

**The effect of water quality on demand for safe drinking
water in rural and peri-urban Cambodia**

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Executive Summary

Policy Question

How does perceived drinking water quality affect household willingness to pay (WTP) for clean water in rural Cambodia?

Background

Inadequate access to improved water and sanitation in the developing world continues to be a major public health and development challenge. UNICEF estimates that nearly 2 million child deaths are attributable to diarrhea (UNICEF, 2008). The excessive burden of diarrhea-related morbidity and mortality is partly attributable to inadequate access to safe drinking water. Poor access to high-quality and convenient water sources may partly be a problem of low demand (Whittington et al., 2009). In fact, there is relatively limited evidence in the literature on demand for water and sanitation services.

In this paper, we consider the demand for improved water quality only (rather than changes in both quality and convenience) in two communities in Kandal province, Cambodia. Importantly, many households in these communities already have access to convenient sources of water, either in the form of private connections to piped water networks, or via rainwater harvesting and storage where they live. These sources, however, are of variable quality, and water treatment, both at the system or household-level, is inconsistent.

We hypothesize that household WTP for improved water quality depends in part on individual perceptions of the safety of existing drinking water sources. Investigating the relationship between perceptions of and demand for water quality is important for two reasons. First, households may not accurately perceive the risks associated with their existing water, which would suggest the need for education on such risks, or the provision of information

related to their water quality. Second, promoters of improved access to water supply need to understand what features of such services are most important to households to achieve better targeting to consumer preferences. Understanding what role perceptions play as a determinant of WTP for improved water quality will allow for targeted interventions to affect demand for safe water.

Methodology

The contingent valuation methodology (CVM) is a commonly used way to measure demand for goods or services where markets are incomplete, imperfect, or inexistent (Dutta et al. 2005). Since markets for private water services tend to be imperfect, the CVM can be useful for capturing more accurate household demand values for improved water supply.

A number of CVM studies have been conducted in the developing world to measure the WTP for water services and treatment options. In addition, most CVM studies focusing on the water sector in developing countries have attempted to measure consumer WTP for improved water supply rather than improved water quality. Studies that have measured WTP for improved water quality in developing countries have not attempted to measure household perceptions of existing sources as a determinant of WTP for clean water.

Research in the United States that has included perceptions in WTP estimates concludes that as the perception of water quality increases, WTP for improvements in drinking water decreases. It seems probable that many of the same unobserved characteristics that influence WTP may also affect subjective quality perceptions (Whitehead 2006). Therefore, past studies that have attempted to include perceptions as an indicator of WTP for quality improvements may have had a biased coefficient on the quality perception variable in the WTP regression, because of the correlation in the error terms in the WTP and quality perception models.

In this paper, I estimate WTP for improved water quality using a basic logit model, investigating the effects of perceptions of water quality and actual water quality as covariates.

I also employ a two-stage least squares model (2SLS) to address the potential endogeneity of perceptions in predicting WTP for improved water quality. I utilize the coefficients from these models to estimate the mean WTP for improved water quality.

Data

The data for this study come from a household survey of 915 households in two communities in Kandal province, Cambodia. The survey included questions on household demographics, diarrhea incidence, water storage, handling, and treatment practices, water quality perceptions, and WTP for improved water quality. Water samples were collected for all households with piped connections and tested in laboratory settings.

Perceptions of water quality were measured on a scale of 1-10 using subjective probability games. Respondents were asked both about perceptions of source water quality and water quality after in-house handling, storage, and treatment. Respondents also participated in a WTP scenario in which they tasted three samples of treated water and were offered a binary price choice for 200 liters of their favorite sample.

Results

Simple correlation tests showed that there is little correlation between actual water quality and perceptions of water quality. Households were generally very confident that their in-house water was 100% safe to drink. Results from the WTP scenario illustrate a downward shaping demand curve for improvements to improved water quality.

Estimates from the basic logit model do not show that perceptions of water quality are statistically significant in affecting WTP for improved water quality. Under certain specifications of the basic model, actual water quality is statistically significant in affecting WTP for improved water quality. However, the marginal probabilities associated with actual water quality in these models are very small.

Estimates from the 2SLS model show that perceptions of both source and in-house water quality are negative and statistically significant in affecting WTP for clean water. Both of these perception measures have very large marginal probabilities. This result implies that as households believe that their water quality is better, the likelihood of rejecting the price offer for improved water quality decreases significantly.

From the regression output, I estimate mean household WTP for improved water quality of approximately \$2.50 per month for households in this sample. I also find that beliefs that existing levels of water quality are high have a significantly negative impact on WTP for improved water quality. Households that believe their in-house water quality is perfectly unsafe are willing to pay approximately \$1.50 more per month than households that believe their in-house water quality is perfectly safe.

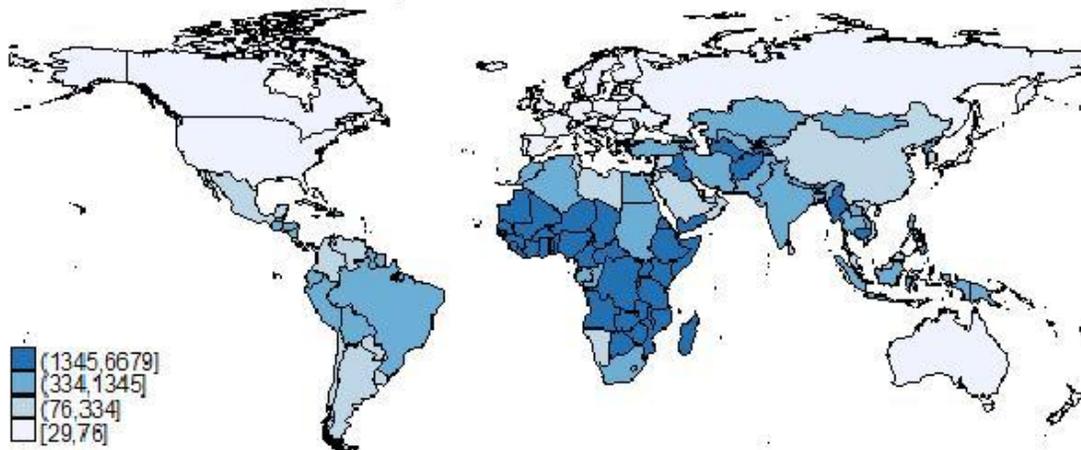
Discussion

The data gathered concerning perceptions about water quality and WTP in this study may be used to inform the design of future interventions in similar sites that have already made partial investments to improve access to water supplies. While there was not a very large sample size of actual water quality, the data suggests low correlation between perceived and actual water quality. The 2SLS models provide evidence that perceptions of water quality are greatly influencing demand, while the basic models imply that actual water quality does not have a large effect on demand. Since perceptions of in-house water quality in particular seemed to be overstated, one way to increase demand for improved water quality may be through educational campaigns to help align perceptions with actual water quality.

Introduction

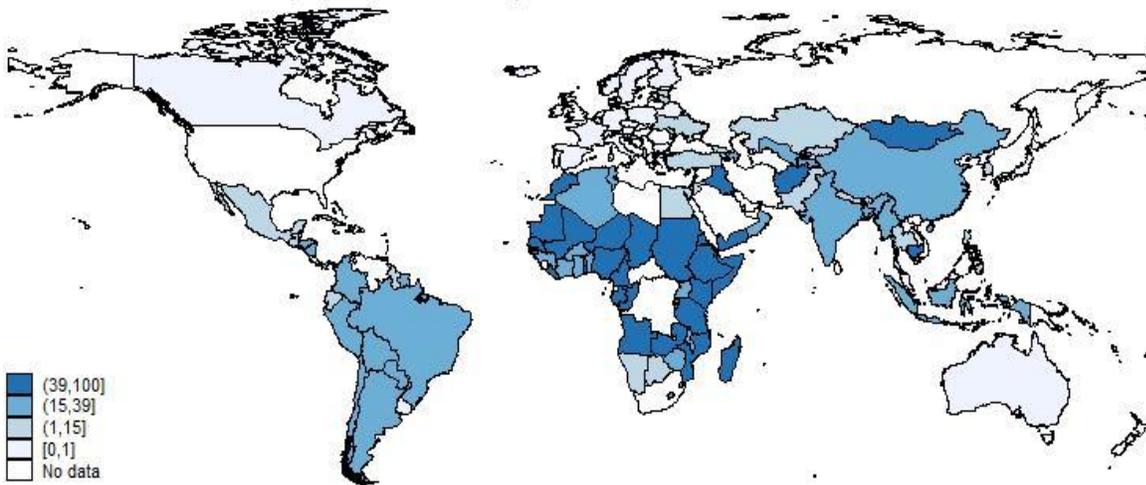
Inadequate access to improved water and sanitation in the developing world continues to be a major public health and development challenge. UNICEF estimates that nearly 2 million child deaths are attributable to diarrhea (UNICEF, 2008). The excessive burden of diarrhea-related morbidity and mortality is partly attributable to inadequate access to safe drinking water. The World Health Organization estimates that more than 894 million people worldwide lack access to an adequate amount of safe drinking water (UN Water, 2011). The following maps highlight the relationship between diarrhea DALYs and inadequate access to safe drinking water.

Map 1: DALYS Attributable to Diarrhea



Source: World Health Organization, 2008

Map 2: Percent of Rural Population that Lacks Access to Rural Water Source



Source: World Health Organization, 2010

Poor access to high-quality and convenient water sources may partly be a problem of low demand (Whittington et al., 2009). In fact, there is relatively limited evidence in the literature on demand for water and sanitation services. A recent meta-analysis of 40 stated preference studies for improved water supply estimated mean willingness-to-pay (WTP) values from \$4.90 to \$20.30 (2008 USD) per month (Van Houtven et al. 2011). Whittington et al. (2009) report somewhat lower values for piped connections (\$1.4-11.7 per month in 1998 USD) and public taps (\$0.30-3.70) from surveys. These differences may reflect both variations in quality of

these two types of sources, as well as quantity of water available from the sources. Actual expenses by households in urban areas in Africa, South Asia and Latin America (\$1.0-12.4 per month for private connections and \$4.4-\$13.9 from vendors) vary considerably as well. These values are generally well below the \$20-40 per household per month estimated full cost of piped water services.

In this paper, we consider the demand for improved water quality only (rather than changes in both quality and convenience) in two communities in Kandal province, Cambodia. Importantly, many households in these communities already have access to convenient sources of water, either in the form of private connections to piped water networks, or via rainwater harvesting and storage where they live. These sources, however, are of variable quality; and water treatment, both at the system or household-level, is inconsistent. A 2010 DHS report indicated that roughly 40% of Cambodians lacked access to improved drinking water sources (DHS Cambodia, 2010). This low level of access combined with poor handling and storage practices contributes to a childhood diarrhea prevalence of 26.4% (DHS Cambodia, 2010). In 2004, there were 309,933 reported cases of diarrhea in Cambodia out of a population of roughly 13 million (WHO, 2004). Indeed, as the above maps indicate, Cambodia is among the countries with the highest burden of disease related to diarrhea (measured in terms of disability-adjusted life years), and with the lowest access to improved water sources. Understanding whether the challenge of poor quality water can be addressed by promoting water treatment within existing systems therefore relies on accurate measurement of household demand for safe water.

We hypothesize that household WTP for improved water quality depends in part on individual perceptions of the safety of existing drinking water sources. Investigating the relationship between perceptions of and demand for water quality is important for two reasons. First, households may not accurately perceive the risks associated with their existing water, which would suggest the need for education on such risks, or the provision of information related to their water quality. Second, promoters of improved access to water supply need to understand what features of such services are most important to households to

achieve better targeting to consumer preferences. Understanding what role perceptions play as a determinant of WTP for improved water quality will allow for targeted interventions to affect demand for safe water.

The remainder of this paper is organized as follows. The next section presents background on the contingent valuation method and on previous work linking perceptions to willingness-to-pay for improved water quality. Section 3 describes the modeling framework. Section 4 discusses the survey and data collected. Results and a discussion follow in Sections 5 and 6.

Background

The contingent valuation methodology (CVM) is a commonly used way to measure demand for goods or services where markets are incomplete, imperfect, or inexistent (Dutta et al. 2005). Since markets for private water services tend to be imperfect, the CVM can be useful for capturing more accurate household demand values for improved water supply.

While the CVM is now widely accepted as a useful methodology for measuring demand in imperfect or nonexistent markets, social desirability and time pressures can bias results (Davis 2004). Additionally, CVM studies are often subject to hypothetical bias, in which respondents may value a hypothetical situation with which they have not had personal experience (Carson, 2000).

Despite the weaknesses of CVM studies, careful survey design can minimize these biases (Carson, 2000). A number of CVM studies have been conducted in the developing world to measure the WTP for water services and treatment options (Ahmad, Goldar & Misra 2005; Altaf, Whittington, et al. 1995; McPhail 1993; Murty, James & Misra 1998; Ntengwe 2004; Whittington & Lauria 1991; Whittington et al. 2002; Whittington et al. 1990). Most of these studies use regression techniques to isolate the determinants of WTP. Several of these studies highlight the importance of household preferences as determinants of WTP (Altaf 1994;

Kanyoka et al. 2008). In addition, most CVM studies focusing on the water sector in developing countries have attempted to measure consumer WTP for improved water supply rather than improved water quality (Briscoe et al. 1990, Casey et al. 2005, Goldblatt et al. 1998). Studies that have measured WTP for improved water quality in developing countries have not attempted to measure household perceptions of existing sources as a determinant of WTP for clean water (Rosado, et al. 2006, Dutta et al. 2005).

While the research on WTP measures for water quality improvements in the developing world has been very limited, a number of researchers have used CVM to obtain WTP estimates for quality improvements in the United States. Mitchell and Carson emphasize the importance of describing pre- policy and post-policy quality levels to respondents (Mitchell and Carson 1989). However, even when pre- and post-policy levels are thoroughly described, respondents may have different subjective perceptions about the current quality levels and hypothetical changes described in the WTP scenario (Whitehead 2006). Ignoring these varying subjective perceptions may contribute error to WTP estimates, and may therefore influence the policy advice that is generated by such demand studies. Research in the United States that has included perceptions in WTP estimates concludes that as the perception of water quality increases, WTP for improvements in drinking water decreases (Kwak et al. 2007, Yoo and Yang 2001). In both of these previous studies, perceptions were represented on a scale measuring attitudes or satisfaction with current drinking water.

It seems probable that many of the same unobserved characteristics that influence WTP may also affect subjective quality perceptions (Whitehead 2006). Therefore, past studies that have attempted to include perceptions as an indicator of WTP for quality improvements may have had a biased coefficient on the quality perception variable in the WTP regression, because of the correlation in the error terms in the WTP and quality perception models. Whitehead uses a two-stage least squares (2SLS) model to account for the endogeneity of quality perceptions in a study measuring WTP for water quality improvements in the Neuse River basin in North Carolina (Whitehead 2006).

Model

We start with a simple logit model that treats perceptions as an independent variable in the WTP estimation equation.

$$WTP = \sum_{i=1}^n \beta_i X_{1i} + \beta_p p_i + \alpha q_i + \varepsilon_{1i} \quad (1)$$

In this model, WTP is a dichotomous variable indicating if the respondent accepted a randomly-specified price offer p_i for improved water quality. X_{1i} is a vector of independent variables that includes a constant, education level, respondent and household demographics, and other variables that influence household i 's WTP for improved water quality, and β_i are coefficients that are estimated for the relative contribution of these independent variables to WTP. The term α is the coefficient on the water quality variable, represented by q_i . The term ε_{1i} represents a normally distributed error term. The first version of this model includes perceptions of water quality, and treats these as exogenous determinants of WTP. The second version uses actual laboratory-tested water quality instead. Standard errors are clustered at the village level.

As noted previously, it is likely that many of the characteristics that influence WTP cannot be observed, and that these unobservable characteristics are also correlated with perceptions of water quality leading to endogeneity bias in the model represented by equation 1 (Whitehead 2006). It is unlikely that actual water quality is subject to the same endogeneity biases. This correlation will bias the coefficient estimate α for water quality. However, the direction of this bias is unclear. On the one hand, households that perceive water quality to be low may also be engaged in safe drinking water storage, handling and in-house treatment practices, such that their WTP for further improvements is low. Not controlling adequately for the role of

perceptions in this case in reducing WTP will lead to downward bias in the demand estimates for improved water quality. On the other hand, cautious households may place a higher value on improved quality than others, such that their WTP is high whether or not they engage in protective treatment practices already, and depending on what they think or know about the safety of their water. We investigate these various possibilities using two measures of perceived and actual quality: source water, prior to in-house storage and treatment, and drinking water after storage and in-house treatment.

To study this issue, we first estimate water quality perceptions:

$$q_i = \sum_{i=1}^n \gamma_i X_{2i} + \varepsilon_{2i} \tag{2}$$

In this model, γ_i is a vector of estimated coefficients multiplied by X_{2i} , which represents the vector of variables that explain variation in actual or perceived water quality, and ε_{2i} represents a normally distributed error term.

To avoid biasing the coefficient on water quality in equation 1, we then follow the Whitehead model of using a 2SLS model. The first stage predicts perceived water quality using variables (X_{2i}) that have high explanatory power in equation 2 for quality, and low explanatory power in the WTP equation. The second stage then uses the predicted values of perceived water quality obtained from the first stage to predict WTP for improved water quality as shown in equation 3:

$$WTP = \sum_{i=1}^n \beta_i X_{1i} + \beta_p p_i + \alpha \hat{q}_i + \varepsilon_{1i} , \tag{3}$$

where \hat{q}_i are the predicted values of water quality obtained from the estimation of equation 2. Again, equation (1) will be estimated using both perceptions and actual water quality, while equation (3) will only be estimated using predicted perceptions of water quality that may be subject to endogeneity biases.

We then use the regression output from Equation (1) and Equation (3) to obtain estimates of mean WTP in these Cambodian communities where:

$$\text{Mean WTP} = - \frac{\sum \beta_i X_i}{\beta_{\text{WTPOFFER}}} \quad (4)$$

Data

The data for this study come from a household survey of 915 households in two communities in Kandal province, Cambodia. Site selection for this study was based on the following criteria: a) Sufficient proximity to Phnom Penh to ensure water samples could reach laboratories within 1 day; b) at least 400 households at each site to ensure sufficient statistical power; c) at least partial reliance on piped water supply in the community¹; d) sufficiently unreliable quality in piped water to potentially justify new treatment; and e) moderate to high incidence of diarrhea in the site, as determined through focus groups with village leaders and households in the communities. These criteria describe a large number of communities in rural and peri-urban villages in Kandal Province.

Based on these criteria, two sites were selected and 915 households were interviewed. Table 1 describes key characteristics of the sites. The survey included questions on household demographics, diarrhea incidence, water storage, handling, and treatment practices, water quality perceptions, and WTP for improved water quality. Key survey activities and selected groups of questions from the questionnaire were first tested in focus groups, and the complete questionnaire was pretested with 56 households in a neighboring community to Svey Ampear.

¹ The data gathered through this study was intended to inform a future piped-water treatment intervention. As a result, having at least partial reliance on piped water systems was an important site selection criterion.

Table 1: Description of Communities Surveyed

	Number of Communes	Names of Communes	Number of Villages	Number of households surveyed
Site 1:	1	Svey Ampear	5	444
Site 2:	2*	Peuk Ang Snoul	32	471

*Two communes are included in the second site, because they are provided by the same water supplier

In the villages selected, households use a variety of water sources that are treated to varying degrees (primarily at the household-level). Thus, there is great heterogeneity in the quality of water among households. As such, the survey included water testing and elicitation of subjective perceptions of water quality.

Surveys in developing countries have not historically asked about subjective probabilities, because of illiteracy or lack of understanding among respondents (Delavande et al., 2010). Delavande finds that employing visual aids to elicit subjective probabilities is a much more effective method than simply asking respondents to explain their level of certainty in probabilistic terms. This study employed a variation on a subjective perceptions “game” outlined in Delavande et al., 2010. The “game” consisted of distributing 10 small candies and a sheet of paper with two large circles labeled “safe” and “unsafe” to respondents. Enumerators instructed respondents to place candies in the circles according to what they believed about the safety of their drinking water. For example, if respondents felt that their water was 100% safe to drink, they would place all 10 candies in the safe circle. If respondents felt that their water was 100% unsafe to drink, they would place all 10 candies in the unsafe circle. If the respondent felt that their water was mostly safe to drink, they would place seven or eight candies in the safe circle, and so on. Respondents first participated in this activity regarding the water obtained directly from the source prior to any household treatment, storage or handling. They then repeated the activity for their drinking water after any household treatment, storage or handling, and just before consumption. Thus, two measures of perceptions were obtained:

perceptions of source water quality, and perceptions of water quality after in-house handling, storage, and treatment.

In addition, water samples were taken for microbiological testing from all households with working piped water connections (n = 144), directly from the tap (n = 144), and from combined rainwater storage and/or other long-term storage containers (n = 218). Finally, if different from those two locations (i.e. after additional treatment), respondents were asked to produce a sample of their drinking water (n = 79). Due to laboratory constraints, we were not able to collect water samples from all households. In addition, we were not able to take samples from every household with a piped connection because many households turn off their pipes during the rainy season.

Households were next asked about their WTP for improved water quality.² The WTP scenario carefully described the pre-policy quality of water as the household's status quo. In order to minimize hypothetical bias, respondents were first asked to sample three double-blinded samples of treated water (one bottled and two treated with two different Aquatabs products for disinfection).³ In addition to randomizing the order of the three products each day, the concentrations of the Aquatabs were also varied. Respondents were asked to select a favorite and least favorite sample after these taste tests. Then, to minimize the possibility that WTP would be suppressed by poor taste (a common criticism of chlorinated treatment), respondents were informed that the treated water in the WTP scenario was their favorite sample. To attempt to gauge respondent satisfaction with the taste and smell of their favorite sample, the questionnaire asked them to compare it to their current primary drinking water. The WTP models in this paper will be applied to the full sample, as well as a split sample of those that preferred their current drinking water to their favorite taste test sample and those that did not prefer their current drinking water to their favorite taste test sample, in order to assess the

² Appendix A contains the full WTP script used in the survey.

³ Aquatabs and TM Aquatabs are produced Medentech ©. They are both chlorination tablets designed to treat contaminated water. TM Aquatabs is designed to mask the chlorine taste. Population Services International has successfully marketed Aquatabs in a number of Cambodian villages. More information about the products can be found on Medentech's website: <http://www.medentech.com/>.

degree to which taste and satisfaction (rather than water quality) played a role in the expressed demand for improved water.

Immediately following the taste tests, respondents were offered a discrete fixed-price question for treated water. The quality of the treated water that was offered was carefully described as being perfectly safe to drink. Six price levels (\$0.25, \$0.75, \$1.25, \$1.88, \$3.75, \$6.25) were randomized among respondents. These price levels were selected based on a number of CVM exercises with focus groups in similar communities. Prior to answering, respondents were reminded of their budget constraints and were read a script designed to minimize strategic bias (see Appendix A). They were then asked whether they would pay the specified amount for 200 liters of their favorite sample. Two hundred liters is the amount of water that is typically treated by one Aquatab. Since this quantity of water may not be fully intuitive to respondents, they were also shown what 200 liters would be in terms of water bottles with which they would have some familiarity. To attempt to minimize hypothetical bias that may exist in CVM studies, respondents were also asked in debriefing questions how certain they were that they would or would not pay the given price. Respondents ranked their certainty on a scale of “very certain”, “fairly certain”, “fairly uncertain”, and “very uncertain.”

The survey instrument also included a section in which respondents chose preferred options from a set of choice tasks in which they were asked to make tradeoffs between different attributes of water treatment. In the survey, we presented water treatment options to respondents that varied in price, effectiveness at protecting from diarrheal disease, taste of water, and convenience. In future work, the choices made by respondents will be analyzed to isolate which attributes of water treatment are most valuable to consumers and at what levels. For the purposes of this paper, it is important to note however that since price levels for water treatment were included in the choice set section, these prices may have primed respondents for the WTP section. For example, if respondents saw relatively low prices presented in the choice sets and a higher price was offered during the WTP section, the respondent may have been more likely to reject the offer due to anchoring. To determine if

the survey design had an effect on WTP responses, we randomized the order of the choice set and WTP sections in each questionnaire, such that half of respondents completed the choice tasks before the take-it-or-leave-it WTP offer, and half received the WTP offer first. Such split-sample experiments are useful for assessing the potential threats posed by ordering effects in surveys (Lucas 2007).

Results

Table 2 includes some key descriptive statistics from the household survey. The average household size surveyed was 5.3, with 72% of respondents being female. Of the households surveyed, 25% use piped water either during the rainy or dry season and 76% treat their water daily in some way. Among the households with children under the age of five, childhood diarrheal disease incidence is 8%, based on a seven-day recall period.

Table 2: Descriptive Statistics

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
Accept WTP offer	907	0.49	0.5	0	1
Perceptions of water at source	912	3.72	2.63	0	10
Perceptions of water after in-house handling & treatment	911	9.1	1.44	0	10
# of children under five years old	915	0.49	0.65	0	4
Household size	913	5.3	2.22	1	14
Avg. Adult Education (years)	913	5.74	3.42	0	22.5
Female respondent	911	0.72	0.45	0	1
Age of respondent	912	42.25	14.25	15	82
Piped connection	915	0.25	0.43	0	1
Treats water daily	913	0.76	0.42	0	1
Number of televisions owned	903	0.93	0.64	0	10
Number of motorcycles household owns	903	0.88	0.88	0	5
Number of cellphones household owns	903	1.63	1.52	0	12
Observed that household had soap	915	0.8	0.4	0	1
Scale of how long household stores water from treatment until consumption (0=does not treat, 5=more than 7 days)	904	1.18	0.92	0	5
Child diarrheal disease incidence	370	0.08	0.27	0	1
Predicted Income ⁴ (natural log, Riel ⁵)	902	13.84	0.52	5	17.11
Satisfaction with current drinking water taste & smell (1=Like it, 0=Do not like it)	915	0.76	0.43	0	1
Predicted source <i>E.coli</i> concentration	144	512.34	2906.84	0	28600
Predicted in-house <i>E.coli</i> concentration	79	349.11	1886.05	0	16000

Perceptions and Quality Data

Figure 1 illustrates how respondents' perceptions of water quality. It illustrates that most respondents believed their water to be in an unsafe category when collected from the source (0-50%). However, after in-house handling, storage, and treatment, nearly all respondents believed their drinking water to be in a safe category (60-100%), with an overwhelming

⁴ Since not all households reported income, a predicted measure of income based on OLS predictions is used. The regression used to predict income can be found in Appendix B.

⁵ At the time of the survey, 4,100 Riel=\$1.00

number of respondents believing their water to be 100% safe. This is in spite of the fact that not all households treat their water regularly, and that there is considerable variation in the safety of in-house handling and storage practices. The correlation between source quality perceptions and in-house quality perceptions is 0.10.

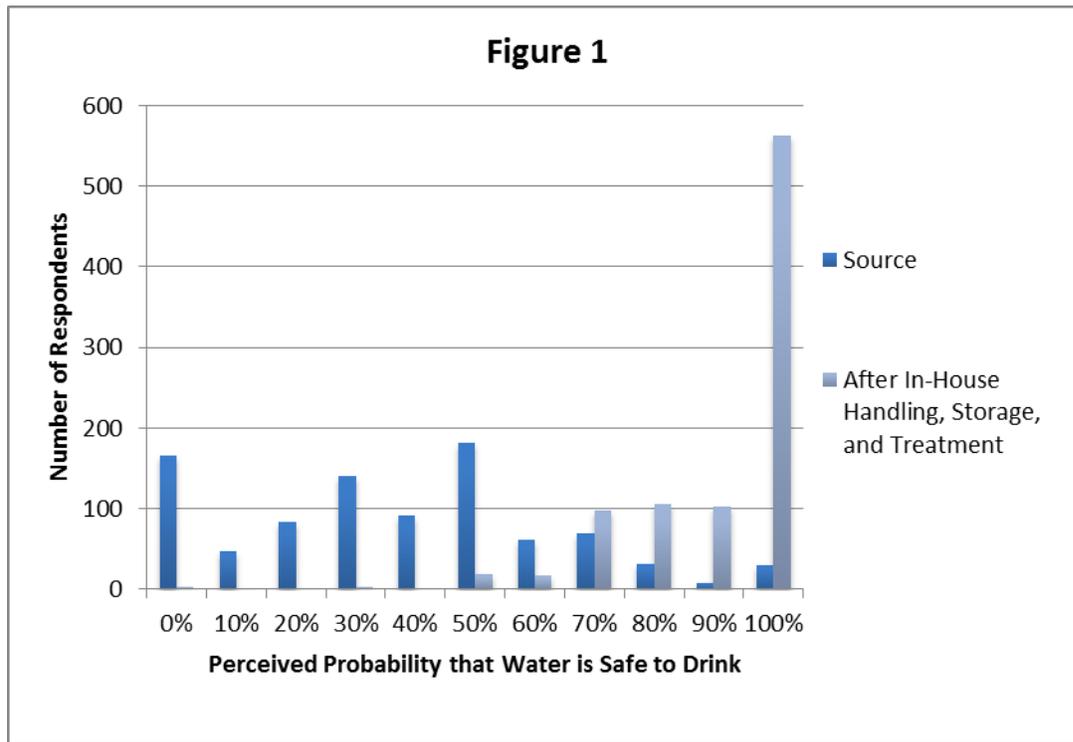


Figure 1: Perceptions of Water Quality

Figure 2 further maps perceptions of source water quality of all piped households to actual water quality of those we were able to sample. The first category on the x-axis (e.g. 0 Compliance) indicates standard categorizations⁶ for *E. coli* per 100 mL. The second category on the x-axis (e.g. 10 Perfect Quality) groups perceptions using sub-categories from the 0-10 scale on which respondents assessed their perceptions of water quality. While the sample size is not very large and the perceptions categories are subjective, the chart shows that more households tend to have conservative views of their source water and appear to perceive that it is less safe than it is in reality. However, the correlation between *E. coli* categorization and water perceptions is very low, 0.0392, suggesting that household perceptions of source water

⁶ These categorizations were previously used by the WHO, and are now standard practice. Throughout this paper, they will be referred to as “Former WHO Categories.”

quality are often inaccurate.

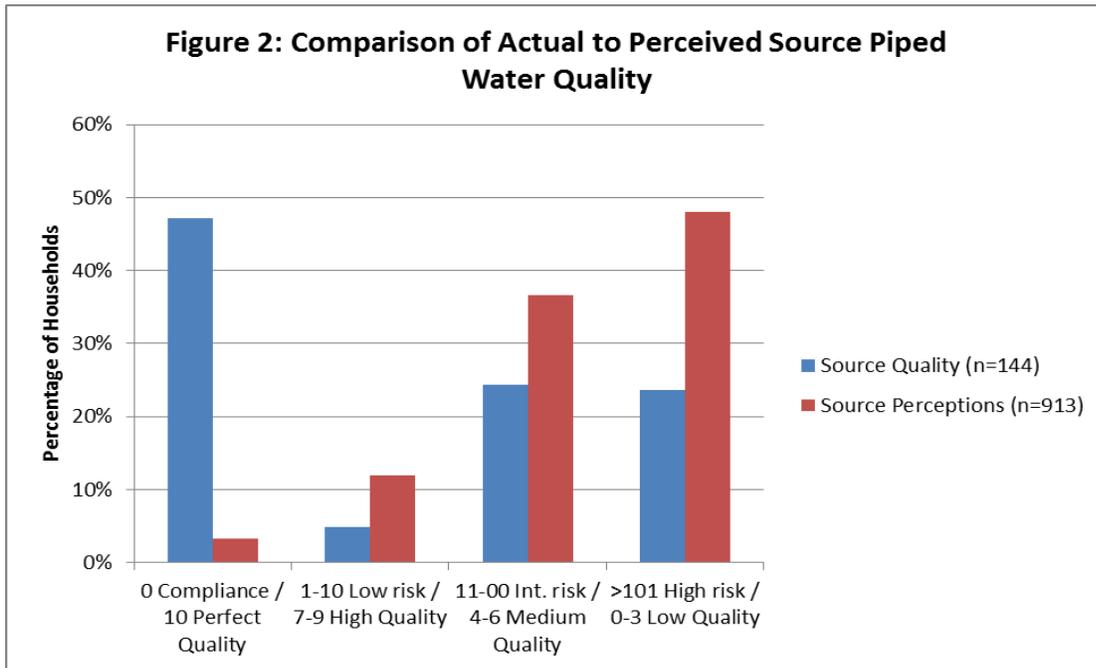
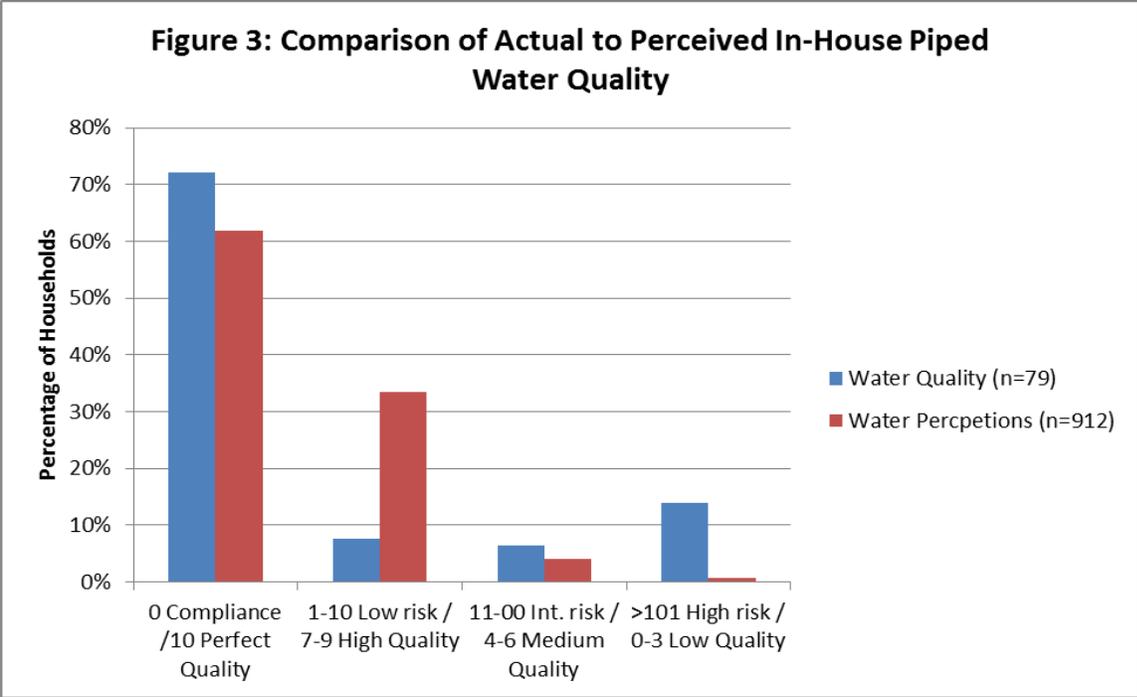


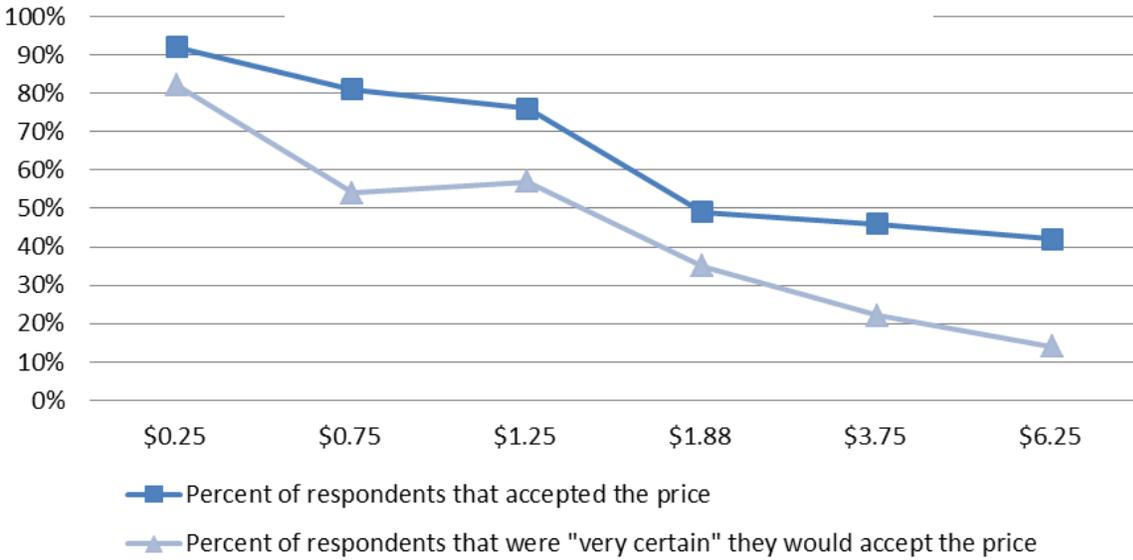
Figure 3 shows the comparison between treated water of piped households and the perceptions of piped households that reported treating their water. Respondents seem to be overconfident in their perceptions of water quality at the intermediate to high risk levels. The correlation coefficient between water perceptions of in-house water and actual *E.coli* categorization is low and in this case negative (-0.13).



Willingness to Pay Data

Figure 4 illustrates WTP responses for treatment of 200 liters at the six randomized price levels used in the survey. The dark line in Figure 5 indicates the percentage of respondents that stated they would pay for 200 liters of their favorite sample from the taste tests at the given price. After responding to this question, enumerators asked respondents how certain they were of their responses. The light line shows the percentage of respondents that were very certain that they would accept the price. Both lines indicate a downward-sloping demand curve, with the price sensitivity of very certain “yes” responses being considerably higher than including the less certain “yes” responses. Because we believe the “very certain” responses better indicate true WTP, the remainder of the analyses included in this paper use these responses, rather than the less conservative affirmative responses to the WTP offer. It is important to note that WTP responses did not significantly differ by taste test preference. For example, respondents that preferred bottled water did not systematically have different WTP responses from those that preferred either of the Aquatab options (results not shown).

Figure 4: Willingness to Pay for Clean Water



Basic WTP Model

Table 3 displays a basic logit model for WTP treating perceptions of source water quality as exogenous (Equation 1). The model shown in Table 3 relies on a continuous variable for perceptions. The perceptions variable ranges from zero to ten according to the responses in the game described previously.

Table 3: Basic Model, source perceptions (Full sample)

Variables	(1): Logit Accept WTP offer	Full sample Marginal Probabilities
WTP offer	-0.657*** (0.0629)	-0.130
Perceptions of source water quality	-0.0220 (0.0283)	-0.004
Primary source is piped water	-0.487*** (0.186)	-0.096
Primary source is rain water	-0.259 (0.210)	-0.051
Average years of adult education in hh	0.0717*** (0.0252)	0.014
Respondent gender (1=female)	0.157 (0.145)	0.031
Respondent age (years)	-0.00123 (0.00473)	0.000
Predicted total earnings (natural log)	0.544*** (0.202)	0.107
Choice set section appeared first	0.336 (0.209)	0.066
Community indicator (1=Ang Snoul)	-0.359* (0.215)	-0.071
Observed faeces in hh (1=yes)	-0.284** (0.139)	-0.056
Treats water daily	-0.274 (0.241)	-0.054
Days of storage before consumption	0.00673 (0.0499)	0.001
Soap observed in hh (1=yes)	-0.121 (0.309)	-0.024
Satisfied with current drinking water taste and smell (1=yes)	-0.613*** (0.168)	-0.121
Constant	-5.712** (2.743)	
R-squared	0.168	
Observations	883	

Robust clustered standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

The full sample regression contained in Table 3 suggests that perceptions of source water quality do not affect WTP for improved water quality. However, use of piped water as the primary water source has a statistically significant negative relationship with willingness to pay the stated price, relative to other sources such as surface water, water vendors, and wells. This may indicate a belief that piped sources are of better quality than the alternatives. Education and income are positively related with willingness to pay, which is consistent with expectations since more educated respondents may be more aware of the importance of safe water, and higher income households can afford higher bids. The variable indicating that the choice set section appeared before the WTP section in the questionnaire is not statistically significant implying that those respondents completing choice tasks prior to the WTP scenario were neither more nor less likely to accept the stated price. The community indicator has a negative and significant relationship, indicating that households in Ang Snoul (the second community) were significantly more likely to reject the WTP offer. Interestingly, these households tended to have worse actual water quality than households in Svey Ampear, which were more likely to accept the WTP offer (see Appendix C). The dummy variable indicating whether animal faeces are present in the household is statistically significant and negative, implying that households with faeces in their household are not overly concerned with water contamination and thus have lower demand for water quality improvements. The dummy variable indicating that the households preferred the taste and smell of their favorite water sample to their regular drinking water was negative and statistically significant. This result indicates that households that were already satisfied with drinking water taste and smell were less likely to be concerned about water quality improvements, and suggests that perhaps preferences for taste and smell could confound preferences for the safety of drinking water, an issue which we investigate further below.

Table 4 contains the results of the basic model for the split sample. The first column shows the results for households that did not prefer the treated water sample to their current water sample. The second column shows results for the remaining households that did prefer the treated water sample to their current water sample. Perceptions of source water quality are

statistically significant at the 10% level for the sample that did not prefer the taste test water sample to their own drinking water. Perceptions are not significant for households that preferred the taste test sample to their own drinking water.

Table 4: Basic Model, source perceptions (Split sample)

Variables	(2): Logit Accept WTP offer	Did not prefer water sample: Marginal Probabilities	(3): Logit Accept WTP offer	Did prefer water sample: Marginal Probabilities
WTP offer	-0.633*** (0.107)	-0.121	-0.691*** (0.0756)	-0.131
Perceptions of source water quality	-0.0702* (0.0373)	-0.013	0.0270 (0.0366)	0.005
Primary source is piped water	-0.254 (0.324)	-0.049	-0.734*** (0.270)	-0.140
Primary source is rain water	-0.129 (0.467)	-0.025	-0.355* (0.197)	-0.067
Average years of adult education in hh	0.0691** (0.0348)	0.013	0.0654** (0.0296)	0.012
Respondent gender (1=female)	0.433** (0.214)	0.083	-0.0365 (0.226)	-0.007
Respondent age (years)	0.00118 (0.00729)	0.000	-0.00167 (0.00584)	0.000
Predicted total earnings (natural log)	0.393 (0.243)	0.076	0.929** (0.381)	0.177
Choice set section appeared first	0.623** (0.283)	0.120	0.0918 (0.271)	0.017
Community indicator (1=Ang Snoul)	-0.493* (0.276)	-0.095	-0.265 (0.250)	-0.050
Observed faeces in hh (1=yes)	-0.119 (0.275)	-0.023	-0.430** (0.193)	-0.082
Treats water daily	-0.523 (0.463)	-0.100	-0.0239 (0.270)	-0.005
Days of storage before consumption	0.0507 (0.0993)	0.010	0.000897 (0.0670)	0.000
Soap observed in hh (1=yes)	-0.0178 (0.364)	-0.003	-0.136 (0.360)	-0.026
Satisfied with current drinking water taste and smell (1=yes)	-1.176*** (0.329)	-0.226	-0.348** (0.176)	-0.066
Constant	-3.812 (3.265)		-10.74** (5.310)	
R-squared	0.180		0.192	
Observations	389		488	

Robust clustered standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Table 5 contains the basic logit model for WTP treating actual source water quality as exogenous (Equation 1). Primary water sources are excluded as control variables from these regressions because water quality samples were only taken from households with piped connections (due to laboratory constraints). The columns in Table 5 display different measures of source water quality. Column 1 in Table 5 shows that source water quality as a continuous variable is statistically significant and positive, implying that as the *E.coli* count increases at the source, household demand for water quality improvements increases. Column 4 shows a reversal of the sign when including a squared measure of the actual source water quality that implies that as the *E. coli* count increases at the source, household demand for water quality improvements increase. However, the marginal effect of source water quality in these models is small. For example, the marginal probability associated with column 4 (not reported) shows that an additional 100 *E. coli* cell in source water increases the probability of accepting the WTP offer by 0.26 percentage points. Columns 2 and 3 show that categorizing *E.coli* quantities by the former WHO standards and using the natural log of actual *E.coli* counts do not yield statistically significant results.

Table 5: Basic model, actual source quality

Variables	(1): Logit Accept WTP offer	(2): Logit Accept WTP offer	(3): Logit Accept WTP offer	(4): Logit Accept WTP offer
WTP offer	-0.955*** (0.181)	-0.977*** (0.202)	-0.972*** (0.199)	-0.959*** (0.200)
Raw <i>E.coli</i> count	0.000150** (6.81e-05)			-0.00166* (0.000920)
Source <i>E.coli</i> count (Former WHO Categories)		-0.215 (0.166)		
Source <i>E.coli</i> count (natural log)			-0.0389 (0.0357)	
Source <i>E.coli</i> count (squared)				1.27e-07 (6.36e-07)
Average years of adult education in hh	0.0418 (0.0709)	0.0354 (0.0703)	0.0345 (0.0707)	0.0535 (0.0763)
Respondent gender (1=female)	-0.226 (0.593)	-0.185 (0.566)	-0.181 (0.565)	-0.138 (0.622)
Respondent age (years)	-0.00624 (0.0137)	-0.00928 (0.0155)	-0.00924 (0.0153)	-0.00111 (0.0148)
Predicted total earnings (natural log)	1.056* (0.578)	1.039 (0.640)	1.041 (0.636)	1.043* (0.607)
Choice set section appeared first	-0.192 (0.551)	-0.0742 (0.628)	-0.0860 (0.629)	0.0558 (0.575)
Community indicator (1=Ang Snoul)	-1.272*** (0.471)	-1.362*** (0.470)	-1.368*** (0.480)	-1.328*** (0.401)
Observed faeces in hh (1=yes)	-0.729* (0.376)	-0.927** (0.386)	-0.904** (0.390)	-0.883** (0.433)
Treats water daily	1.371** (0.588)	0.971 (0.655)	0.973 (0.662)	1.480** (0.599)
Days of storage before consumption	0.00232 (0.152)	-0.0596 (0.160)	-0.0615 (0.161)	0.0146 (0.146)
Soap observed in hh (1=yes)	-0.711 (1.091)	-0.816 (1.076)	-0.753 (1.062)	-0.999 (1.113)
Satisfied with current drinking water taste and smell (1=yes)	-0.792 (0.691)	-0.904 (0.676)	-0.907 (0.683)	-0.653 (0.632)
Constant	-12.04 (7.895)	-10.39 (8.762)	-10.98 (8.906)	-12.02 (8.379)
R-squared	0.262	0.260	0.258	0.291
Observations	136	136	136	136
Robust clustered standard errors in parentheses				
*** p<0.01, ** p<0.05, * p<0.1				

We use similar basic logit models to estimate the effects of actual and perceived water quality of in-house water – after handling, storage, and treatment – on WTP estimates (Tables 6-8). The results using in-house water quality perceptions as a predictor of WTP as shown in Table 6 and Table 7 are similar to those obtained using source water perceptions from Table 3 and Table 4. In both full sample models (Table 3 and Table 6), variables representing households that rely on piped water for their primary water source, average years of adult education, predicted total earnings, community indicator, observed faeces in household, and satisfaction with current drinking water taste and smell are all significant. Perceptions in both models are negative, but not statistically significant and have small marginal probabilities.

Table 6: Basic Model, in-house perceptions (Full sample)

Variables	(1): Logit Accept WTP offer	Marginal Probabilities
WTP offer	-0.657*** (0.0649)	-0.130
Perceptions of in-house water quality	-0.0517 (0.0634)	-0.010
Primary source is piped water	-0.487*** (0.186)	-0.096
Primary source is rain water	-0.253 (0.206)	-0.050
Average years of adult education in hh	0.0735*** (0.0256)	0.015
Respondent gender (1=female)	0.155 (0.151)	0.031
Respondent age (years)	-0.00167 (0.00490)	0.000
Predicted total earnings (natural log)	0.558*** (0.204)	0.110
Choice set section appeared first	0.320 (0.212)	0.063
Community indicator (1=Ang Snoul)	-0.357* (0.214)	-0.071
Observed faeces in hh (1=yes)	-0.288** (0.142)	-0.057
Treats water daily	-0.270 (0.241)	-0.053
Days of storage before consumption	-0.000834 (0.0516)	0.000
Soap observed in hh (1=yes)	-0.118 (0.305)	-0.023
Satisfied with current drinking water taste and smell (1=yes)	-0.617*** (0.157)	-0.122
Constant	-5.488** (2.778)	
R-squared		
	0.169	
Observations		
	882	
Robust clustered standard errors in parentheses		
*** p<0.01, ** p<0.05, * p<0.1		

For the subsample that did not prefer the taste test water sample to their own drinking water (Table 4 and Table 7), variables representing average years of adult education, respondent gender, whether the choice set section appeared first, and satisfaction with current drinking water taste and smell are statistically significant. While perceptions of source water quality are significant for this subsample (Table 4), perceptions of in-house water quality are not. Furthermore, predicted total earnings are significant in this model at the 10% level while they are not in the model that included perceptions of source water quality (Table 4).

Water sources, adult education, predicted earnings, observable faeces, and satisfaction with the taste and smell of current drinking water are all significant for the subsample that did prefer the taste test water sample to their own drinking water in both models that included source perceptions and in-house perceptions (Table 4 and Table 7). Perceptions of water quality are not statistically significant in either of these models.

Table 7: Basic Model, in-house perceptions (Split sample)

Variables	(2): Logit Accept WTP offer	Did not prefer water sample: Marginal Probabilities	(3): Logit Accept WTP offer	Did prefer water sample: Marginal Probabilities
WTP offer	-0.625*** (0.108)	-0.121	-0.693*** (0.0765)	-0.132
Perceptions of in-house water quality	-0.0278 (0.101)	-0.005	-0.0821 (0.0890)	-0.016
Primary source is piped water	-0.253 (0.311)	-0.049	-0.756*** (0.265)	-0.144
Primary source is rain water	-0.177 (0.452)	-0.034	-0.337* (0.195)	-0.064
Average years of adult education in hh	0.0730** (0.0368)	0.014	0.0671** (0.0298)	0.013
Respondent gender (1=female)	0.494** (0.231)	0.095	-0.0446 (0.232)	-0.008
Respondent age (years)	0.000597 (0.00691)	0.000	-0.00170 (0.00622)	0.000
Predicted total earnings (natural log)	0.427* (0.247)	0.082	0.942** (0.373)	0.179
Choice set section appeared first	0.588** (0.288)	0.114	0.0894 (0.265)	0.017
Community indicator (1=Ang Snoul)	-0.457 (0.289)	-0.088	-0.273 (0.249)	-0.052
Observed faeces in hh (1=yes)	-0.0915 (0.276)	-0.018	-0.446** (0.193)	-0.085
Treats water daily	-0.468 (0.464)	-0.090	-0.0825 (0.286)	-0.016
Days of storage before consumption	0.0262 (0.100)	0.005	-0.00643 (0.0684)	-0.001
Soap observed in hh (1=yes)	-0.00925 (0.342)	-0.002	-0.136 (0.358)	-0.026
Satisfied with current drinking water taste and smell (1=yes)	-1.202*** (0.312)	-0.232	-0.295* (0.159)	-0.056
Constant	-4.294 (3.287)		-10.05* (5.590)	
R-squared	0.176		0.193	
Observations	389		487	

Robust clustered standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 8 explores the relationship between actual in-house water quality and WTP for water quality improvements. Again, primary water sources are excluded as covariates because water quality samples were only taken from households with piped water. Including in-house categorizations of *E.coli* counts yields a negative and statistically significant coefficient on in-house water quality, with a marginal effect of -.08. This result implies that as households move up one point on the former WHO water quality scale (lower numbers on the scale indicate better water quality), their probability of accepting the WTP offer decreases by 8%. This finding may imply that households with cleaner water are already displaying a preference for improved water quality. The coefficient on in-house *E. coli* concentration in the model that includes a squared term (column 4) is also negative and statistically significant, which runs counter to the finding when including the former WHO categorization. This negative coefficient implies that as actual in-house water quality worsens, WTP for improved water quality decreases. However, the coefficient is small with a corresponding marginal effect of -0.02 for 100 *E. coli* counts, which implies that as the in-house *E. coli* count increases by 100, the household is 2% less likely to accept the WTP offer.

Table 8: Basic Model, actual in-house quality

Variables	(1): Logit Accept WTP offer	(2): Logit Accept WTP offer	(3): Logit Accept WTP offer	(4): Logit Accept WTP offer
WTP offer	-1.282*** (0.463)	-1.402*** (0.463)	-1.374*** (0.454)	-1.421*** (0.466)
Raw in-house <i>E.coli</i> count	3.69e-05 (0.000110)			-0.00191*** (0.000477)
In-house <i>E.coli</i> count (Former WHO Categories)		-0.557* (0.293)		
In-house <i>E.coli</i> count (natural log)			-0.0953 (0.0581)	
In-house <i>E.coli</i> count (squared)				1.37e-07*** (3.32e-08)
Average years of adult education in hh	0.100 (0.0872)	0.101 (0.0816)	0.107 (0.0801)	0.0588 (0.0792)
Respondent gender (1=female)	-1.020 (0.965)	-1.287 (0.969)	-1.243 (0.987)	-1.150 (1.052)
Respondent age (years)	0.0120 (0.0251)	0.0229 (0.0290)	0.0206 (0.0286)	0.0205 (0.0252)
Predicted total earnings (natural log)	0.755 (0.853)	0.891 (0.839)	0.838 (0.828)	0.855 (0.897)
Choice set section appeared first	-0.260 (0.690)	0.133 (0.854)	0.0946 (0.835)	-0.331 (0.674)
Community indicator (1=Ang Snoul)	-2.765 (1.742)	-2.998* (1.543)	-2.813* (1.591)	-2.182 (1.484)
Observed faeces in hh (1=yes)	-0.119 (0.558)	-0.0344 (0.559)	-0.0967 (0.546)	0.130 (0.499)
Treats water daily	0.0829 (1.334)	-0.392 (1.427)	-0.498 (1.491)	-0.282 (1.372)
Days of storage before consumption	-0.584 (0.470)	-0.606 (0.490)	-0.625 (0.474)	-0.506 (0.495)
Soap observed in hh (1=yes)	-1.114 (0.949)	-1.561** (0.772)	-1.518* (0.808)	-2.869*** (0.682)
Satisfied with current drinking water taste and smell (1=yes)	-0.172 (0.868)	0.153 (0.900)	0.115 (0.865)	0.0991 (0.873)
Constant	-4.845 (10.23)	-5.494 (9.770)	-5.967 (9.723)	-4.896 (10.72)
R-squared	0.308	0.341	0.332	0.349
Observations	72	72	72	72
Robust clustered standard errors in parentheses				
*** p<0.01, ** p<0.05, * p<0.1				

Two-stage least squares WTP model

The models specified in Tables 3-6 do not take into account the potential endogeneity of actual quality or quality perceptions in estimating WTP for improved quality. Table 9 illustrates that using the 2SLS model to account for endogeneity of perceptions results in a statistically significant coefficient for perceived water quality (Equation 3), both in the full sample as well as the split samples. Primary water sources, adult education, income, respondent sex, respondent age and a binary variable for community were used to predict perceptions of source water quality. We expect water source to play an important role in affecting perceptions of source water quality. However, the first column of Table 9 indicates that source does not play a statistically significant role in influencing perceptions of source water quality. Rather, income, community, the presence of animal faeces in the household, and whether the household was satisfied with the taste and smell of their water are statistically significant indicators of perceptions of water quality. Since the number of households that we were able to obtain water samples from is relatively low (n=149), we do not include actual *E.coli* counts as a predictor of source water quality perceptions.

Table 9: 2SLS Model, source perceptions (Full sample)

Variables	(1) OLS Perceptions of source water quality	(2) Logit Accept WTP offer	Marginal Probability
WTP offer		-0.658*** (0.0637)	-0.130
Predicted perceptions of source water quality		-0.821*** (0.211)	-0.162
Primary source is piped water	-0.295 (0.222)	-0.731*** (0.207)	-0.144
Primary source is rain water	0.0678 (0.241)	-0.207 (0.206)	-0.041
Average years of adult education in hh	-0.0465 (0.0421)	0.0339 (0.0309)	0.007
Respondent gender (1=female)	-0.209 (0.163)	-0.0172 (0.172)	-0.003
Respondent age (years)	0.00891 (0.00718)	0.00562 (0.00495)	0.001
Predicted total earnings (natural log)	-0.383* (0.214)	0.239 (0.229)	0.047
Choice set section appeared first		0.319 (0.210)	0.063
Community indicator (1=Ang Snoul)	-0.466** (0.191)	-0.737*** (0.224)	-0.146
Observed faeces in hh (1=yes)	-0.270* (0.139)	-0.495*** (0.164)	-0.098
Treats water daily		-0.250 (0.242)	-0.049
Days of storage before consumption		0.00317 (0.0520)	0.001
Soap observed in hh (1=yes)		-0.135 (0.307)	-0.027
Satisfied with current drinking water taste and smell (1=yes)	0.764*** (0.180)		
Constant	8.870*** (3.012)	1.407 (3.647)	
Observations	898	884	
R-squared	0.046	0.168	
Robust clustered standard errors in parentheses			
*** p<0.01, ** p<0.05, * p<0.1			

In the second stage of the model, the sign on the predicted perceptions coefficient is negative, which is consistent with the hypothesis that as perceptions of source water quality improve, household demand for improved water quality will decrease. The coefficient of the predicted

perceptions is statistically significant in the model with the full sample. This finding supports the hypothesis that perceptions are likely endogenous in the basic model. Piped connections, the community indicator, and observable faeces remain significant in this model, and the signs are the same as those in the basic model (Table 3). However, education and total earnings lose their significance in this model compared with the basic model (Table 3). One potential explanation for the loss of significance in these variables is that their effects are partially being captured by the predicted perceptions variable. However, the coefficient on price is not significantly different from the coefficient in Table 3, which implies stability between the models.

Table 10 displays the results from the split sample. The predicted perceptions used in this second stage estimation are the same as those from the first stage used in Table 9. The marginal probability for those that did not prefer the water sample to their current water sample (-0.31) is much larger than the marginal probability for those that did prefer the water sample (-0.08). This result implies that perceptions of source water quality were much more important in influencing demand among those who were generally satisfied with the taste and smell of their water (those that did not prefer the taste test water sample to their own). On the other hand, perceptions of source quality were much less important in driving WTP among households that were not as satisfied with the taste and smell of their own water (those that did prefer the taste test water sample to their own), which is why the marginal probability of their source water quality perceptions is significantly lower. It is important to note that the variable indicating whether the household was currently satisfied with the taste or smell of their current water was omitted from the second stage of the regression because it also measures perception (of taste and smell rather than quality) and thus is subject to the same endogeneity biases as the quality perception variables. However, only one predicted variable can be estimated using a 2SLS model.

Table 10: 2SLS Model (1st stage in Table 9) , source perceptions (Split sample)

Variables	(3): Logit Accept WTP offer	Did not prefer water sample: Marginal probabilities	(4): Logit Accept WTP offer	Did prefer water sample: Marginal probabilities
WTP offer	-0.631*** (0.110)	-0.122	-0.690*** (0.0748)	-0.131
Predicted perceptions of source water quality	-1.559*** (0.410)	-0.302	-0.421* (0.219)	-0.080
Primary source is piped water	-0.731** (0.336)	-0.142	-0.862*** (0.299)	-0.164
Primary source is rain water	-0.0693 (0.446)	-0.013	-0.332* (0.196)	-0.063
Average years of adult education in hh	-0.00130 (0.0496)	0.000	0.0452 (0.0327)	0.009
Respondent gender (1=female)	0.135 (0.252)	0.026	-0.123 (0.256)	-0.023
Respondent age (years)	0.0141 (0.00883)	0.003	0.00260 (0.00599)	0.000
Predicted total earnings (natural log)	-0.167 (0.262)	-0.032	0.763* (0.426)	0.145
Choice set section appeared first	0.549* (0.285)	0.106	0.0947 (0.269)	0.018
Community indicator (1=Ang Snoul)	-1.188*** (0.311)	-0.230	-0.459* (0.277)	-0.087
Observed faeces in hh (1=yes)	-0.495 (0.315)	-0.096	-0.546*** (0.193)	-0.104
Treats water daily	-0.445 (0.462)	-0.086	-0.0504 (0.278)	-0.010
Days of storage before consumption	0.0268 (0.0999)	0.005	0.00440 (0.0649)	0.001
Soap observed in hh (1=yes)	-0.0654 (0.344)	-0.013	-0.135 (0.359)	-0.026
Constant	9.349** (4.633)		-6.869 (6.488)	
Observations	390		488	
R-squared	0.174		0.191	
Robust clustered standard errors in parentheses				
*** p<0.01, ** p<0.05, * p<0.1				

The 2SLS model in Table 11 accounts for this potential endogeneity of water quality for in-house drinking water perceptions (rather than source water quality as shown in Table 9). Several additional variables were used to predict these perceptions (compared to those for

source perceptions as included in Table 9), because it is likely that more handling, storage, and treatment characteristics will influence a household's perceptions of in-house water quality.

Table 11: 2SLS Model, in-house perceptions (Full sample)

Variables	(1) OLS Perceptions of in- house water quality	(2) Logit Accept WTP offer	Marginal probabilities
WTP offer		-0.658*** (0.0637)	-0.130
Predicted perceptions of in-house water quality		-1.741*** (0.448)	-0.344
Primary source is piped water	-0.0542 (0.123)	-0.583*** (0.192)	-0.115
Primary source is rain water	0.276* (0.142)	0.219 (0.216)	0.043
Average years of adult education in hh	0.0158 (0.0128)	0.0996*** (0.0239)	0.020
Respondent gender (1=female)	-0.0695 (0.0718)	0.0338 (0.164)	0.007
Respondent age (years)	-0.00135 (0.00484)	-0.00404 (0.00508)	-0.001
Predicted total earnings (natural log)	0.0581 (0.0646)	0.654*** (0.201)	0.129
Choice set section appeared first		0.319 (0.210)	0.063
Community indicator (1=Ang Snoul)	0.200*** (0.0672)	-0.00606 (0.242)	-0.001
Observed faeces in hh (1=yes)	-0.0325 (0.0630)	-0.330** (0.145)	-0.065
Treats water daily	-0.0905 (0.130)	-0.407* (0.234)	-0.080
Days of storage before consumption	-0.0250 (0.0361)	-0.0403 (0.0517)	-0.008
Soap observed in hh (1=yes)	0.105 (0.131)	0.0477 (0.315)	0.009
Satisfied with current drinking water taste and smell (1=yes)	0.360** (0.158)		
Constant	7.768*** (0.822)	7.653 (4.889)	
Observations	888	884	
R-squared	0.036	0.168	
Robust clustered standard errors in parentheses			
*** p<0.01, ** p<0.05, * p<0.1			

Similar to the 2SLS model for source water quality perceptions, Table 11 shows that after the 2SLS adjustment, perceptions of in-house water quality are statistically significant in affecting WTP. Similar to the coefficient on source water quality perceptions, the 2SLS output in Table 8 confirms the hypothesized negative relationship between predicted values of in-house water perceptions and WTP for improved water quality. Table 12 contains the results from the split sample, using the same first stage prediction from Table 11. The perceptions of in-house water quality were much more important in influencing demand among those who were generally satisfied with the taste and smell of their water (those that did not prefer the taste test water sample to their own). The marginal probability in the split sample for those that did not prefer the water sample relative to their own drinking water (-0.64) is larger than that for those that did prefer the water sample to their own drinking water (-0.17). Similarly to the interpretation for source perceptions, this result implies that perceptions of drinking water quality were more important in influencing demand for water treatment among those who were generally satisfied with the taste and smell of their water (those that did not prefer the water sample to their own drinking water) than those who did not.

Table 12: 2SLS Model (1st stage in Table 11), in-house perceptions (Split sample)

Variables	(3): Logit Accept WTP offer	Did not prefer water sample: Marginal probability	(4): Logit Accept WTP offer	Did prefer water sample: Marginal Probability
WTP offer	-0.631*** (0.110)	-0.122	-0.690*** (0.0748)	-0.131
Predicted perceptions of in-house water quality	-3.307*** (0.870)	-0.641	-0.893* (0.464)	-0.170
Primary source is piped water	-0.449 (0.316)	-0.087	-0.786*** (0.282)	-0.150
Primary source is rain water	0.739* (0.436)	0.143	-0.114 (0.232)	-0.022
Average years of adult education in hh	0.124*** (0.0310)	0.024	0.0789*** (0.0302)	0.015
Respondent gender (1=female)	0.231 (0.242)	0.045	-0.0965 (0.247)	-0.018
Respondent age (years)	-0.00431 (0.00700)	-0.001	-0.00236 (0.00595)	0.000
Predicted total earnings (natural log)	0.622** (0.261)	0.121	0.976*** (0.370)	0.186
Choice set section appeared first	0.549* (0.285)	0.106	0.0947 (0.269)	0.018
Community indicator (1=Ang Snoul)	0.199 (0.354)	0.039	-0.0846 (0.260)	-0.016
Observed faeces in hh (1=yes)	-0.182 (0.281)	-0.035	-0.461** (0.191)	-0.088
Treats water daily	-0.744* (0.448)	-0.144	-0.131 (0.273)	-0.025
Days of storage before consumption	-0.0557 (0.0967)	-0.011	-0.0179 (0.0637)	-0.003
Soap observed in hh (1=yes)	0.282 (0.337)	0.055	-0.0408 (0.376)	-0.008
Satisfied with current drinking water taste and smell (1=yes)				
Constant	21.21*** (7.215)		-3.666 (7.737)	
Observations	390		488	
R-squared	0.174		0.191	
Robust clustered standard errors in parentheses				
*** p<0.01, ** p<0.05, * p<0.1				

Estimating Average WTP

We calculate four estimates of WTP, using the models in Tables 3-12. The mean WTP estimate obtained from the basic model using source perceptions (Table 3) is \$1.61 for 200 liters of clean water. Since most other WTP measures are provided as a monthly amount, I used the British Dietetic Association recommended drinking amount 1.89 liters of uncontaminated water per day (British Dietetic Association, 2007) to convert this into a monthly figure. Based on this estimate, the average monthly WTP for the average household of 5.3 people in rural Cambodia is \$2.42 per month. Table 13 provides similar WTP estimates across the different models using both perceived and actual quality estimates. The values range from \$1.81 to \$3.07 per month, with an average of \$2.45 across models.

Table 13: Mean Willingness to Pay Estimates

	Source Perceptions	Actual Source Quality	In-House Perceptions	Actual In-House Quality
Basic Model	\$2.44	\$1.82	\$2.43	\$3.07
2SLS	\$2.43	X	\$2.50	X

A recent working paper contains a meta-analysis on stated preference studies for improved water supply estimated mean WTP values from \$4.89 to \$20.27 per month (Van Houtven et al. 2011). The WTP estimates obtained in this Cambodia study focused solely on WTP for improved water quality, which may be why they are lower than the WTP for improved water supply estimates from the meta-analysis. Indeed, many of the households interviewed in this survey already had convenient water supply, in the form of extensive rainwater harvesting or via piped water connections. This evidence may reflect the fact that a desire for improved water quality is not the major driver in demand for water supply improvements. Consumers may place higher value on the convenience or other components of improved water supply than they do on water quality. Of course, similar estimates of WTP measures for improved water quality in other locations are needed to generalize this conclusion.

Table 14 contains ranges of WTP estimates for different subgroups of the survey sample. Controlling for other factors, piped households have lowest mean WTP and households with low perceptions of in-house water quality have the highest mean WTP. Piped households are likely already paying above average for monthly connections and thus may have a lower WTP for additional water quality improvements. It is logical that households with lowest perceptions of in-house water quality would have a high mean WTP, because these households are those that are most concerned with the quality of their drinking water.

Table 14: Willingness to Pay Estimate Ranges by Subgroup

Subgroup Categories	Mean WTP	WTP range
Piped users	\$1.65	\$1.04-\$2.05
Rainwater users	\$2.67	\$2.56-\$2.87
Other source users	\$2.96	\$2.37-\$3.17
Ang Snoul residents	\$1.75	\$0.85-\$2.50
Svey Ampear residents	\$3.18	\$2.51-\$4.73
Households that treat water daily	\$2.43	\$2.28-\$3.09
Households that do not treat water daily	\$2.51	\$0.18-\$3.21
Households that have soap	\$2.34	\$1.60-2.81
Households that do not have soap	\$2.87	\$2.41-4.11
Households that were satisfied with taste/smell of their current water	\$2.18	\$1.52-\$3.02
Households that were not satisfied with taste/smell of their current water	\$3.25	\$2.77-3.51
Households that had visible faeces in home	\$2.12	\$1.32-3.01
Households that did not have visible faeces in home	\$2.87	\$2.47-\$3.15
Households with high source perceptions (perceptions=10)	\$2.49	\$2.47-\$3.15
Households with low source perceptions (perceptions=0)	\$2.99	\$2.85-\$3.15
Households with high in-house perceptions (perceptions=10)	\$2.69	\$2.47-2.87
Households with low in-house perceptions (perceptions=0)	\$3.87	\$3.07-\$4.97

Table 14 shows that households that already were displaying strong treatment and hygiene behaviors (e.g. treating water daily or having soap in the household) had a lower mean WTP than households that did not engage in such behaviors. Households that were not satisfied with the taste/smell of their current water had a much higher mean WTP than households that were not. As hypothesized, households with low in-house perceptions had higher mean WTPs than households with high in-house perceptions. Table 14 also shows a dramatic difference in the mean WTP between households in Ang Snoul and households in Svey

Ampear. Households in Ang Snoul are willing to pay on average \$1.43 less per month than households in Svey Ampear. Though these communities have similar perceptions of water quality, the actual water quality in Ang Snoul is much worse (see Appendix C).

Table 15 contains mean WTP estimates from the split sample models. This table illustrates that households that did prefer the taste test water sample had a mean WTP of approximately \$1.00 higher than those that did not prefer the taste test water sample. Households that preferred the taste test sample to their own drinking water are more likely to switch away from their own water and thus have a higher WTP for the water provided in the taste sample.

Table 15: Mean Willingness to Pay Estimates for Split Sample

		Source Perceptions	In-House Perceptions	Mean for split sample
Did not prefer taste test sample:	Basic Model	\$2.20	\$2.31	\$2.48
	2SLS	\$2.83	\$2.57	
Did prefer taste test sample:	Basic Model	\$3.39	\$3.50	\$3.50
	2SLS	\$3.59	\$3.52	

Discussion

This paper uses a 2SLS model to estimate the effect of perceived and actual water quality on WTP for a water quality improvement. We use the coefficients obtained in these regressions to obtain estimates of mean WTP for improved water quality, ranging from \$1.82 to \$3.07 per month. The 2SLS models show that perceived source and in-house water quality have large and significantly negative relationship with WTP (Tables 9-12). Certain specifications of the basic models that use actual water quality as a predictor of WTP for improved water quality show (Table 5 and Table 8) show that actual water quality is statistically significant in influencing WTP. However, the coefficients have very small marginal probability effects.

This paper also shows that treating water quality perceptions as endogenous through the 2SLS

model helps in understanding what role perceptions play in affecting demand. Both the source and in-house perceptions models confirmed the hypothesis that as perceptions of water quality improve, the demand for better water quality decreases. However, the price coefficients in the 2SLS models are not significantly different than those obtained from the basic logit predictions.

Furthermore, the split sample in the 2SLS show that perceptions of water quality played a larger role influencing demand in the households that did not prefer the sample to their own drinking water. Households that already are satisfied with the taste and smell of their water tend to be more concerned with water quality than households that preferred the water sample to their own drinking water.

Additionally, this paper contributes a new WTP measure for water quality to a relatively limited literature on this subject in the developing world. We estimate that households in peri-urban Cambodia will pay an average of \$2.45 per month for improved water quality. While this estimate is lower than a recent meta-analysis, our study only looks at improvements in quality. Consumers may place higher value on convenience, or other components of improved water supply than they do on water quality.

The data gathered concerning perceptions about water quality and WTP in this study may be used to inform the design of future interventions in similar sites that have already made partial investments to improve access to water supplies. While we did not have a very large sample size of actual water quality, our data suggests low correlation between perceived and actual water quality. The 2SLS models provide evidence that perceptions of water quality are greatly influencing demand, while the basic models imply that actual water quality does not have a large effect on demand. Since perceptions of in-house water quality in particular seemed to be overstated, one way to increase demand for improved water quality may be through educational campaigns to help align perceptions with actual water quality. Informational campaigns have proven particularly successful in the water and sanitation sector (Jalan and Somanthan 2008).

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Appendix A: Willingness to Pay Script

7.1 Now I am going to ask you about your willingness to pay for your preferred water option. Know that this water is high quality and perfectly safe to drink. As you know, water treatments do not all cost the same.

Do you have any questions about what I have told you? _____

7.2. I want to know if you would buy this water at a specific price. Note that I am not selling this water to you today, but I want to know your opinion.

Do you have any questions about what I have told you? _____

7.3. When you answer this question, you should consider the following factors:

- a) The current source of water you use, including its price, the cost of treatment to you, the quality and taste or smell of the water
- b) The taste and smell of the new water, the quality, and the price of this water
- c) Your household budget, and the other things you would like to spend money for.

Do you have any questions about what I have told you? _____

7.4. Let me give you some examples:

a) First, you may not pay much for the water you currently drink, but perhaps it is of poor quality and sometimes leads to illness among those who drink it. Some people in this case will choose to buy the new water because they like the higher quality. Other people will say that the higher price of the new water is not worth the change in quality.

b) Second, you may feel that the quality of your existing water is adequate, but the taste and smell of this water is not good. Some people in this situation will choose to buy the new water because they like the taste. Other people will find that the improved taste and smell is not justified for the higher cost.

Do you have any questions about what I have told you? _____

7.5. When you answer this question, I want you to be truthful about whether you would be willing to pay the price that I will offer you. The response you provide may be used to decide how to best serve your community with improved water. If you say “no” that you would not buy this water but actually think “yes” that you would, we may think that people in this community do not want the better water enough to justify the cost, and the community could lose the opportunity to have this improved water. On the other hand, if you or others say “yes” that you would pay the price but in reality think “no”, your community may end up with a water supply that is expensive and that you do not want. This water system could replace other projects that would have higher benefit for your community.

Do you have any questions about what I have told you? _____

8. Would you be willing to pay _____ Riel for 200 liters of your favorite sample?

[1] Yes

[2] No

[-9] Don't know/ Unsure (***Skip to next section***)

9. How certain are you that you would or would not pay ____ Riel for 200 liters of your favorite sample?

[1] Very certain

[2] Fairly certain

[3] Fairly uncertain

[4] Very uncertain

[-9] Don't know/ Unsure

Appendix B: Income Predictions

Table 16: Regression to predict total earnings for full sample

Variables	(1) OLS Ln(Total Earnings)
Average years of adult education in hh	0.00510 (0.0113)
Community indicator (1=Ang Snoul)	-0.0516 (0.0872)
Number of refrigerators owned	0.757** (0.340)
Number of electric fans owned	0.0233 (0.0449)
Number of televisions owned	0.0173 (0.0658)
Number of bicycles owned	0.0785* (0.0441)
Number of motorcycles owned	0.226*** (0.0577)
Number of cars/trucks owned	0.278** (0.125)
Number of tractors owned	0.435*** (0.144)
Number of cellphones owned	0.115*** (0.0380)
Number of mosquito nets owned	0.0395 (0.0253)
Does HH own or rent house (1=own)	0.126 (0.0988)
Constant	13.01*** (0.152)
Observations	688
R-squared	0.218
Standard errors in parentheses	
*** p<0.01, ** p<0.05, * p<0.1	

Appendix C: Community Water Quality and WTP

Table 15: Water Quality by Community

	Ang Snoul	Svey Ampear
Mean <i>E.coli</i> count/100mL for source water (Std. Dev.)	608 (3489)	321 (1020)
Mean <i>E.coli</i> count/100mL for in-house water (Std. Dev.)	448 (2158)	37 (97)
Perceptions of source water quality (Std. Dev.)	3.48 (2.62)	3.96 (2.62)
Perceptions of in-house water quality (Std. Dev.)	9.25 (1.28)	8.93 (1.58)
Mean WTP	\$1.75	\$3.18