implying that reducing the risk from 50/1,000 to zero is worth \$250. The value of this ratio potentially could induce a starting point bias in subsequent responses. This possibility is explicitly addressed in both the survey design and the empirical estimation, as discussed below.

Figure 3 illustrates the iterative process for this particular set of initial choices. For all survey choice sets, the objective of the series of options is to present a succession of trade-off rates that are designed to lead respondents to a point of indifference, or to switch from their initial choice to the other option in order to put numerical bounds on their value. If respondents initially prefer the new treatment, the next question in the iteration decreases its effectiveness for the same cost, making the new treatment less attractive. Analogously, if respondents initially prefer the current lower cost treatment, in the next choice the cost of the new treatment declines, making it more attractive than in the previous question. The goal is to reach a point of indifference or to place bounds on each respondent's valuation.

9 By way of comparison, Levin et al. (2002) estimate increased water treatment costs in the first decade of this century of \$38 billion, or an average total cost increase of over \$50 per year for households receiving a water bill from a utility.

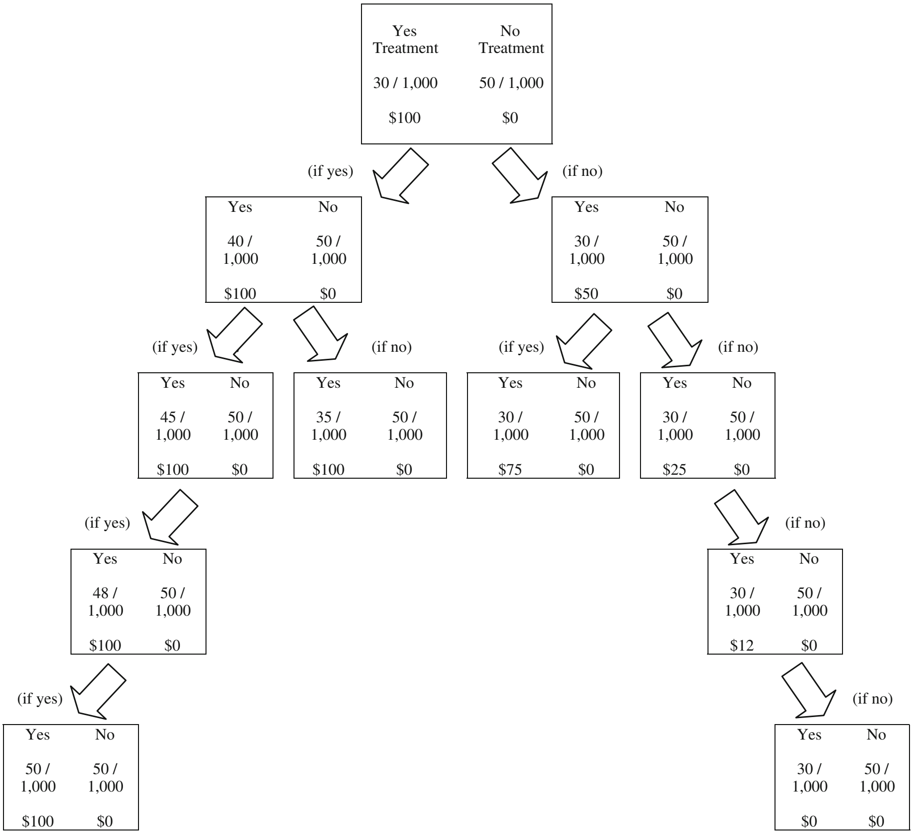


Fig. 3 Survey decision tree: starting cost difference of $100, starting risk difference of 20/1,000

Respondents are allowed to persist in choosing a particular direction until they reach one of the dominated choices shown in the lower corners of Fig. 3. Thus, those who always prefer the status quo on the right side of the survey decision tree might choose it over a policy with the same cost but lower risk. Similarly, for those who persist in choosing the new treatment and follow the path on the left side of the decision tree, the final choice offers no risk improvement but imposes an additional cost. Both of these responses are irrational, and respondents are told they may have misinterpreted the question and given the chance to revise their response. However, respondents who persist in choosing the dominated alternative are labeled inconsistent and excluded from the analysis. This rationality test eliminates respondents who make choices that do not adhere to basic principles of economic rationality. Overall, 13% of the sample failed this test.[10]

Those who reach a corner but do not prefer a dominated choice have values that are unbounded on one side. The distribution of those reaching the corners was very even, with 6% unbounded at the high end and 8% unbounded at the low end.[11] While tradeoff values

10 Analysis of sample selection effects using standard Heckman selection procedures failed to indicate any statistically significant selection effect from excluding these respondents from the regression analysis.

11 A previous survey on a different topic but with a similar question structure discussed in Viscusi et al. (2008) had 5% inconsistent responses and 19% unbounded responses.

might have been determined for these respondents by continuing the iterations, in this analysis these values are estimated using interval regression.

In addition to testing whether each respondent passed a dominated choice task, the survey also incorporated other validity tests to examine the general consistency and rationality of the responses. The results pass the more standard overall scope test as higher costs decrease the attractiveness of a choice, while greater risk reductions increase the likelihood that the option will be selected. We also will show that the results pass other more refined affective scope and behavioral scope tests such as those developed by Heberlein et al. (2005) for environmental surveys generally. The respondents pass affective scope tests as those who indicate that they are environmentalists[12] or have higher risk beliefs regarding drinking water were found to value water quality improvements more highly. The results are also consistent with behavioral scope tests as those who undertake self-protective actions such as drinking bottled water or using water filters placed a higher value on reductions in drinking water risks, which is the expected economic relationship. While passing such tests cannot ensure the validity of the survey results, they provide an important check on survey validity.

3 Sample Characteristics

The survey was administered in 2008 and 2009 by Knowledge Networks (KN) to adults age 18 and above. The KN panel is a Web-based panel constructed using probability sampling of the U.S. population. The KN panel is nationally representative, made possible by extra efforts to recruit demographic groups who often do not take part in surveys and by providing, where needed, computers and internet access.[13] The response rate for the survey was 69%. Our analysis focuses on the 3,585 respondents with valid answers to the willingness-to-pay question.[14] Appendix Table A1 provides a comparison of the sample used in the analysis and the U.S. population, which indicates a close correspondence of the characteristics of respondents with the U.S. adult population generally. The means and standard deviations of the variables used in our analysis are summarized in Table 1.

Two variables that pertain directly to the valuation of tap water quality are the number of glasses of tap water the respondent drinks per day and the household's yearly water bill. The average sample member drinks 2.8 glasses of tap water per day and for those with a water bill its average annual cost is $497, which is very similar to the average cost in the U.S.[15] About one-third of the respondents indicate that they do not receive a water bill, as, for example, their water costs may be included as part of their apartment rental. The personal costs of water quality improvements may be perceived to be lower to these people and, in the most extreme case, they may view the willingness-to-pay (WTP) question as a referendum pertinent to others' expenditures instead of their own. We discuss the differences in valuations by whether the respondent receives a water bill in the following section.

[12] While tap water treated to be safer may not be an environmental good itself, water as a natural resource is, which environmentalists tend to value more highly than non-environmentalists.

[13] Our use of the KN panel for our EPA-funded water quality surveys has been specifically reviewed and approved by the Office of Information and Regulatory Affairs, U.S. Office of Management and Budget. For additional information on the characteristics of the KN panel, see http://www.knowledgenetworks.com/knpanel/KNPanel-Design-Summary.pdf.

[14] While 4,131 people took the survey, 523 failed the dominated choice question, 7 others skipped a question within the decision tree, and one respondent did not complete the survey.

[15] Rubin (2004) reports the annual cost of water and wastewater service per household of $476 per year.

Table 1 Characteristics of variables used in the analysis

Variable	Mean	SD
Household income	$60,792	$41,503
Years of education	13.76	2.63
Age	48.39	16.21
Considers self environmentalist	0.43	0.50
Gender: female	0.52	0.50
Race: White	0.82	0.38
Race: Black	0.10	0.30
Race: other	0.08	0.27
Hispanic	0.09	0.29
Household size	2.53	1.42
Homeowner	0.77	0.42
Well user	0.21	0.40
Receives a water bill	0.67	0.47
Glasses of tap water per day	2.80	2.41
Filter use	0.40	0.49
Bottled water use	0.71	0.45
Considers own risk high	0.06	0.24
Considers own risk low	0.64	0.48
Ever afraid of tap water	0.25	0.44
Yearly water bill	$374	$407
Live in metropolitan statistical area	0.83	0.38
Region: Northeast	0.19	0.39
Region: South	0.35	0.48
Region: West	0.21	0.41
Region: Midwest	0.24	0.43
WTP value unbounded high	0.06	0.24
WTP value unbounded low	0.08	0.28
Starting ratio	$4.55	$1.55
Starting baseline risk level (X/1,000)	53.23	11.10
Missing: considers self environmentalist	6.4E−3	0.08
Missing: race	2.2E−3	0.05
Missing: receives a water bill	0.02	0.14
Missing: glasses of tap water	0.02	0.15
Missing: filter use	0.02	0.12
Missing: bottled water use	2.2E−3	0.05
Missing: ever afraid of tap water	2.8E−3	0.05

Several variables included in the analysis pertain to the perceived risk levels for tap water and likely aversion to such risks. After learning that 5% is the national average annual GI illness risk from water, respondents were asked to assess their relative risk as being above that amount, below that amount, or equal to that amount. We created two 0–1 indicator variables, one for whether the respondent believes their own risk to be higher and one for those who believe their risk to be lower than the stated national average. A related risk perception binary variable pertains to whether the respondent has ever had tap water that the respondent was afraid to drink (Ever Afraid of Tap Water).

Personal protective behaviors with respect to drinking water risks are also expected to affect valuations of water quality improvements, as such behaviors should be more common among those who value tap water quality highly or perceive greater risk levels. People who currently use bottled water or who have installed a filter in their home may be exposed to riskier tap water, may face higher personal risks from exposure, or may value the risks more highly than do others, leading to higher valuations of improvements in water safety. However, a possible countervailing factor is that after undertaking self-protection through filters or bottled water, such efforts may reduce their risk exposure and make them less likely to value further water quality improvements to tap water.

The respondent's general willingness to pay to protect the environment is captured through a binary variable for whether the respondent considers himself or herself to be an environmentalist. One would expect environmentalists to have a higher valuation of reductions in the risks posed by drinking water since safe water is a prominent environmental amenity. To the extent that health risk reduction is a normal good, one would expect a positive effect of income on valuations, although the effect of income may largely be captured by the environmentalist variable and the various personal self-protection variables.

4 Interval Regression Estimates

The survey elicited the annual increase in the cost of drinking water that the respondent is willing to incur for improvements in drinking water safety. More specifically, let c_1 be the cost of new treatment and c_0 be the cost of existing treatment. The current risk level is r_0, and the risk with new treatment is r_1. For respondents expressing indifference to the two options, the tradeoff v between risk and cost is

$$v = (c_1 - c_0) / (r_0 - r_1) . \tag{1}$$

The standard terminology in the related literature on risk-money tradeoffs would refer to the value of v as the implicit value of an expected acute GI illness. Given the small probabilities involved, this is a more meaningful frame of reference to use in getting a sense of the magnitude of the effect of how much of a water bill increase people would be willing to incur to eliminate their current level of risk.

The empirical analysis uses the tradeoff rate v as the dependent variable. Our focus on the cost-risk tradeoff is on a variable that is directly analogous to measures such as the value of statistical life except that the ill health state does not involve death. Based on the theoretical literature that is usually in terms of health states in general and previous empirical estimates of money-risk tradeoffs for injuries, illnesses, and fatalities, one would expect the determinant of this tradeoff rate to be similar to those of other adverse health outcomes. For example, one would predict a positive income elasticity of the cost-risk tradeoff rate since more affluent respondents should be willing to pay more per unit of risk reduction.[16]

Direct regression formulations in which the cost difference is the dependent variable and the risk difference is an independent variable are not feasible since the iterative structure of

[16] See Viscusi and Aldy (2003).

the survey presented choices to respondents based on their revealed preferences, the cost and risk variables are endogenously related.

4.1 Interval Regression Estimates of Valuations

The empirical analysis uses interval regression to deal with the survey structure outcomes, which are of three types, all of which will be characterized by a particular interval. For respondents indicating indifference between the policy option and the current situation, the revealed tradeoff rate v between cost and GI risk is directly observable. A respondent indicating a valuation v_{12} by reaching a point of indifference in the interval $[v_1, v_2]$ is treated as having a point estimate in the interval $[v_{12}, v_{12}]$. Respondents who switch their preferences, such as indicating a preference for the current policy after the new policy option has decreased in attractiveness, have a value in the interval $[v_1, v_2]$. The estimated value within that interval is determined by the interval regression estimator. The final set of possible responses consists of those who are unbounded beyond the lower bound v_l or the upper bound v_{u}. The lower unbounded responses are treated as falling in the interval $(-\infty, v_l]$ and the upper unbounded values are treated as lying in the interval $[v_{\mathrm{u}}, \infty)$. Thus, the interval regression addresses both the unbounded aspect of some responses and the valuations that are at some point within an interval range.

A question arises about whether the dependent variable v should be represented in logarithmic terms. Figure 4 illustrates the raw valuations of the cost-risk tradeoffs in which the respondent's expression within interval valuations are valued at the midpoint of the interval, and respondents reaching the corners are assigned the corner values. As shown in Fig. 4, valuations exhibit a strong positive skew but the logged values are symmetrical and reasonably normal. Accordingly, the interval regression analysis uses the natural log of v as the dependent variable.

Table 2 reports the interval regression estimates for an equation that includes variables pertaining to the survey structure, demographic factors, drinking water risks, and related behaviors. This equation provides the mean cost-risk tradeoff rate taking into account both the unbounded and interval nature of responses. Because the dependent variable is the log of v, the mean estimate of v is calculated using the procedure described by Train (2003). If a logged distribution has a mean M and a variance S, then the mean of the unlogged distribution is $e^{(M+S/2)}$. In this application, we took M to be the mean predicted logged value across respondents and S to be the variance of those predictions. To do so, we simulate each respondent's expected valuation using the equation in Table 2. Assuming constant rates of tradeoff between dollars and risk, on average respondents are willing to pay an extra \$525 to completely eliminate the 0.05 average annual risk of GI illness. In practice, policies would likely be less than totally effective so that, for example, we find a willingness of pay of \$105 for a 20% reduction in the level of the risk.

The valuations exhibit heterogeneity across the population. The most consequential demographics are income, age, gender, and minority status. The estimates have the expected income effect, and values also increase with age. Some studies have shown that females are more risk-averse than males, which is consistent with their higher drinking water safety valuation amounts.[17] African Americans and Hispanics indicate higher valuations of risk reductions for drinking water, which may reflect greater previous exposure to risk by minorities and therefore greater aversion to the illness. Respondents living in the Southern U.S. are willing

[17] For a review of the literature on gender differences in risk aversion, see Eckel and Grossman (2008).

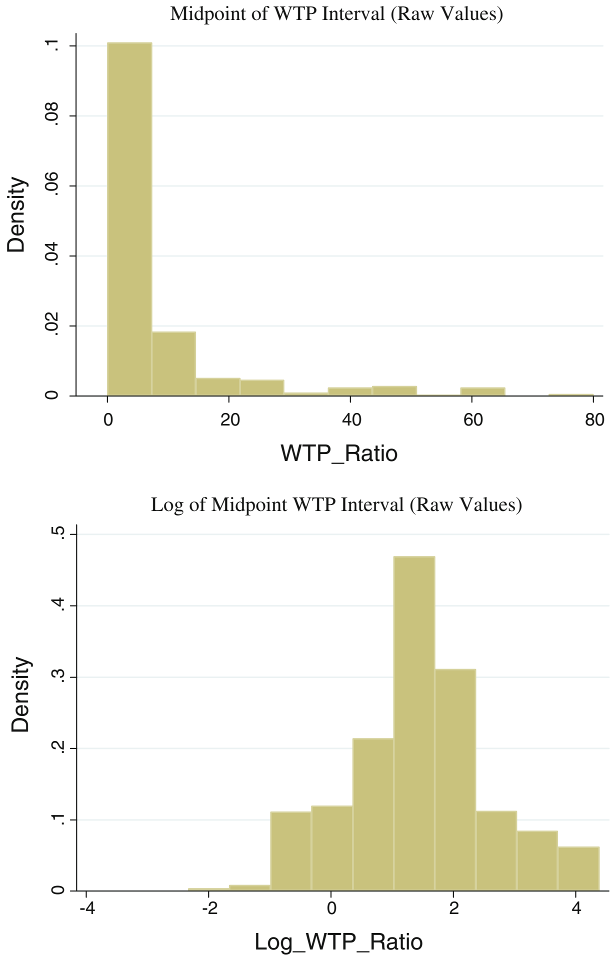


Fig. 4 Distributions of drinking water values, non-log vs log

to pay significantly more for safer water, which is consistent with the lower quality tap water in those states.[18]

Several variables correlated with high valuations of environmental quality and environmental risk reductions have the expected positive effect on valuations. Willingness-to-pay is greater for self-described environmentalists and for people who consider their own acute GI risk from water to be high, while low perceived risk has a negative impact on value. Similarly, precautionary self-protection efforts through use of water filters or bottled water are positively related to valuation amounts. Respondents for whom the higher water bills are likely to be most salient—homeowners and those who receive a water bill—have lower values, consistent with greater price sensitivity. It is possible that those who do not receive a water bill and are not on a well could have difficulty with the survey question scenario,

18 Using state level data available from the Environmental Working Group's National Drinking Water Database at http://www.ewg.org/tap-water/statereports, respondents in our sample from southern states had significantly more cases of chemicals in tap water exceeding legal limits compared to the rest of respondents.

Table 2 Interval regression of log willingness to pay per unit risk

Variable	Coefficient	SE
Log (income)	0.0534*	0.0313
Years of education	0.0135	0.0092
Age	0.0028*	0.0016
Considers self environmentalist	0.2415 ***	0.0457
Gender: female	0.0788*	0.0442
Race: Black	0.3290 ***	0.0777
Race: other	−0.1084	0.0844
Hispanic	0.1429*	0.0774
Household size	−0.0111	0.0178
Homeowner	−0.1957 ***	0.0613
Well user	−0.1362*	0.0717
Receives a water bill	−0.2295 ***	0.0645
Glasses of tap water per day	0.0291 ***	0.0095
Filter use	0.0994 **	0.0453
Bottled water use	0.1040 **	0.0509
Considers own risk high	0.2333 **	0.0970
Considers own risk low	−0.1097 **	0.0515
Ever afraid of tap water	0.0508	0.0535
Yearly water bill	5.12E − 06	6.17E−05
Live in metropolitan statistical area	−0.0921	0.0607
Region: Northeast	0.0302	0.0675
Region: South	0.1518 ***	0.0579
Region: West	0.1230*	0.0664
Log of starting ratio	0.6586 ***	0.0570
Baseline risk level	−0.0006	0.0020
Intercept	−0.3664	0.3405
Observations	3,585	
Log likelihood	−7010.3358	

* significant at the 0.10 level, ** 0.05 level, and *** 0.01 level. The equation also includes missing value indicators for observations missing responses to the variables noted in the bottom of Table 1

since those respondents likely would not pay directly for any quality improvement to their drinking water. This effect is demonstrated in Table 3, using models comparing the 592 non-well users in the sample who do not receive a water bill to the 2,258 non-well users who do receive a bill. These models produced value estimates for the non-bill subsample that are 23% higher than those who do receive a bill. The bill-paying subsample demonstrates a positive income effect not seen in the non-bill paying subsample. For the non-bill paying subsample, the values may be higher because someone other than the respondent would pay for the improvement.

Following the usual dose-response relationships, a person's GI risk should increase with the amount of water consumed, so that the annual willingness to pay for safer water should exhibit the observed positive relationship with respect to the variable for the number of glasses of tap water consumed per day. Viewed somewhat differently, the dependent variable reflects the annual willingness to pay per 1/1,000 GI risk reduction for the average quantity of water

Table 3 Interval regression of log willingness to pay per unit risk for respondents on municipal water who do not receive a water bill

Variable	Receive water bill		Do not receive water bill	
	Coefficient	SE	Coefficient	SE
Log (income)	0.0943 **	0.0422	−0.0852	0.0633
Years of education	0.0030	0.0119	0.0589 ***	0.0208
Age	0.0018	0.0020	−0.0009	0.0036
Considers self environmentalist	0.2890 ***	0.0594	0.2365 **	0.1079
Gender: female	0.1366 **	0.0570	−0.1377	0.1040
Race: Black	0.2715 ***	0.0993	0.3598 **	0.1514
Race: other	−0.2579 **	0.1068	0.1051	0.1776
Hispanic	0.3014 ***	0.0997	−0.1367	0.1549
Household size	−0.0016	0.0221	−0.0051	0.0456
Homeowner	−0.1646 **	0.0818	−0.1717	0.1234
Glasses of tap water per day	0.0463 ***	0.0122	−0.0036	0.0223
Filter use	0.1515 ***	0.0586	−0.0006	0.1078
Bottled water use	0.1188*	0.0663	0.2954 **	0.1179
Considers own risk high	0.1645	0.1278	0.1022	0.1959
Considers own risk low	−0.1260*	0.0655	−0.1521	0.1149
Ever afraid of tap water	−0.0049	0.0677	0.1078	0.1184
Live in metropolitan statistical area	−0.1534*	0.0832	−0.1440	0.1960
Region: Northeast	0.0606	0.0927	0.0141	0.1524
Region: South	0.1946 ***	0.0737	0.2803*	0.1588
Region: West	0.1469*	0.0858	0.1257	0.1550
Log of starting ratio	0.5873 ***	0.0774	0.7572 ***	0.0847
Baseline risk level	0.0010	0.0025	−0.0101 **	0.0048
Intercept	−0.9585 **	0.4583	1.1509	0.7275
Observations	2,258		592	
Log likelihood	−4481.1062		−1097.5223	

* significant at the 0.10 level, ** 0.05 level, and *** 0.01 level. The equation also includes missing value indicators for observations missing responses to the variables noted in the bottom of Table 1

used. For people who consume large quantities of tap water, the annual risk may be greater so that the unit cost of risk reduction per glass of tap water consumed is less. Thus, the glasses of tap water used per day is significant as expected, while total household water bill is not, consistent with the fact that total water used includes a substantial amount of water that is not used for drinking and includes regional price differences for water.

It may be that variables such as glasses of tap water per day, bottled water use, and the cost of the yearly water bill are endogenous in that cost-risk tradeoffs could affect these behaviors, and inclusion of these variables might influence the results. To test against such a possibility, an otherwise identical version of the model excluding these variables, shown in Table A2, produces results that are substantially the same as Table 2, with a virtually identical estimated value (less than $1 difference in value to eliminate drinking water gastrointestinal illness (GI) risks from the 5% national average).

The fact that well use is a significant factor in valuation, in addition to the survey differences required to present credible scenarios to those whose water is treated elsewhere and those who must treat it themselves, suggests that this factor be examined more closely. Table 4 presents two models: the first is the model estimated in Table 2 only for non-well users, followed by that model again only for well users. The EPA estimates that about 15% of Americans get their water from their own drinking water supply.[19] That proportion closely matches our sample, where 16% use a private well on their own property, with another 4% getting their water from community wells. The value of reducing the GI risk from the 5% probability to zero is $545 for those not on wells and $454 for well users. We hypothesize that well users may have lower valuations because of a greater sense of control over the risk level.

In summary, the findings provide a clear economic picture. Valuation for water quality positively follows a combination of appropriate self-protective actions and is negatively related to price sensitivity. Higher values arise from those who consider their own risk high, who consume more water, have higher incomes, are older, and are females and minorities. Price sensitivity and lower valuations are generated by homeowners and those who pay their own water bills.

5 Adjusting Estimates of Valuations for Survey Effects

We now turn to whether the particular values of the initial choice given to the respondent affected their valuations. The variables included in the equation included the log of the starting ratio v presented in the initial choice and the baseline or lowest risk level from which improvements are made. The baseline risk level is not statistically significant. Changes in the base risk level within the range presented in the survey do not alter valuations. However, the log of the starting ratio variable is significant. The coefficient of 0.67 can be directly interpreted as an elasticity indicating that that the final valuation depends strongly on the first choice provided. Ideally, one would want the valuations to be unaffected by the starting tradeoff rates considered, but in practice this is unlikely to be the case.

To address similar starting point effects in iterative choice models, Huber et al. (2008) proposed that valuations be determined by what they term the equitable start point. In particular, the equitable start point reflects the starting ratio that would result in an even split between the two options across the relevant population.

The survey produced a split close to the 50–50 initial split through pretests that enabled us to approximate this norm. Overall, the sample chooses the higher cost, lower risk new treatment option 50.7% of the time. This equitable initial tradeoff continues to later stages of the survey in which 6% of the responses are unbounded at the high end while 8% of responses are unbounded at the low end.

The influence of the initial tradeoff rate on choices is illustrated in Fig. 5, which shows the percentage of respondents who declined the new treatment at each of the starting point levels. At the lowest starting ratio of $0.50 per 1/1,000 chance risk reduction, only 21% of respondents with a preference declined the new treatment. The percentage increases steadily as the starting ratio rises, to around 63% declining the new treatment at the highest starting ratio of $8. This pattern of influence is exactly what one would expect. Higher cost-risk tradeoff rates diminish the attractiveness of new treatment policies. These differences in starting ratios also affect the estimated valuations, as shown in Fig. 6. The lowest starting ratio of $0.50 leads to a value estimate of $2.68 for a 1/1,000 GI risk reduction (or $134 for elimination of risk

[19] http://water.epa.gov/drink/info/well/index.cfm.

Table 4 Interval regression of log willingness to pay per unit risk by well users

Variable	Non-well users		Well users	
	Coefficient	SE	Coefficient	SE
Log (income)	0.0777	0.0677	0.0476	0.0353
Years of education	0.0064	0.0202	0.0155	0.0104
Age	0.0071*	0.0034	0.0016	0.0018
Considers self environmentalist	0.1466	0.0929	0.2680***	0.0523
Gender: female	0.0484	0.0921	0.0856*	0.0503
Race: Black	0.7934***	0.2336	0.2737***	0.0832
Race: other	0.2554	0.2141	−0.1805**	0.0922
Hispanic	−0.0420	0.2039	0.1604*	0.0842
Household size	−0.0299	0.0386	−0.0022	0.0200
Homeowner	−0.1056	0.1454	−0.1879***	0.0691
Receives a water bill	0.1004	0.1554	−0.3179***	0.0761
Glasses of tap water per day	−0.0038	0.0203	0.0369***	0.0108
Filter use	0.0690	0.0925	0.1126**	0.0518
Bottled water use	−0.1145	0.1011	0.1676***	0.0585
Considers own risk high	0.4741**	0.2303	0.1880*	0.1076
Considers own risk low	0.0263	0.1200	−0.1286**	0.0573
Ever afraid of tap water	0.1406	0.1257	0.0277	0.0592
Yearly water bill	−0.0002	0.0003	0.0000	0.0001
Live in metropolitan statistical area	−0.0243	0.0964	−0.1439*	0.0766
Region: Northeast	0.0227	0.1271	0.0314	0.0791
Region: South	−0.0468	0.1155	0.1997***	0.0668
Region: West	0.0258	0.1447	0.1428*	0.0754
Log of starting ratio	0.7423***	0.1226	0.6408***	0.0642
Baseline risk level	0.0001	0.0045	−0.0009	0.0022
Intercept	−0.9220	0.7425	−0.2224	0.3823
N	735		2,850	
Log likelihood	−1355.621		−5603.3137	

* significant at the 0.10 level, ** 0.05 level, and *** 0.01 level, all two-tailed tests. The equations also include missing value indicators for observations missing responses to the variables noted in the bottom of Table 1

at the national average), and steadily rising to a high of $15.50 at the highest starting ratio of $8.00 (a $775 elimination value). To adjust estimated values to account for a starting ratio bias, we estimate the starting value that would generate a 50–50 split among those expressing a preference on the initial pairwise choice. To do so, we ran a logistic regression predicting the likelihood of choosing the higher risk, lower cost option as a function of the starting ratio (change in cost/change in risk) reported in Table 5.

At the equitable start point, there is a 50–50 split between the two choices. Thus, the log odds is the log (0.5/0.5) = 0. The starting ratio that satisfies this requirement is (0.9628259/0.2057336) = $4.68. This start ratio is slightly larger than the mean starting ratio of $4.55. These values must be multiplied by 1,000 to determine the benefit value per unit risk because the risk data are per 1,000 population.

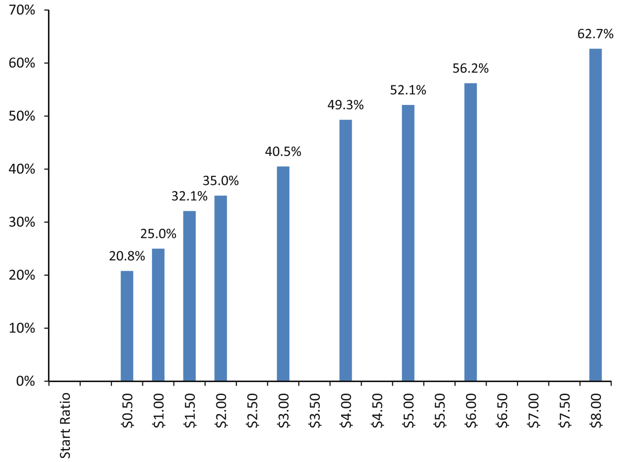


Fig. 5 Percent of respondents who declined new treatment by starting ratio

Table 5 Logit for probability of initial choice of new treatment equation estimates used for equitable trade-off calculation

First choice new treatment	Coefficient	SE
Starting ratio	−0.2057***	0.0255
Intercept	0.9628***	0.1220
Logit		
N	2,740	
Log likelihood	−1863.3791	
Pseudo R^2	0.0179	

Coefficients have been transformed to reflect marginal probabilities. Asterisks denote *** 0.01 level, two-tailed test

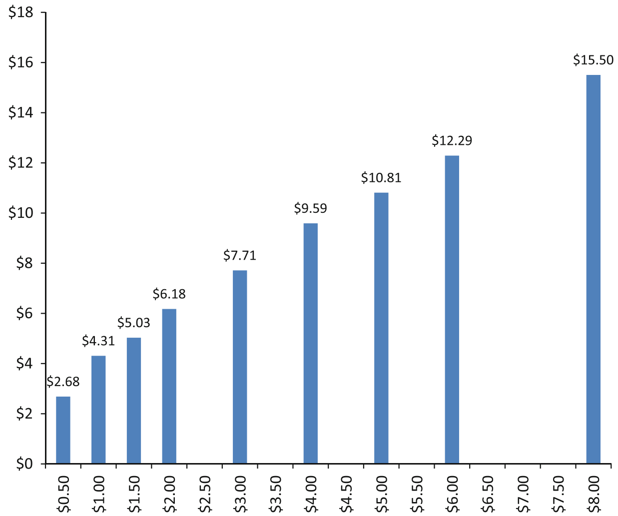


Fig. 6 Estimated value by starting ratio

Substituting the equitable start point for each respondent's actual start point raises the mean annual value of drinking water improvements that would eliminate the average acute GI risk level from \$508 to \$525. Because of the balanced design of the study, this 4% starting point bias effect was minimal.

In addition, there were a substantial number of no preference choices for the first choice, with 24% indicating that they did not prefer either option over the other. The relatively large number of no preference respondents is not of great concern since the survey choices presented to respondents were designed to induce a 50–50 split between the new policy and the current policy regime. With such equality one would also expect that many respondents would find the policy equally attractive and will indicate indifference. If one were to exclude those without a strong preference between the initial choices, that would have reduced the variance of the log-linear evaluations, raising unadjusted values by 14% at the interval midpoints and raising estimates 42% in the interval regression model. However, since the study achieved a near balanced split of answers to the first choice, the unadjusted overall values of indifferent respondents are arrayed near the overall median value.

5.1 Determinants of the First Choice Decision

Path dependence is a well known phenomenon in iterative choices such as ours. Rather than attempting to model that process, we take the final estimate that comes out of the process as an estimate of the value. This is not fundamentally different from analyses of revealed preference from individual purchase behavior that abstracts from the path that led to that decision. That said, we do adjust for a particular kind of path dependence. Our previous work on this topic made us conscious of starting point bias, so we attempted to find initial tradeoffs in terms of cost and risk differences over five rounds of administration that led to a near 50–50 initial split between the choices, in order to minimize any such biases.

If there were other sorts of path dependence, we might expect there to be differences between the demographic characteristics affecting the first choice, where such behavior is unavailable to the respondent, and the interval estimate after the full path of choices is completed. As Table A3 shows, every variable that is significant in the interval regression from Table 2 is significant in the first choice probit, with the exception of a significant positive education effect on choosing the new treatment in the first choice, and an expected reversal of the signs for log of starting ratio. Higher starting ratios lead fewer people to choose the new treatment, as such options are less attractive than questions with lower cost per risk reduced ratios. However, once into the iterations as shown above, higher starting values produce higher ultimate tradeoffs.

If path dependence were affecting results, we would expect to see effects with different patterns than seen in a single choice. As there are no drastic differences, it provides evidence that respondents are, as intended, using subsequent choices to refine their expressed value from the more coarse higher versus lower first choice.

In addition, we do not find that respondents answer questions in a fundamentally different way depending on which side of the decision tree they proceed (high value with costs static while good diminishes vs. low value with good static while costs diminish). We had a nearly identical first choice split of 1,383 high value responses versus 1,347 low value responses. For the second high value response, 54% continue high, while 34% reverse. For the second low value response, 56% continue low, while 39% reverse. This pattern of similar splits continues through the later splits, ultimately leading to 6% unbounded high values and 8% unbounded low values.

5.2 The Determinants of Unbounded Interval Responses

While our analysis accounts for respondents giving unbounded responses, the nature of the unbounded intervals at the extremes is interesting both with respect to illuminating the underpinnings of our analysis of the unbounded responses as well as providing insight into the factors that account for very high and very low valuations for risk reductions. Table 6 provides two sets of probit estimates for the probability of reaching a corner valuation, where coefficients have been transformed to reflect marginal probabilities. The first set of results pertains to the probability that a respondent's value is unbounded at the high end, while the second set pertains to the probabilities of being unbounded at the low end. The coefficients for the whether there is a large initial cost or risk difference make sense. If the respondent faced an initial choice with a large cost increase, the respondent is less likely to be unbounded at the high end and more likely to be unbounded at the low end since the high initial tradeoff encourages defections from the high end and discourages those from the low end. By similar reasoning, if the initial risk reduction is large, then the respondent is more likely to be unbounded at the high end and less likely to be unbounded at the low end.

The explanatory variables have directions of influence on the high and low valuation amounts that are generally consistent with the interval regression results on evaluations shown in Table 2. In this case, the coefficients relate to the probability respondents with that characteristic will take a particularly strong position with respect to the tradeoff. In particular, the probability of being unbounded at the high end is positively related to being Black or Hispanic, and positively related to use of water filters and belief that one's own GI risk is high. The probability of taking a strong, unbounded position at the low end is negatively related to being an environmentalist and using water filters, and is also negatively related to being female, suggesting a lessened willingness to take a strong polarized position against among women in our sample.

5.3 Quantile Regression Estimates

As the analysis of the unbounded observations at the two corners of the valuation distribution indicated, the factors that influence the respondent's valuation of drinking water safety differ somewhat for those who have valuations at one of the extremes. Here we extend this analysis to different segments of the valuation distribution using quantile regression models. While quantile regressions utilize the entire set of observations to estimate the determinants of valuations across the entire distribution, our particular focus is on the 25th percentile, the median, and the 75th percentile in order to understand how the determinants of water safety vary with low, median and high values for risk reduction.

Table 7 presents the three quantile regressions.[20] Several key variables have consistent effects throughout the distribution. A higher starting ratio boosts values at each of the three quartiles. Other influences maintain the same sign and significance throughout, but differ in magnitude, such as the influence of being an environmentalist, which is most influential in boosting the very low values at the 25th percentile and the very high values at the 75th percentile.

[20] The dependent variable in the quantile regressions is the log of the raw value of v which is the upper or lower bound for the censored values, the midpoint of the interval for those who switch within an interval, and the tradeoff rate for those who reach a point of indifference.

Table 6 Probit estimates of the likelihood of unbounded responses at high and low extremes

Variable	Unbounded high		Unbounded low	
	Coefficient	SE	Coefficient	SE
Log (income)	0.0048	0.0056	−0.0026	0.0064
Years of education	0.0011	0.0016	−0.0025	0.0019
Age	0.0003	0.0003	0.0003	0.0003
Considers self environmentalist	0.0115	0.0083	−0.0323 * **	0.0090
Gender: female	0.0091	0.0079	−0.0194 * *	0.0091
Race: Black	0.0301**	0.0165	−0.0269*	0.0135
Race: other	−0.0101	0.0135	0.0246	0.0199
Hispanic	0.0286**	0.0165	−0.0077	0.0153
Household size	−0.0039	0.0033	0.0014	0.0035
Homeowner	−0.0129	0.0116	0.0183	0.0117
Well user	−0.0178	0.0111	0.0104	0.0158
Receives a water bill	−0.0042	0.0114	0.0245*	0.0126
Glasses of tap water per day	0.0025	0.0017	−0.0030	0.0019
Filter use	0.0144*	0.0083	−0.0170*	0.0091
Bottled water use	−0.0045	0.0093	−0.0106	0.0106
Considers own risk high	0.0346*	0.0214	−0.0088	0.0196
Considers own risk low	−0.0034	0.0093	0.0115	0.0103
Ever afraid of tap water	0.0077	0.0098	−0.0067	0.0108
Yearly water bill	1.33E−6	1.10E−5	1.65E − 5	1.22E−5
Live in metropolitan statistical area	−0.0198*	0.0124	−0.0015	0.0122
Region: Northeast	0.0068	0.0133	0.0069	0.0140
Region: South	0.0170	0.0114	−0.0095	0.0113
Region: West	0.0136	0.0134	−0.0138	0.0126
Starting cost difference	−0.0004**	0.0002	0.0004*	0.0002
Starting risk difference	0.0007*	0.0004	−0.0015 * **	0.0006
Baseline risk level	−0.0002	0.0004	0.0004	0.0004
N	3,575		3,577	
Log likelihood	−809.9293		−994.6015	
Pseudo R^2	0.0296		0.0372	

Coefficients have been transformed to reflect marginal probabilities. * significant at the 0.10 level, ** 0.05 level, and *** 0.01 level, all two-tailed tests. The equations also include missing value indicators for observations missing responses to the 8 different variables noted in the bottom of Table 1

The effects that are most intriguing are those that display a differential pattern across the quantiles. First, sensitivity to respondent characteristics generally has a greater impact distinguishing those who provide relatively high valuations for healthy water. For example, income has a statistically positive effect at the 75th percentile but not at lower quartiles. The same is true of education, which is a proxy for lifetime wealth and may also reflect knowledge of water quality. Thus, while there are two overall income or education effects observed throughout the distribution, the influence of these factors does come into play for the highest valuation levels. Age likewise comes into play for the median and 75th

Table 7 Quantile regressions on value of avoiding GI risk

Estimate at quantile	25% Quantile ($2.53)		Median quantile ($4.55)		75% Quantile ($8.17)	
	Coefficient	SE	Coefficient	SE	Coefficient	SE
Log (income)	0.0401	0.0352	0.0124	0.0082	0.0646*	0.0360
Years of education	−0.0058	0.0105	0.0021	0.0024	0.0348***	0.0105
Age	0.0018	0.0018	0.0007*	0.0004	0.0049***	0.0018
Considers self environmentalist	0.2209***	0.0522	0.0670***	0.0120	0.2824***	0.0529
Gender: female	0.0872*	0.0497	0.0285**	0.0116	−0.0224	0.0511
Race: Black	0.2874***	0.0882	0.0589***	0.0204	0.3965***	0.0890
Race: other	−0.1618*	0.0947	−0.0068	0.0220	−0.1219	0.0966
Hispanic	0.0573	0.0853	0.0331	0.0203	0.1857**	0.0891
Household size	0.0013	0.0208	0.0004	0.0047	0.0016	0.0205
Homeowner	−0.1954***	0.0692	−0.0383**	0.0160	−0.2674***	0.0707
Well user	−0.0638	0.0792	−0.0419**	0.0188	−0.1469*	0.0849
Receives a water bill	−0.2620***	0.0728	−0.0766***	0.0169	−0.1250	0.0763
Glasses of tap water per day	0.0158	0.0108	0.0061**	0.0025	0.0320***	0.0111
Filter use	0.1111**	0.0510	0.0267**	0.0119	0.0171	0.0527
Bottled water use	0.1492***	0.0571	0.0332**	0.0133	0.0890	0.0595
Considers own risk high	0.0813	0.1086	0.0458*	0.0253	0.4286***	0.1128
Considers own risk low	−0.1407**	0.0580	−0.0363***	0.0135	−0.0678	0.0594
Ever afraid of tap water	0.0266	0.0602	0.0219	0.0140	0.1176*	0.0618
Yearly water bill	−4.16E−5	6.90E−5	1.66E−5	1.62E−5	8.35E−5	7.04E−5
Live in metropolitan statistical area	−0.0985	0.0681	−0.0205	0.0159	−0.0769	0.0703
Region: Northeast	0.0460	0.0764	0.0058	0.0177	0.0344	0.0779
Region: South	0.1429**	0.0655	0.0472***	0.0152	0.1561**	0.0669
Region: West	0.1051	0.0750	0.0389**	0.0174	0.0343	0.0762
Log of starting ratio	0.6641***	0.0650	0.8687***	0.0149	0.5795***	0.0660
Baseline risk level	−5.78E−6	0.0022	0.0002	0.0005	−0.0014	0.0023
Intercept	−0.4686	0.3780	−0.0162	0.0893	−0.1966	0.3939
Pseudo R^2	0.0654		0.0719		0.0519	

* significant at the 0.10 levels, ** 0.05 level, and *** 0.01 level, all two-tailed tests. The equations also include missing value indicators for observations missing responses to the 8 different variables noted in the bottom of Table 1

percentile, but not at the 25th percentile. The effect of several perceptual variables similarly rises across the quantiles. The starkest rise across the quantiles is the variable for whether the person perceives their own risk from drinking tap water to be high, which has its largest effect at the 75th percentile. Having ever been afraid to drink tap water also exhibits increasing effects at higher quantiles. The counterpart of these rising positive effects is that there is an increasingly large negative effect of being on well water as one moves across the valuation distribution, as people who get their water from wells are particularly unlikely to place extremely high valuations on drinking water safety. There are only a few exceptions to the finding of greater sensitivity at the 75th percentile. In particular, women and those who use water bottles are more determinant of valuations at the 25th percentile.

Overall, the examination of the quantile results reinforces the earlier findings and yields results consistent with expectations regarding the economic factors that should affect the results. The statistically significant sources of heterogeneity are more in evidence at the 75th quantile than at the median or 25th quantile. This result is consistent with those who provide high valuations being more likely to consider their resources, attitudes and behaviors to justify the higher cost. What is noteworthy is that the changes in the patterns of influences from the quantile regressions are quite reasonable, and paint a richer picture that that displayed in the interval regression.

6 Conclusion

The distribution of valuations for reducing drinking water risks is skewed, consistent with a lognormal distribution. People at the 75th percentile of valuation value reductions in risk by over three and a half times as much as do those at the 25th percentile. Much of the variation in valuations stems from heterogeneity in attitudes toward risk. Key determinants of the differences in valuations include the amount of tap water drunk per day, perceptions of one's personal risks from tap water, and current efforts of self protection through use of filters and bottled water. The mean annual value of eliminating acute GI risks is \$525, or more than double the sample median value of \$219.

Given the substantial number of people affected by GI illnesses from unsafe drinking water, the national benefits from eliminating these risks are considerable. Based on the estimate of 16.4 million GI cases from drinking water cited by Messner et al. (2006), the national benefit of eliminating drinking water-related acute GI risks is \$59 billion. Even the lower estimates of illness frequency by using the midpoint of the Colford et al. (2006) frequencies imply an annual \$31 billion national benefit value for safe drinking water. These benefit amounts are the annual values related to eliminating acute GI illness risk. If policies also eliminated risks of other illnesses, such as cancer, these values would be even higher.

By way of comparison, the total cost for Americans who receive water bills is \$34 billion annually. Even the lower bound estimate of the national benefits from eliminating GI illness is double the current expenditure. While we expect that focusing on this particular GI risk in water increased its importance and value, these results suggest that there is a strong economic basis for improvements in the quality of U.S. drinking water.

The iterative choice structure used in this study provided an opportunity to examine the properties of this survey approach. A potential consequence of presenting respondents with policy choices is that the tradeoffs presented in these choices can influence the estimated valuations. The baseline risk value proved not to be consequential, but the starting cost-risk tradeoff rate could potentially influence responses. To minimize any bias that might result from this effect, the survey design adopted an equitable tradeoff approach in which the options presented ideally should result in a 50–50 split between those expressing higher or lower valuations, thus not inducing a bias in any particular direction. The survey did achieve a split that approximated this goal so that the effect of moving to an exactly equitable start point was very small.

Appendix

See Tables A1, A2, A3 and A4.

Table A1 Comparison of sample to the national adult population

Demographic variable	U.S. adult population percent	Sample ($n = 3,585$) percent
Gender		
Male	48.4	47.8
Female	51.6	52.2
Age		
18–24 years old	12.6	8.4
25–34 years old	17.9	14.1
35–44 years old	18.8	19.0
45–54 years old	19.6	20.6
55–64 years old	14.8	20.9
64–74 years old	8.7	11.6
75 years old or older	7.7	5.4
Educational attainment		
Less than high school diploma	14.2	11.4
High school diploma or higher	58.8	59.6
Bachelor's degree or higher	26.9	29.0
Race/Ethnicity		
White	81.3	82.4
Black/African–American	11.7	9.7
American Indian or Alaska native	2.4	1.3
Asian/Pacific Islander/other	4.6	6.4
Hispanic	13.5	9.3
Marital status		
Married	55.0	58.7
Single (never married)	26.0	21.9
Divorced	10.4	11.9
Widowed	6.4	5.3
Household income		
Less than $15,000	13.3	11.2
$15,000–$24,999	11.6	9.8
$25,000–$34,999	10.7	10.3
$35,000–$49,999	14.2	16.8
$50,000–$74,999	18.2	20.8
$75,000 or more	32.0	31.1

U.S. Census Bureau (http://www.census.gov/). 2008 adult population (18 years+)

Table A2 Interval regression of log willingness to pay per unit risk, without endogenous variables

Variable	Coefficient	SE
Log (income)	0.0541*	0.0310
Years of education	0.0142	0.0092
Age	0.0029*	0.0015
Considers self environmentalist	0.2454***	0.0458
Gender: female	0.0901**	0.0439
Race: Black	0.3535***	0.0773

Table A2 continued

Variable	Coefficient	SE
Race: other	−0.0935	0.0843
Hispanic	0.1468*	0.0775
Household size	−0.0072	0.0177
Homeowner	−0.1964 * **	0.0611
Well user	−0.1252*	0.0695
Receives a water bill	−0.2159 * **	0.0602
Glasses of tap water per day		
Filter use	0.1092 * *	0.0453
Bottled water use		
Considers own risk high	0.2323 * *	0.0970
Considers own risk low	−0.1005 * *	0.0512
Ever afraid of tap water	0.0455	0.0527
Yearly water bill		
Live in metropolitan statistical area	−0.0918	0.0608
Region: Northeast	0.0273	0.0675
Region: South	0.1490 * **	0.0579
Region: West	0.1238*	0.0664
Log of starting ratio	0.6637 * **	0.0515
Baseline risk level	−0.0010	0.0020
Intercept	−0.2581	0.3363
N	3,585	
Log likelihood	−6986.6274	

* significant at the 0.10 level, ** 0.05 level, and *** 0.01 level, all two-tailed tests. The equations also include missing value indicators for observations missing responses to the variables noted in the bottom of Table 1

Table A3 Probit estimates of the likelihood of choosing new treatment in first choice

Variable	Coefficient	SE
Log (income)	0.0184	0.0145
Years of education	0.0087 * *	0.0042
Age	0.0014 * *	0.0007
Considers self environmentalist	0.0923 * **	0.0203
Gender: female	0.0237	0.0200
Race: Black	0.1309 * **	0.0342
Race: other	−0.0242	0.0379
Hispanic	0.0422	0.0342
Household size	0.0046	0.0079
Homeowner	−0.0769 * **	0.0280
Well user	−0.0692 * *	0.0330
Receives a water bill	−0.1109 * **	0.0288
Glasses of tap water per day	0.0099 * *	0.0043
Filter use	0.0315	0.0204
Bottled water use	0.0360	0.0231
Considers own risk high	0.0890 * *	0.0429
Considers own risk low	−0.0442*	0.0238
Ever afraid of tap water	0.0278	0.0237
Yearly water bill	1.79E − 5	2.79E−5

Table A3 continued

Variable	Coefficient	SE
Live in metropolitan statistical area	−0.0384	0.0278
Region: Northeast	0.0217	0.0306
Region: South	0.0501∗	0.0262
Region: West	0.0379	0.0301
Starting cost difference	−0.0018 ∗ ∗∗	0.0005
Starting risk difference	0.0083 ∗ ∗∗	0.0012
Baseline risk level	0.0007	0.0009
N	2,724	
Log likelihood	−1790.027	
Pseudo R^2	0.0518	

Coefficients have been transformed to reflect marginal probabilities. * significant at the 0.10 level, ** 0.05 level, and *** 0.01 level, all two-tailed tests. The equations also include missing value indicators for observations missing responses to the variables noted in the bottom of Table 1

Table A4 Ordered probit of willingness to pay per unit risk

Variable	Coefficient	SE
Log (income)	0.0296	0.0336
Years of education	0.0133	0.0099
Age	2.84E − 5	0.0017
Considers self environmentalist	0.1720 ∗ ∗∗	0.0493
Gender: female	0.1089 ∗ ∗	0.0476
Race: Black	0.2176 ∗ ∗∗	0.0835
Race: other	−0.1314	0.0904
Hispanic	0.1296	0.0832
Household size	−0.0207	0.0190
Homeowner	−0.1196∗	0.0658
Well user	−0.0988	0.0770
Receives a water bill	−0.1026	0.0694
Glasses of tap water per day	0.0208 ∗ ∗	0.0102
Filter use	0.1202 ∗ ∗	0.0489
Bottled water use	0.0270	0.0547
Considers own risk high	0.1714∗	0.1038
Considers own risk low	−0.0542	0.0554
Ever afraid of tap water	0.0554	0.0576
Yearly water bill	−5.69E − 5	6.67E−5
Live in metropolitan statistical area	−0.0615	0.0651
Region: Northeast	−0.0036	0.0725
Region: South	0.1030∗	0.0623
Region: West	0.1031	0.0719
Log of starting ratio	−0.2188 ∗ ∗∗	0.0611
Baseline risk level	−0.0024	0.0021
N	3,585	
Log likelihood	−1798.8391	
Pseudo R^2	0.0270	

* significant at the 0.10 level, ** 0.05 level, and *** 0.01 level, all two-tailed tests. The equations also include missing value indicators for observations missing responses to the variables noted in the bottom of Table 1

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