Risk Perceptions of Arsenic in Tap Water and Consumption of Bottled Water

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Abstract: The demand for bottled water has increased rapidly over the past decade, but bottled water is extremely costly compared to tap water. The convenience of bottled water surely matters to consumers, but are others factors at work? This manuscript examines whether purchases of bottled water are associated with the perceived risk of tap water. All of the past studies on bottled water consumption have used simple scale measures of perceived risk that do not correspond to risk measures used by risk analysts. We elicit a probability-based measure of risk and find that as perceived risks rise, expenditures for bottled water rise.

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Introduction

Global bottled water consumption was about 41 billion gallons in 2005, a 57 percent increase over consumption in 1999 (Arnold and Larson, 2006). In the United States today bottled water constitutes a significant proportion of the beverage industry's sales, with nearly 10% growth in per capita consumption between 1999 and 2005 and the share of bottled water in the beverage market moving ahead of coffee. Sellers include members of the soda industry; for example, the Coca-Cola Company sells the Dasani brand of bottled water whereas Pepsicola sells the Aquafina brand. In the late 1990's about 54% of the U.S. population regularly consumed bottled water (Olson, 1999), and the number may be as high as 70% today. Generally speaking, tap water is safe to drink in most areas of the U.S., so one could question why people in the U.S. drink bottled water, especially when bottled water can be 240 and 10,000 times more expensive than tap water (Ferrier, 2001).[1] Is it rational to purchase something that can be up to 10,000 times more expensive than a near perfect substitute? While bottled water may be very convenient for consumers, surely there must be other factors at work in the burgeoning demand for bottled water.

In this manuscript we focus on the role that perceived risks of tap water play in the demand for bottled water. Our study centers on a population that is known to be at risk from arsenic contamination of publicly supplied water or of private well water. We begin by reviewing the drinking water literature and find that none of these studies uses a measure of perceived risk corresponding to known exposures. We then describe our data,

[1] Indeed, if one considers water obtained at, say, the workplace drinking fountain as a free good, then bottled water is infinitely more expensive than tap water.

which were collected in communities in which respondents are exposed to arsenic concentrations in excess of current drinking water standards. In particular, we elicit perceived risk of arsenic exposure in a way that can be evaluated against scientists' best available measures of mortality risk. Models linking the probability-based perceived risk to community arsenic concentrations are presented, after which we examine how expenditures for bottled water vary according to perceived risk. Perceived risk is found to be a statistically significant factor in determining bottled water expenditures.

Motivation/Literature Review

Given the high cost of bottled water relative to tap water, one might reasonably ask why people buy bottled water. From a purely price perspective, are people who consume bottled water simply irrational? Cherry, Crocker and Shogren [2003] define rational behavior as people making the best decisions they can with the resources available to them. Rationality, they argue, may be a scarce commodity because of constraints on individuals' cognitive and computational skills. Are people unable to compute the cost of bottled water such that they do not realize just how expensive it really is relative to tap water? If people do understand the relative prices, then we might suspect purchases of bottled water are irrational unless we can find a strong off-setting reason for its purchase.

In addition to price, there are other factors that distinguish bottled water from tap water. Bottles of one liter or less are very convenient for those traveling or at work. Larger containers used for in-home consumption may allow the consumer to purchase water of better quality than tap water: it may taste better, smell better, look better, or pose less of a health risk. It is this last characteristic that is of concern in this paper. Data we have collected allows us to investigate whether people purchase bottled water for the very rational reason of avoiding risk.

Averting Behavior Models

Averting behavior models explicitly or implicitly assume that households “produce” better health by using inputs to reduce the adverse consequences of exposure to toxic or harmful substances: people will engage in activities or purchases designed to protect themselves from health risks. The subject of water quality has appeared frequently in the averting behavior literature but many of these studies do not directly address the issue of perceived risks of exposure to contaminated water. For example, Smith and Desvousges [1986] found that 30% of households in their Boston, Massachusetts sample said they purchased bottled water expressly to avoid hazardous wastes, but the authors were unable to link this behavior directly to risk perceptions. Larson and Gnedenko [1999] estimate several models of whether individuals engage in different types of averting behavior. The authors report that people are more likely to purchase bottled water when their incomes are higher but the study did not include a measure of risk. Yoo [2003] focuses on a statistical model relating bottle water purchases to demographics, concluding that more affluent households with young children are more likely to purchase bottled water if they have reason to suspect their water quality; Yoo and Yang [2000], using the same data set, find similar results with a slightly different model. The data set used in both analyses by Yoo does not appear to contain information on perceived risks faced by the households, though it contains some information regarding perceived water quality. Similarly, Rosado *et al.* [2006] and McConnell and Rosado [2004] examine averting choices as a function of the costs of each activity and demographic factors but, once again, do not include an objective or subjective measure of risk. Um *et al.* [2002] find that perceived quality of drinking water affects averting behavior, but the models make no link to perceived health risks of consuming tap water.

We have found few studies linking the perceived risk of drinking water to associated averting behaviors, and none of those have used a measure of risk comparable to the probability-based measure used by risk analysts. Instead, economists have generally captured the influence of risk concerns through the use of a qualitative scale or a dummy variable rather than a technical measure of risk. Abdalla *et al.* [1992] use a 5-point scale of perceived health risk for exposure to trichloroethylene contamination in groundwater and find that expenditures on averting activities increase as perceived risk increases. Abrahams *et al.* [2000] use a very simple measure of risk: a binary variable takes the value of zero if people think their tap water is safe and the value of one if they think it is somewhat unsafe or unsafe. The authors conclude that perceived risk is more important in determining averting actions than other water quality factors. Janmaat [2007] used principal component analysis to develop a measure of perceived risk concerns from a variety of qualitative responses to survey questions, a fundamentally different approach from that used by previous authors but one that still does not permit the analyst to compare perceived risk to objectively measured risk. This risk measure, however, was not a statistically significant determinant of household water treatment activities.

Objective and Perceived Risk

The scale-based risk measures used in the studies cited above have two key flaws. First, different people will use the scale-based measures differently: one person's "three" on a five-point qualitative scale may or may not mean the same thing as another person's "three". That is, the same point on a rating scale may measure perceived risks that actually differ across the two individuals (see the discussion of various risk ratings in Viscusi and Hakes, 2003). A second problem is that scale measures such as those used in previous studies, and the principal components measures used by Janmaat [2007], can establish only an ordinal link between contaminant exposures and perceived risks. The analyst may be able to estimate a statistical relationship between the perceived risk scale and exposure, but the model will not yield information on how the qualitative scale corresponds to scientists' best estimates of probability-based risk.

Risk analysts estimate health risks using population-level probabilities of a given health outcome, calibrated by exposures. For example, it is estimated that the "background" level of lung and bladder cancer is about 60 deaths per 100,000 people, but exposure to arsenic in drinking water at a concentration of 50 parts per billion for twenty years will increase the mortality rate to 1000 cases per 100,000 people, or 1 in one hundred (see U.S. EPA, 2000). If a person smokes and is exposed to arsenic at 50 ppb for twenty years, the rate rises to 2000 deaths per 100,000. These risks are often converted to probabilities (0.0006, 0.01, and 0.02, respectively). If perceived risk can be elicited in the form of probabilities rather than a qualitative scale, then one may use statistical models to evaluate the degree to which subjectively evaluated risk corresponds to the objective risk as measured by scientists.

This is important because perceived risks are often quite different from science-based estimates of risk (Slovic, 1987, provides the seminal reference). Slovic found that dangers to which people choose to voluntarily expose themselves, such as alcohol consumption, are frequently found to have perceived risks that are much lower than scientists' best estimates of risk. Other characteristics of risk also cause perceived risks to diverge from objectively measured risks: those risks that are believed to be controllable (*e.g.*, automobile accidents), for which fatal consequences are limited to one person or just a few people at a time (again, automobile accidents), or have health or mortality effects that are delayed (*e.g.*, environmental exposures) tend to have perceived risks that are less than objective risks. Dangers over which people have little control, kill large numbers of people at one time, or have immediate mortality effects tend to have perceived risks greater than those measured by risk analysts. For example, in their study of high-level radioactive nuclear waste storage and transportation, Riddel and Shaw [2006] find that the public believes potential mortality risks from a leak to be thousands of times higher than science-based estimates.

A key conclusion of this literature is that people will behave according to their personal perception of risk, and not according to the objective measure risk as calculated by scientists. Averting behavior models, then, should use perceived risk measures and, if one wishes to draw policy inferences from such models, the analyst must be able to compare perceived risk to objectively measured risks. Communicating risks and eliciting perceived risks has proven to be quite difficult, though, which may explain why the averting behavior studies of the past have relied upon simple risk scales rather than a probabilistic measure. In our study, risks of arsenic exposure were communicated carefully to sample respondents, and a measure of perceived risk corresponding to a probability was elicited, making it easier to assess the degree to which perceptions match scientists' best risk estimates for known exposure levels.

The Sample and Data

The data used in this study come from a sample of people living in areas of the United States that have arsenic contamination in drinking water supplies. A detailed description of the survey process is provided in Nguyen [2008]. Briefly, the sample was obtained by targeting four regions of the United States that were in violation of the new federal standard for arsenic in drinking water (10 ppb). The public water supply systems of Albuquerque, New Mexico, Fernley, Nevada and Oklahoma City, Oklahoma were not in compliance with this federal standard for arsenic. The Outagamie County/Appleton region in the state of Wisconsin was selected for the study because of the high arsenic levels in privately owned wells. Private wells are not regulated under the Safe Drinking Water Act, so any knowledge that well owners have about their well quality is obtained on their own or in conjunction with a state or local health agency. The sample was not designed to be representative of all people living in the United States, but rather was collected to reflect the behaviors and decisions of people living in areas with arsenic contamination issues.

The survey followed a telephone-mail-telephone format. Potential respondents were initially contacted via a random digit dial process and asked about general perceptions of local drinking water quality. If the respondent agreed to participate in a follow-up survey, he or she was sent a brochure describing the health consequences of exposure to arsenic, the ways in which risks can be mitigated, and the level of exposure in the respondent's community as measured by arsenic concentrations. For those people served by public water supply systems, the respondent's exposure level was determined from water quality reports required by the US Environmental Protection Agency.

Arsenic concentrations in all communities served by public systems were greater than 10 ppb but less than 50 ppb. For those on private systems, the concentration level was reported as a range, where the range was based on discussions with health officials with knowledge of local arsenic concentrations. Households in this region could have arsenic concentrations in excess of 100 ppb.

Risks were communicated using text and graphics. The text provided numeric information about the background risk of lung and bladder cancer (60 deaths per 100,000 people), the risk of these cancers following exposure at 50 ppb for twenty years when a person did not smoke (1000 deaths per 100,000 people), and the risks to a smoker following exposure at 50 ppb for twenty years (2000 deaths per 100,000 people).[2] These data were also graphically depicted on three rungs of a risk ladder, with other risks such as the risk of dying by lightning strike, automobile accident, *etc.*, presented on other rungs of the ladder. Arrayed vertically to the right of the ladder were 25 tick marks, each labeled with a number from one to twenty-five and corresponding to a known mortality probability (Figure 1). During the follow-up telephone interview, respondents were asked to consider the amount of tap water they drink and the community's reported arsenic concentration, and to indicate the number of the tick mark that best corresponded to their perceived risk (see Appendix for survey questions). Some 353 people completed all phases of the survey; we focus our analysis on the 201 respondents who provided point estimates of perceived risk. Another 96 respondents exhibited "ambiguity" and provided only a range within which the perceived risk lay. We drop this last group from

[2]The brochure mentioned other mortality risks of arsenic exposure such as a heart attack, but focused on lung and bladder cancer because these are the best documented risks.

the analysis because its inclusion greatly increases the statistical complexity of the analysis (see Nguyen *et al.,* 2008) and distracts from the primary thesis of this study.[3]

Statistical Results

The goals of our statistical models are two-fold: first, we would like to know if the risk elicitation method (and subsequent conversion to a probability measure) was successful. We evaluate this process by comparing perceived risks to objective risks as measured by scientists. Second, if the perceived risk measure seems reasonable, we would like to link this measure to observed behavior. That is, does the measure of perceived risk correspond to averting behavior in a way that makes sense?

Table 1 presents some simple statistical results for the sample that relate to demographics, smoking and drinking water habits. The average respondent had lived in their current residence for 11 years and had completed at least some post-secondary education. Some 63% of respondents were male, and the average annual household income was nearly $66,000. The respondent's self-assessment of health was elicited using a discrete scale of 1 (excellent) to 5 (poor). The vast majority of respondents report themselves to be in "good" to "excellent" health, with only 10% considering themselves in "fair" or "poor" health. About 51% of the sample had never smoked, with 35% saying that had smoked in the past and about 14% stating that they currently smoked. Two-thirds of respondents received tap water from a public system; the remainder received tap water from a private well. Almost 60% of the sample said they were "very concerned"

[3] A probit model was used to examine differences between those who provided point estimates of risk and those who did not. Of the six demographic variables used to explain these differences, only income was statistically significant (P=0.06); those with greater incomes were less likely to report a point estimate. Length of tenure in a community, education, gender, age and health status were each statistically insignificant. The overall model was statistically insignificant (P=0.42). Full results are available upon request.

about the water quality in drinking water sources. Water quality concerns were elicited before mailing the arsenic information brochure and thus represent "prior" perceptions of water quality. A little over one-third of respondents reported buying bottled water, though very few of these people relied exclusively upon bottled water for cooking and drinking. The mean monthly expenditure for bottled water amongst those purchasing bottled water was $27.

Perceived Risks

Our simple evaluation of the risk elicitation method is presented in Table 2. Overall, the mean perceived risk of mortality from arsenic contamination at local concentration levels is 0.0059, or 590 deaths out of 100,000 over twenty years of exposure at local arsenic concentrations. This is above the background level mortality risk for lung and bladder cancer in the absence of arsenic contamination (0.0006) but below that for exposure at 50 ppb (0.01). After controlling for smoking history, the results are encouraging. Respondents who have never smoked have the lowest perceived mortality risk (0.0038) whereas those currently smoking have the highest perceived risk (0.0139). Those who currently smoke, or have had a history of smoking, appear to understand that smokers are at higher risks from drinking arsenic-laden water.

The results presented in Table 2 do not account for other factors that influence perceived risk. In particular we are interested in how smoking, the level of arsenic exposure, and other factors may influence peoples' perceived risk. We use multivariate regression analysis to accomplish this, using the regression model

$$y = \beta' X + \varepsilon$$

where y is perceived risk, X is a set of explanatory variables, β is a set of parameters to be estimated, and ε is the error term. The elements of X include not only exposure to arsenic and smoking history, but also other factors suggested by the literature and our focus group work: the source of drinking water (a public water system or a private well), length of tenure in the community, and the respondent's age, gender, educational level, and self-reported health status.[4]

Table 3 reports results of our ordinary least squares model of perceived risk. The longer a respondent had lived in their current residence (*Years in Current Residence*), the lower they believe subjective risks are, and this variable is strongly significant. Those getting tap water from a *Public Water System* believe themselves to be at higher risk than those on private systems. *Gender* and *Education* appear to have no statistical influence on perceived arsenic mortality risk. People in poorer health (*Health Status*) report higher subjective arsenic risks, perhaps resulting from a belief that they are more vulnerable to environmental contaminants than those who are in better health.

Consistent with the results presented in Table 2, those who identified themselves as a *Current or Former Smoker* have significantly greater perceived risk than those who have never smoked. All else equal, smokers and former smokers believe that a history of smoking causes the risks of lung and bladder cancer mortality to rise by an additional 370 deaths per 100,000 people. Our statistical model also shows that perceived mortality risks rise with exposure to arsenic (*PPB*). The sign on arsenic concentration is positive and significant. All else equal, the model indicates that respondents believe mortality risks rise by 20 deaths per 100,000 people for every one part per billion increase in

[4] We are unable to control for other factors that might influence perceived risk, *e.g.*, a history of cancer in the family, the total volume of water consumed, and the amount of water consumed away from home.

arsenic concentration. Our finding that perceived risk increases as contaminant exposure increases is consistent with the analyses of Poe *et al.* [1998] and Poe and Bishop [1999].

To make a comparison of arsenic mortality risks as assessed by our sample with scientists' best estimates of risk, we predict perceived risks under the assumption that everyone in the sample is exposed to an arsenic concentration of 50 ppb.[5] At an exposure concentration of 50 ppb, but holding all other variables at the levels reported by the respondent, the mean overall risk for the sample is 0.0069, or 690 cases per 100,000. For non-smokers the predicted risk was 0.0045, or 450 deaths per 100,000 people, which is below the best scientific estimate for 50 ppb exposures of 1000 deaths. For those who had ever smoked the predicted risk was 0.0092, or 920 cases out of 100,000 people; again this is below the scientists' best estimate of 2000 deaths per 100,000 people. Our sample respondents appear to systematically underestimate the risks of arsenic exposure but this is not unusual. The risk perception literature indicates that lay persons frequently underestimate the risks that can be controlled, are not catastrophic, and have delayed health effects (Slovic, 1987; Brewer *et al*., 2004; Flynn *et al*., 1993; Rowe and Wright, 2001).

Bottled Water Expenditures

Having established that respondents' perceived risks are correlated with arsenic exposure and exacerbating habits (smoking), our next task is to assess whether our measure of perceived risk affects consumer behavior. Past research has indicated that perceived water quality and perceived risk, as measured by a qualitative response scale, do affect

[5] We estimate of perceived risk by using the model coefficients reported in Table 3 by setting arsenic exposure (*PPB*) equal to 50 and using the actual values reported by the respondent for all other right hand side variables. Although ordinary least squares was used, we predicted no cases of a negative perceived risk.

the demand for bottled water. Our data do not contain self-reported information on the actual volume of water used by the household because our focus group work indicated that households would have a difficult time recalling volumes of water used or purchased. A somewhat easier question for respondents to answer is their typical monthly expenditure on bottled water (reported in Table 1). The mean expenditures for those purchasing bottled water was $27 per month, but some 64% of the sample did not buy bottled water.

We are interested in expenditures on bottled water, which may be expressed with the following model,

$$w = \tau' F + \upsilon \qquad [1]$$

where w is the measure of bottled water expenditures, F is a vector of variables explaining expenditures, τ is a parameter vector to be estimated and υ is the stochastic error term associated with the model. Under the standard assumptions of an ordinary least squares (OLS) model, the expected value of the left hand side would be $\tau' F$, but this approach would not account for all the people who spent no money on bottled water. That is, the OLS model given above actually measures expected expenditures *given that expenditures were greater than zero*.

To gauge the full effects of perceived risk on demand for bottled water, the modeling procedure must recognize that the majority of people choose not to purchase bottled. That is, our modeling should reflect a participation decision, or "selection effect", that accounts for differences across people in deciding to buy any bottled water at all, as well as a quantity decision—how much bottled water to buy. Heckman [1979] formalized the econometric approach to modeling such processes, and variations of this methodology have become common in the literature (see, for example, Hoehn, 2006; Yoo and Yang, 2000; or Bockstael *et al.*, 1990).

The model can be thought of as a two-stage decision process, with participation at the first stage and expenditures at the second. At the first stage the consumer decides if he or she will consume bottled water,

$$z^* = \alpha' W + u \qquad [2]$$

where z^* represents an unobservable index of propensity to purchase bottled water, W is the vector of variables affecting this propensity, α is a parameter vector to be estimated and u is the error term. The error terms for equations [1] and [2] are correlated with one another, causing inconsistency of the OLS estimates in equation [1] had all observations–purchasers and non-purchasers–been included in the estimation.

z^* may be unobservable, yet we can take advantage of an indicator variable, z, to be used as the basis of a probit specification:

$$z = 1 \text{ if } z^* > 0$$

$$z = 0 \text{ if } z^* \leq 0$$

A probit model of participation ($z = 1$ means the person buys bottled water) will yield estimates of α, which are used to form the inverse Mill's ratio, $\lambda = \varphi(\alpha' W)/\Phi(\alpha' W)$, where φ(.) and Φ(.) are the standard normal density and cumulative distribution functions, respectively. The inverse Mill's ratio is then used as an explanatory variable on the right hand side of equation [1], so that

$$w = \tau' F + \rho\sigma\lambda$$

ρ and σ correspond to the correlation of the error terms across equations [1] and [2] and the standard deviation of the error term in equation [1], respectively. Estimating equations [1] and [2] via full information maximum likelihood (with the full dataset of buyers and non-buyers) yields efficient and consistent parameter estimates for both equations and fully accounts for the role of perceived risk in the decision to purchase bottled water.

Table 4 reports the results of two Heckman selection models of bottled water expenditures. The upper portion of the table contains the coefficient estimates for the bottled water expenditures model (how much bottled water to buy) whereas the lower portion contains the results of the selection equation (the decision to buy any bottled water at all). The two models differ in the specification of the expenditures equation but share identical specifications for the selection model.

Turning first to the selection model in the lower portion of Table 4, results were qualitatively identical for both Model #1 and Model #2. *Perceived Risk* is not statistically significant, indicating that our probabilistic measure of risk does not affect the decision to purchase bottled water. Instead, *Perceived Water Quality* plays a larger role in people's decision to purchase bottled water. This suggests that factors such as taste, smell, and clarity of drinking water are of greater concern than risks associated with arsenic in deciding to buy bottled water. Among other factors, being on a *Public Water System* significantly increases the probability of purchasing bottled water. It is possible that those on private wells are less aware of the contaminants in their water source; public systems have the responsibility to provide customers with water quality information, but private well owners must get this information themselves. Those with greater levels of *Education* are more likely to purchase bottled water than those with less education. Older people are less likely to consume bottled water than those who are younger (*Age*).

Health Status is not a significant factor in the decision to buy bottled water. We also note that the statistically significant estimates of *Rho* and *Sigma* in the selection models are statistically significant, indicating that the selection model is appropriate in this application.

The bottled water expenditure specifications examine the role of the risk variable and the water quality variable. Our first specification includes only *Perceived Risk* and *Income*, whereas the second specification adds *Perceived Water Quality*. In Model #1, the risk measure is a positive and statistically significant factor in explaining bottled water expenditures: higher subjectively perceived risks lead to increased expenditures on bottled water. *Income* was statistically insignificant. Given that more obvious factors such as taste, smell and clarity of drinking water outweighed the effects of perceived risk at the selection stage, our second specification adds the *Perceived Water Quality* variable to test whether these effects swamp the risk effect at the expenditures stage, too. In this second specification (Model #2) *Perceived Risk* is of the same magnitude and statistical significance as in Model #1, whereas *Perceived Water Quality* is not significant at conventional levels (though the P-value is 0.13, just beyond the 0.10 range). The two specifications in Table 4 indicate that perceived risk is a statistically significant determinant of expenditures on bottled water.

Taking the selection and expenditure stages as a whole, our results suggest that the more overt and easily recognized quality characteristics of water (taste, smell, clarity) have a greater influence than perceived risk in prompting people to buy bottled water at the selection stage. More people clear this “hurdle” due to characteristics of drinking water that are readily apparent than those characteristics that are more subtle. It is at the expenditure stage that the role of perceived risk reveals itself. All else equal, those with greater perceived risks are willing to spend more money on bottled water than those with lower perceived risks. This is an appealing story, in that those who drink bottled water to avoid the serious health consequences of arsenic exposure are willing to buy more than those whose motivation to buy bottled water is based on factors that do not affect health.

Conclusions

Many people are exposed to contaminant risks in drinking water, and numerous authors have examined the choices made by people to avoid these risks. In some cases the researchers did not have access to measures of perceived risk while in other cases the authors used measures of risk that do not correspond well to the way in which risk is measured by risk analysts. In contrast with previous research, this study elicited perceived risks of tap water contamination in such a way as to allow comparison to the objective risks as measured by scientists. Our statistical model demonstrates that the measure of perceived risk follows scientists' best estimate of risk in a manner consistent with the epidemiology. Respondents' perceived risk rises as the level of arsenic exposure rises; further, the perceived risk of smokers and former smokers exceeds that those who have never smoked. We find that perceived risks are lower than objective risks as measured by scientists, but this merely corroborates a result found in the perceived risk literature.

We follow Abdalla *et al.* [1992] and Abrahams *et al.* [2000] in connecting perceived risk to the purchase of bottled water as a substitute for tap water. Similar to other authors, we also consider a scale measure of water quality that accounts for issues such as taste, odor and clarity as a factor in the decision to purchase bottled water. Our statistical model indicates that the more general issue of water quality dominates the role of perceived risk in the decision to buy any bottled water, but that perceived risk is a statistically significant determinant of the amount of bottled water to buy, given that a person has decided to buy bottled water at all. The model allows us to conclude that purchases of bottled water are based on factors other than price: the additional dimension of risk is a rational basis for purchasing bottled water at a price many times that of tap water.

Our models also provide information to policymakers. By using a measure of perceived risk that can be directly connected to exposure levels, one may evaluate the degree to which averting behavior will change as a result of different exposure levels. Our risk and expenditure models indicate that water consumption decisions are made on the basis of perceived risks that are substantially below mortality risks based on the best available scientific evidence and knowledge. If one assumes that scientific risk estimates are an appropriate benchmark, then the fact that people systematically underestimate the true risk means that our population is not purchasing enough bottled water. Policymakers must decide whether consumer choice based on existing perceived risks is acceptable from a public perspective, or if it is in the public interest to provide more information on the risks of tap water consumption and the choices available to consumers.

The risk communication effort appears to have been successful. People understood that higher exposure levels meant higher risks, while smokers also got the signal that they were at higher risks than non-smokers. Thus, while communicating and eliciting risks is known to be a difficult undertaking in survey-based research, this analysis indicates that it is possible to do both. However, the survey approach is costly in that respondents required both written and verbal information to adequately comprehend the complex nature of risk. Therefore, we have concerns about those who would draw behavioral and policy inferences about risks based on less rigorously designed and implemented survey instruments.

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Figure 1: The Risk Ladder

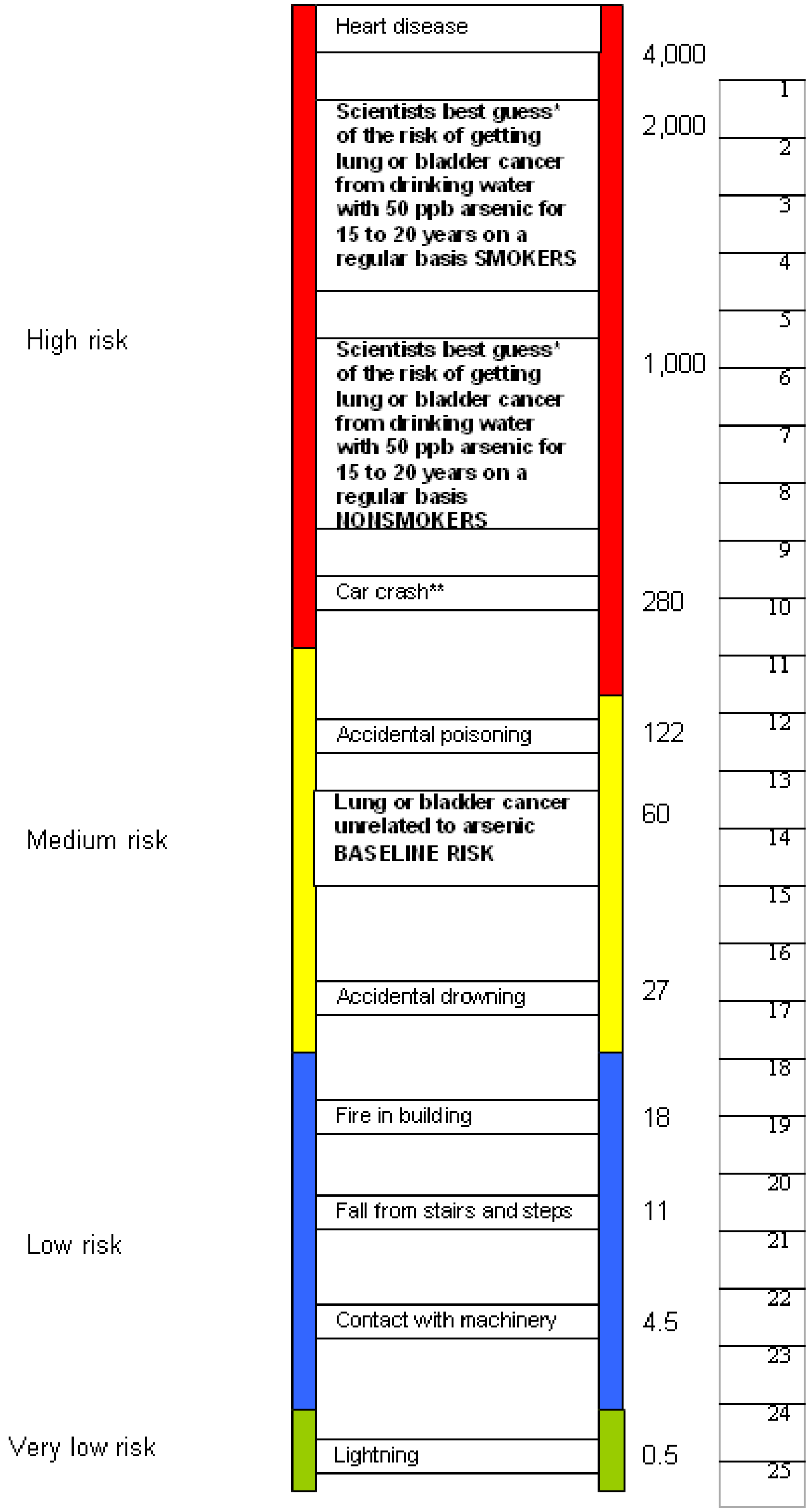

Table 1: Summary Statistics Relating to Drinking and Bottled Water Behavior (Full Sample = 201)

Variable	*Mean/Proportion*	*Standard Error*
Demographics		
Years in Current Residence (n=193)	11.0 years	0.866
Years of Education (n=192)	13.9 years	0.168
Gender (% male) (n=193)	62.7%	0.035
Income (n=187)	$65,862	$2480
Self-rated Health Status (n=201)		
Mean	2.2	0.070
Excellent (1)	28.4%	
Very good (2)	33.3%	
Good (3)	28.4%	
Fair (4)	8.5%	
Poor (5)	1.5%	
Never Smoked (n=102)	50.7%	
Quit Smoking (n=71)	35.3%	
Currently Smoke (n=28)	13.9%	
Water System and Water Quality		
Tap Water from a Public System (n=201)	67.7%	0.033
Concern About Water Quality[a] (n=193)		
Mean	4.23	0.081
Not at all concerned (1)	4.7%	
(2)	4.7%	
(3)	12.4%	
(4)	19.7%	
Very concerned (5)	58.5%	
Purchase Bottled Water (n=201)	35.8%	0.034
Monthly Expenditures for Bottled Water (n=64)	$27.02	$2.90

[a]This variable referred to as *Perceived Water Quality* in subsequent tables

Table 2: Mean Perceived Arsenic-related Mortality Risks for Smokers and Non-smokers

Group (number of observations)	Estimated mean risk (95% confidence interval)
Full sample (n = 201)	0.0059 (0.0045–0.0074)
Respondents who have never smoked (n = 102)	0.0038 (0.0025–0.0051)
Respondents who have ever smoked (n = 99)	0.0081 (0.0055–0.0107)
Respondents who have quit smoking (n = 71)	0.0057 (0.0031–0.0085)
Respondents who current smokers (n = 28)	0.0139 (0.0081–0.0198)

Table 3: Perceived Risk Model for Arsenic (n=192)

Variable	Coefficient (P-value)
Constant	−0.0187 (0.12)
Years in Current Residence	−0.0001 (0.02)
Public Water System	0.0148 (0.03)
Gender (= 1 if male)	−0.0006 (0.68)
Education	−0.0001 (0.85)
Health Status	0.0030 (0.01)
Current or Former Smoker	0.0037 (0.01)
PPB	0.0002 (0.09)
R^2	0.21
Prob > Chisquare	0.01

Table 4: Heckman Models of Bottled Water Expenditures (n=181)		
Variable	*Model #1* Coefficient (P-value)	*Model #2* Coefficient (P-Value)
Expenditure Model		
Constant	44.9096 (0.01)	18.2710 (0.87)
Perceived Risk	588.7337 (0.04)	555.8908 (0.04)
Perceived Water Quality		5.0874 (0.13)
Income ($1000)	−0.0916 (0.37)	−0.0773 (0.44)
Selection Model		
Constant	−2.8527 (0.02)	−2.5251 (0.02)
Perceived Risk	−3.2669 (0.77)	−3.6164 (0.74)
Perceived Water Quality	0.2722 (0.02)	0.2112 (0.06)
Public Water System	0.4960 (0.05)	0.5192 (0.04)
Education	0.1011 (0.05)	0.0995 (0.05)
Age	−0.0169 (0.02)	−0.0178 (0.01)
Health Status	0.0973 (0.36)	0.0954 (0.38)
Sigma	24.2808 (0.01)	22.4733 (0.01)
Rho	−0.6939 (0.01)	−0.6519 (0.05)

Appendix: Key Questions from Followup Telephone Survey

Bottled Water Expenditures

You might use both bottled and tap water at home. Bottled water might be a large container you get delivered to the house or purchase at the store, or it might be those little bottles you can buy at the store in a typical week. Do you or other family members drink bottled water at home?

1 Yes
2 No

About what percent of all of the water you all drink in your household comes from bottled water?

_________ %

About how much total do you pay for bottled water each month?

______$ per month
D Don't Know

Perceived Risk

Now we want to find out your thoughts about risks. Please look at pages 8 and 9 of the information brochure we mailed you.

I want to ask you about the risks that you think you face. Look at Page 9 of the brochure, Risk Ladder 1. Did you make one mark or two marks?

1 One mark
2 Two marks
3 Cannot decide where to mark
4 DID NOT MARK ANY YET
5 Refused to make marks
Why do you refuse to make the marks?

If Certain: What line did you make your mark on? ______
If uncertain: What was the highest line you made your mark on? ______
If uncertain: What was the lowest line you made your mark on? ______