Water quality perceptions and willingness to pay for clean water in peri-urban Cambodian communities

Jennifer Orgill, Ameer Shaheed, Joe Brown and Marc Jeuland

ABSTRACT

This paper studies household demand for improved water quality in peri-urban Cambodia, with particular attention paid to the influence of water quality on willingness to pay (WTP). Utilizing data from 915 household surveys, we analyze responses to a contingent valuation scenario using multivariate logit regression techniques that account for subjective perceptions of water quality. We estimate a mean household WTP for improved water quality of US$3 (roughly 1.2% of mean income) per month for households in this sample. We also find that the majority of households believe that their in-house water after storage, handling, and treatment is safe to drink. Furthermore, beliefs about existing levels of water quality have a significant impact on WTP for improved water quality. However, while perceptions of quality (and thus WTP) are highly related to taste preferences, actual water quality is relatively uncorrelated with water quality perceptions. These findings suggest that interventions aiming to increase the adoption of water treatment should account for underlying perceptions of water quality.

Key words | Cambodia, contingent valuation, point-of-use water treatment, water quality

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INTRODUCTION

Inadequate access to improved water and sanitation in low income countries continues to be a major public health and development challenge, in spite of recent progress towards expanding coverage. UNICEF estimates that nearly 1.3 million child deaths are attributable to diarrhea (UNICEF 2012). The excessive burden of diarrhea-related morbidity and mortality is partly attributable to inadequate access to safe drinking water (Prüss-Üstün & Corvalán 2006). The World Health Organization (WHO) and UNICEF estimate that more than 780 million people worldwide lack access to an adequate amount of safe drinking water, and deficiencies in coverage map closely with the burden of diarrheal disease (WHO/UNICEF JMP 2012). Cambodia, where this study was conducted, is one of the low income countries where this burden of disease, measured in terms of disability-adjusted life years (DALYs), remains quite high in spite of recent gains in coverage (UNDP/UNICEF 2009).

Poor access to high quality and convenient water sources may partly be due to low demand (Whittington *et al.* 2009). Still, there are relatively limited high quality data on the demand for improved water and sanitation services. A recent meta-analysis of 40 stated preference studies for improved water supply in low income countries estimated mean willingness to pay (WTP) values ranging from US$4.90 to US$20.30 (2008 US$) per month (Van Houtven *et al.* 2011). Whittington *et al.* (2009) report somewhat lower survey-based measures for the economic benefits of piped connections (US$1.4–11.7 per month in 1998 US$) and public taps (US$0.30–3.70) in low income countries. Revealed preference measures of demand are even more limited (Ashraf *et al.* 2010; Kremer *et al.* 2011; Luoto *et al.* 2012). Meanwhile, actual expenses by households in urban areas in Africa, South Asia, and Latin America vary considerably as well (US$1.00–12.40 per month for private connections and US$4.40–13.90 from vendors).

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The wide range of demand estimates may reflect variations in the quality of different types of improved sources, the quantity and convenience of the water that can be obtained from them, or different contextual factors or individual preferences that affect demand (Whittington *et al.* 2012). Still, most of the estimates found in the literature are generally well below the US$20–40 per household per month full cost estimate of piped water services; and the evidence on demand for water quality similarly appears well below the cost of most point-of-use solutions (3iE Report 2012).

In this paper, we consider the demand for improved water quality (rather than changes in both quality and access/quantity) in two communities in Kandal Province, Cambodia. Importantly, many households in these communities already have access to improved water sources, as defined by the WHO and UNICEF Joint Monitoring Programme for Water Supply and Sanitation (JMP). The improved sources in this study consist of household connections to a private piped water network (typically a single tap in front of the household), or via household-level rainwater harvesting and storage. Despite being defined as 'improved', these sources provide water that varies in quality. Also, water treatment is inconsistent, both at the system and household level. The lack of regular and effective water treatment, combined with poor handling and storage practices, may partially account for Cambodia's 26.4% observed 2-week prevalence of childhood diarrhea (DHS Cambodia 2010). Understanding how to promote water treatment within existing 'improved' water systems requires accurate measurement of household demand, and its determining factors (e.g., informational, marketing, or subsidy interventions).

In this paper, we test the hypothesis that household WTP for improved water quality depends in part on individual perceptions of the safety and acceptability (e.g., with regards to taste and appearance) 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 because microbial contamination is not readily observable or the germ theory of disease is not recognized. This lack of understanding would suggest the need for educational or informational interventions related to water quality and health implications of water contamination (Somanathan 2010; Hamoudi *et al.* 2012). Second, promoters of improved access to water supply need to understand which features of such services are most important to households to achieve better targeting to consumer preferences (Yang *et al.* 2007).

METHODS

Contingent valuation methodology

The contingent valuation methodology (CVM) is commonly used to measure demand for goods or services where markets are incomplete, imperfect, or nonexistent (Dutta *et al.* 2005). In most settings, and particularly in low income countries, water services are highly subsidized and pricing schemes (such as increasing block tariffs) may not be transparent to users. The distortions in such markets, combined with limited variation in prices, imply that measuring the slope of the demand curve is often quite difficult. In this context, the CVM can be used to more accurately capture household demand, by presenting survey respondents with varying and randomized hypothetical price offers. Indeed, the CVM is now widely accepted as a useful methodology for obtaining measures of demand for such improvements. A number of CVM studies conducted in low income countries measure the WTP for water services and treatment options (Whittington *et al.* 1990, 1991, 2002; McPhail 1993; Altaf *et al.* 1993; Murty *et al.* 1999; Ntengwe 2004; Ahmad *et al.* 2005).

The theoretical advantages of CVM measures notwithstanding, social desirability and time pressures can bias results (Davis 2004). Additionally, CVM studies are often subject to hypothetical bias, in the sense that respondents may be asked to value a hypothetical situation with which they have had only limited or no personal experience. Even so, careful survey design can help minimize these biases (Carson 2000).

Most existing CVM studies for improved water use regression techniques to isolate the determinants of WTP, and most such studies for low income countries have focused on improved water supply rather than improved water quality (Briscoe *et al.* 1990; Goldblatt 1999; Casey *et al.* 2005). Several of these studies highlight the importance of household preferences as determinants of WTP (Altaf *et al.* 1993; Kanyoka *et al.* 2008), but none have dealt with the role of household perceptions of existing sources as a determinant of WTP for clean water (Dutta *et al.* 2005; Rosado *et al.* 2006).

While research on WTP for water quality improvements in low income countries has been very limited, several studies have used the CVM to obtain WTP estimates for quality improvements in the United States. In this vein, Mitchell & Carson (1989) emphasize the importance of describing pre-policy and post-policy quality levels to respondents. However, even when water quality is thoroughly described, respondents may have very different subjective perceptions of what the specified levels actually imply, in terms of negative effects on health and well-being. As a result, the hypothetical changes described in a WTP scenario may vary systematically across respondents (Whitehead 2006). Due to omitted variables bias, ignoring these varying subjective perceptions may lead to error in parametric estimates of WTP even if prices are randomized to respondents. In addition, to the extent that respondents' subjective perceptions of the quality of the proposed improvement do not match its actual quality, the CVM exercise may measure demand for the wrong good. This may lead to the generation of inappropriate policy advice from such demand studies. For example, research in the USA that has included perceptions in WTP estimates concludes that as the perception of baseline water quality increases, WTP for improvements in drinking water decreases, as the marginal improvements proposed become smaller (Yoo & Yang 2001; Kwak *et al.* 1997). In each of these studies, perceptions were represented on a scale measuring attitudes or satisfaction with current drinking water sources.

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 themselves suffer from endogeneity bias, because of correlation between the error term in the WTP model and the measure of perceptions. In this case also, the coefficient on the perception variable in the WTP regression (and the resulting WTP estimate) may be biased. In order to address this concern, Whitehead proposes 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 of North Carolina (Whitehead 2006). In this model, the first stage involves estimation of water quality perceptions, and the second stage utilizes predicted perceptions from the first stage (rather than the actual measures of perceptions) as an explanatory variable for WTP.

Model

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

$$Y_i = \beta_0 + \beta_1 X_{i1} + \cdots + \beta_n X_{in} + \beta_p p_i + \alpha q_i + \varepsilon_i \tag{1}$$

In this model, Y_i is a dichotomous variable that is equal to 1 if the respondent accepted a randomly specified price offer p_i for improved water quality, and zero otherwise. X_{i1} through X_{in} are independent variables that include education level, respondent and household demographics, and other variables that influence household i's demand for improved water quality. The coefficients β_j are estimated using logistic regression; these indicate the average relative effects of each of the independent variables on the probability of accepting the price offer. The term α is the coefficient on the water quality variable, which is represented by q_i. ε_i represents a normally distributed error term. In exploring the influence of water quality on demand, our analysis explores the use of two variables. The first version of this model includes perceptions of water quality, and treats these as exogenous determinants of WTP. The second version, for which full results appear in the Appendix, Tables A2 and A3, uses actual laboratory-tested water quality instead (available online at http://www.iwaponline.com/jwh/011/212.pdf). Standard errors are clustered at the village level.

As noted previously, it is likely that many of the characteristics that influence demand 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). In the model using water quality perceptions, this correlation will bias the estimate of the coefficient 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 reducing WTP in this case will lead to downward bias in the demand estimates for improved water quality. On the other hand, cautious households who tend to overestimate risks related to poor water quality may place a higher value on further improvements in water quality than others. These households will have a high WTP whether or not they engage in protective treatment practices already, and depending on what they think or know about the safety of their water. At the same time, it is unlikely that actual water quality, particularly at the source, is subject to the same problems, although in-house water may be affected by perceptions if these drive differences in storage, handling, and treatment practices.

We investigate these various possibilities using two measures of perceived and actual quality: (1) untreated source water; and (2) drinking water after storage and any in-house treatment. To reduce the risk of biasing the coefficient on water quality perceptions in Equation (1), we then apply the two-stage Whitehead model. In the first stage, we aim to identify factors that influence water quality perceptions:

$$q_i = \gamma_1 X_{i1} + \cdots + \gamma_n X_{in} + \varepsilon_i \tag{2}$$

In this model, the estimated coefficients, γ_j, are multiplied by X_{i1} through X_{in}, which represent variables that explain variation in actual or perceived water quality. ε_i represents a normally distributed error term.

The second stage then uses the predicted values of perceived water quality obtained from the first stage to predict the likelihood of accepting to pay price p_i for improved water quality as shown in Equation (3):

$$Y_i = \beta_0 + \beta_1 X_{i1} + \cdots + \beta_n X_{in} + \beta_p p_i + \alpha\widehat{q}_i + \varepsilon_i \tag{3}$$

where $\widehat{q}_i$ are the predicted values of water quality perceptions obtained from the estimation of Equation (2). Equation (1) is estimated using both perceptions and actual water quality, while Equation (3) is estimated using predicted perceptions of water quality that may be subject to endogeneity bias. In the first stage of the two-stage model, we aim to include variables (X_{ij}) that have high explanatory power in Equation (2) for quality, and low explanatory power in the demand equation.

We then use the regression output from Equation (1) and Equation (3) to obtain estimates of the WTP (in US$) for improved water quality, which is obtained by integrating the estimated demand curves over all prices. We assume an exponential demand curve that is a declining function of price, such that the expression simplifies to:

$$\mathrm{WTP}_i = -\frac{\beta_1 X_{i1} + \cdots + \beta_n X_{in} + \alpha\widehat{q}_i}{\beta_p} \tag{4}$$

By using a simple logit model as well as this two-stage model, we are able to assess the extent to which endogenous perceptions of water quality may lead to bias in estimates of: (1) the influence of perceptions on WTP; and (2) the estimates of WTP themselves. Both of these issues are of considerable interest for the design of policies or interventions to promote improved water quality. In our presentation of results, we primarily compare models (in terms of their estimated coefficients and the resulting mean and bootstrapped standard errors for WTP), although we comment on results using the other alternative measures of perceived and actual water quality (for which full details are presented in the Appendix, Tables A1–A4, http://www.iwaponline.com/jwh/011/212.pdf).

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 one 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 community (the data gathered through this study were 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); (d) sufficiently unreliable quality in piped water to potentially justify supplementary or new treatment; and (e) moderate to high incidence of diarrhea, as determined through focus groups with village leaders and households in the communities. These criteria describe a large number of rural and peri-urban villages in Kandal Province. Based on these criteria and to reach the desired sample size, two communes, made up of 37 villages, were selected (Table 1). We obtained ethical approval from Duke University's Institutional Review Board, the London School of Hygiene and Tropical Medicine, and Cambodia's Ministry of Rural Development before conducting fieldwork for this study.

The survey instrument included questions on household demographics, diarrhea prevalence, water storage, handling, and treatment practices, WTP for improved water quality, and preferences for other features of drinking water supply. In addition, the study included water testing and elicitation of subjective perceptions of 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 one of our site locations.

Surveys in low income countries have not traditionally measured subjective probabilities, because of illiteracy or lack of understanding among respondents (Delavande *et al.* 2011). Delavande finds that employing visual aids to elicit subjective probabilities is, however, an effective method for helping respondents to explain their level of certainty in probabilistic terms. This study employs a variation on a subjective perceptions 'game' outlined in Delavande *et al.* (2011). 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 their beliefs regarding 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 they 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. Both questions thus yield a variable for perceptions that is an integer ranging between 0 and 10.

Table 1 | Description of communities surveyed

	Number of communes	Number of villages	Number of households surveyed
Site A	2	32	471
Site B	1	5	444

Two communes are included in the first site, because they are provided by the same water supplier.

In addition, water samples were taken for microbiological testing from all households with working piped water connections ($n = 144$). Within the household, samples were taken (based on availability) directly from the tap ($n = 144$), from combined rainwater storage and/or other long-term storage containers ($n = 218$), and from containers of water that was treated at the household level ($n = 79$). 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 turned off their pipes during the rainy season, when rainwater could be used as the primary drinking-water source.

Households were next asked about their WTP for improved water quality (see Appendix A for the full script, http://www.iwaponline.com/jwh/011/212.pdf). The WTP scenario carefully described the pre-policy quality of water as the household's status quo, and explained that the treated water being valued would be rendered perfectly safe to drink. To minimize hypothetical bias, respondents were first asked to sample three double-blinded samples of treated water: one non-chlorinated bottled sample and two different samples treated with 'Aquatabs' chlorine disinfection tablets. Aquatabs and TM Aquatabs are produced by Medentech. They are both chlorination tablets designed to treat contaminated water. TM Aquatabs are 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/. In addition to randomizing the order of the three products each day, the concentrations of the Aquatabs were also randomly assigned (ranging between 0.2 and 5 mg/L free chlorine). Respondents were asked to select a favorite and least favorite sample after these taste tests. Then, since we were primarily interested in demand for a change that would result in safe water that had acceptable taste and smell (and not demand for either of the Aquatabs products per se), respondents were informed that they should respond as if the treated water in the WTP scenario corresponded to their favorite sample. To further gage respondent satisfaction with the taste and smell of this favorite sample, enumerators asked them to compare the taste of that favored sample to that of their current primary drinking water.

By accounting for these taste preferences and structuring the CV question in this way, the analysis can yield WTP for safe water that is minimally contaminated by the effects of poor taste (which is a common criticism of chlorinated treatment). Furthermore, using the response on how the favored sample compares to respondents' status quo source of drinking water allows us to parse the data to explore whether WTP among these two subsets of respondents – those preferring the taste of their current water and those not preferring it – is different. To do this, WTP models are estimated for the full pooled sample of respondents as well as these two separate subsamples.

Immediately following the taste tests, respondents were offered a single price for a specified amount (200 L) of treated water. Six price levels (US$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 conducted in similar communities, which were further refined based on the data from the pre-test. The 200-L quantity corresponds to the amount of water that is typically treated by one Aquatab (although 20-L versions also exist and are the variety that is now most commonly sold in Cambodia). Since this quantity of water may not be fully intuitive to respondents, they were also shown what 200 L would be in terms of water bottles with which they would have some familiarity. The treated water that was offered was clearly noted as being safe to drink.

Prior to answering, respondents were reminded of their budget constraints and were read a script designed to minimize strategic bias (see Appendix A, http://www.iwaponline.com/jwh/011/212.pdf). 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 treated water. In these exercises, we presented water treatment options to respondents that varied in price, effectiveness at protecting from waterborne 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 that since price levels for water treatment were included in the choice set section, these prices may have primed respondents for the CV 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 CV sections in the survey, such that half of respondents in the second community 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 *et al.* 2007).

RESULTS

Table 2 presents key descriptive statistics from the household survey. The average household size surveyed is 5.3, and 72% of respondents are female. Across the villages selected for the study, households use a variety of water sources that are treated to varying degrees (primarily at the household level). Twenty-five percent use piped water for at least part of the year. Eighty-three percent of

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 and treatment	911	9.09	1.44	0	10
No. of children under 5 years old	915	0.49	0.65	0	4
Household size	913	5.30	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	14.56	15	82
Piped connection	915	0.25	0.43	0	1
Rainwater as primary source in rainy season	915	0.83	0.38	0	1
Wells as primary source in rainy season	915	0.06	0.23	0	1
Surface water as primary source in rainy season	915	0.04	0.20	0	1
Treats water daily	913	0.77	0.42	0	1
Boils daily	915	0.67	0.47	0	1
Filters water daily	915	0.09	0.09	0	1
Removes treated drinking water from treated storage container by pouring (from piped household sample only)	82	0.50	0.50	0	1
Removes treated drinking water from treated storage container by dipping ladle or cup (from piped household sample only)	82	0.51	0.50	0	1
Washes storage container with soap	904	0.32	0.47	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	0.80	0.40	0	1
Ordinal scale of how long household stores water from treatment until consumption[a]	904	2.17	1.87	0	5
Child diarrheal disease prevalence	370	0.08	0.27	0	1
Ln(Total Earnings) (Riel)[b]	700	13.8	1.1	9.7	20.9
Satisfaction with current drinking water taste and smell: (1 = Like it, 0 = Do not like it)	915	0.76	0.43	0	1

[a] 1 = less than 1 day, 2 = about 1 day, 3 = more than 1 day but less than 3 days, 4 = between 3 and 7 days, 5 = more than 7 days, 6 = do not treat drinking water.

[b] Since not all households reported income, a predicted measure of income based on ordinary least squares (OLS) predictions is used. The prediction used asset measurements, education, and household socioeconomic variables to predict income. At the time of the survey, 4,100 Riel = US$1.00.

households rely on rainwater as their primary drinking water source during the rainy season. Wells account for roughly 2% of the primary water sources used by households, and raw surface water or water from vendors makes up roughly 8% of the primary water sources. Nearly 77% of households treat their water daily in some way, with 84% of these households relying on boiling as their primary treatment method. Furthermore, 23% of households report storing water for more than one day before consumption, and 32% of households report washing their storage containers with soap. Diarrheal disease prevalence for children under the age of five years is 8%, based on a 7-day recall period.

Perceptions and water quality

Figure 1 illustrates respondents' perceptions of water quality, as obtained from the subjective perceptions game. Most respondents believe their water to be towards the unsafe end of the scale when it is collected from the source

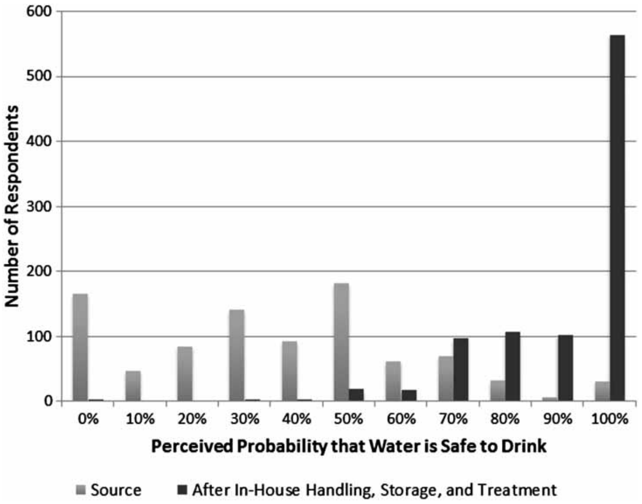

Figure 1 | Perceptions of water quality.

(0–50%). However, after in-house handling, storage, and treatment, nearly all respondents believe their drinking water to be towards the safe end of the scale (60–100%), with an overwhelming number of respondents believing their water to be 100% safe. This confidence in water quality comes 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, as described above. The correlation between source quality perceptions and in-house quality perceptions is, in fact, quite low, at 0.10. In addition, safe water practices in house are significantly correlated with water quality perceptions. The belief that source water is unsafe (i.e., lower on the candy game scale), for example, is significantly associated with several safe handling, storage, and treatment practices, such as not drinking directly from storage containers holding untreated water (0.29, p-value <0.01) and treating drinking water prior to consumption (0.25, p-value <0.01). At the same time, the belief that in-house stored water is safe is positively correlated with practices such as shorter storage time for drinking water (0.12, p-value = 0.016) and water treatment (0.06, p-value = 0.069).

Figure 2 maps perceptions of source water quality to actual water quality among the households with piped water from whom we were able to sample ($n = 144$). While the sample size is not very large, the chart suggests that households often consider their source water to be low in quality. Furthermore, the correlation between *E. coli* categorization and perceptions of source water quality (0.0392, p-value = 0.64) at the household level is very low suggesting that these perceptions are often inaccurate. In fact, the correlation between perceptions of in-house water

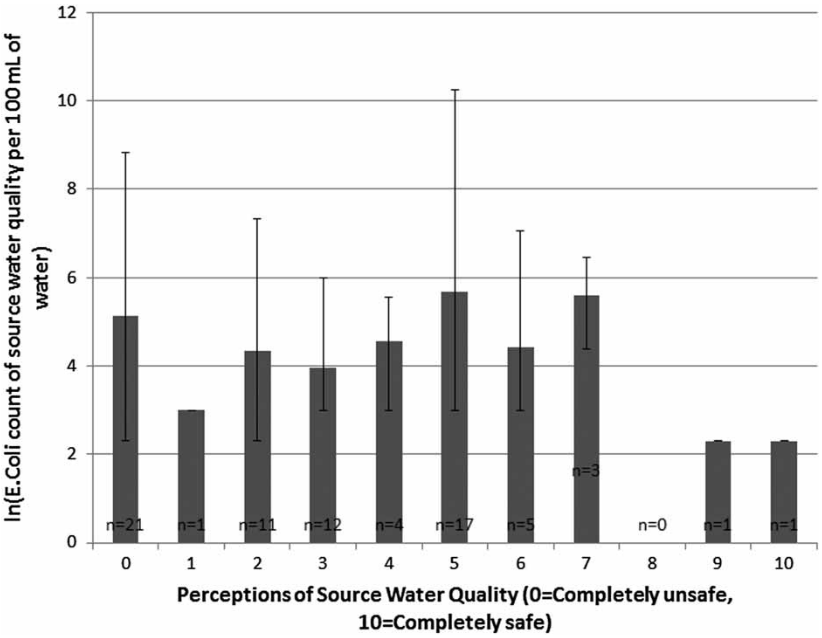

Figure 2 | Comparison of actual to perceived source water quality.

quality, after storage, handling, and treatment, and actual *E. coli* measures of water taken from containers holding treated drinking water in the same households is actually negative (−0.13, p-value = 0.27), although the sample size for this analysis ($n = 78$) is very small in this case and the variation in quality perceptions is low. Given the fact that most such households perceive this water to be either 100% safe or nearly so, we conclude that households often overestimate the safety of their drinking water.

WTP: Responses to the randomized price offers

Figure 3 illustrates WTP responses for treatment of 200 L at the six randomized price levels used in the survey. The pale line in Figure 3 indicates the percentage of respondents that stated they would pay each of the six price offers for 200 L of their favorite sample of safe water. The darker line shows the percentage of respondents that were very certain that they would accept the offer price. Both lines indicate a downward-sloping demand curve, with the price sensitivity of very certain 'yes' responses being considerably higher than that including the uncertain '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 initial 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 preferring the taste of the bottled water samples did not have systematically different WTP responses from those that preferred either of the Aquatabs options (results not shown).

Single-stage WTP model

Table 3 displays the results from estimation of a basic logit model for WTP, treating the variable for perceptions of in-house water quality as exogenous (Equation (1)). The full sample regression contained in column 1 of Table 3 suggests that perceptions of in-house water quality do not affect WTP for improved water quality. Use of piped water as the primary water source has a statistically significant and negative relationship with the probability of accepting the stated price. Average years of adult education and income are positively related with WTP, 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 community

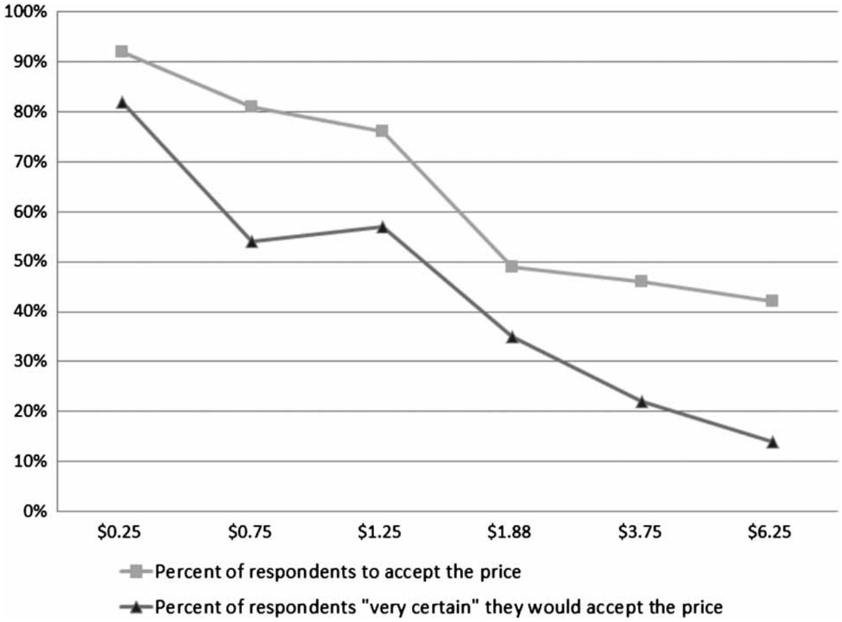

Figure 3 | WTP for clean water.

Table 3 | Single-stage model with in-house water quality perceptions

Variables	**Outcome: Accept WTP offer** **(1): Logit In-house water quality (full sample)**	**(2): Logit In-house water quality (did not prefer sample)**	**(3): Logit In-house water quality (prefer sample)**
WTP offer	-0.66^{a}	-0.63^{a}	-0.69^{a}
	(0.06)	(0.11)	(0.07)
Perceptions of water quality	−0.05	−0.02	−0.08
	(0.05)	(0.11)	(0.09)
Primary source is piped water	-0.49^{b}	−0.24	-0.76^{a}
	(0.19)	(0.31)	(0.27)
Primary source is rain water	−0.25	−0.08	-0.34^{c}
	(0.21)	(0.41)	(0.20)
Average years of adult education in hh	0.07^{a}	0.07^{c}	0.07^{c}
	(0.03)	(0.04)	(0.03)
Respondent gender (1 = female)	0.14	0.41^{c}	−0.04
	(0.18)	(0.24)	(0.23)
Respondent age (years)	−0.00	0.00	−0.00
	(0.01)	(0.01)	(0.01)
Predicted total earnings (natural log, dollars)	0.56^{a}	0.45^{c}	0.94^{a}
	(0.16)	(0.24)	(0.37)
Choice set section appeared first	0.33	0.54^{c}	0.09
	(0.22)	(0.29)	(0.27)
Community indicator (1 = Site A)	-0.35^{c}	-0.44^{c}	−0.27
	(0.19)	(0.27)	(0.25)
Observed feces in hh (1 = yes)	-0.29^{c}	−0.05	-0.45^{b}
	(0.16)	(0.27)	(0.19)
Treats water daily	−0.24	−0.37	−0.08
	(0.28)	(0.47)	(0.29)
Days of storage before consumption	−0.00	0.05	−0.01
	(0.06)	(0.10)	(0.07)
Soap observed in hh (1 = yes)	−0.10	0.01	−0.14
	(0.20)	(0.36)	(0.36)
Satisfied with current drinking water taste and smell (1 = yes)	-0.64^{a}	-1.29^{a}	−0.29
	(0.19)	(0.33)	(0.16)
Constant	-5.56^{b}	−4.68	-10.05^{c}
	(2.28)	(3.21)	(5.59)
R^2	0.17	0.18	0.19
Observations	880	377	487

Robust clustered standard errors in parentheses.

[a] $p < 0.01$.

[b] $p < 0.05$.

[c] $p < 0.1$.

indicator for Site A has a negative and significant coefficient, indicating that households there were significantly more likely to reject the WTP offer, despite the fact that their actual water quality was worse. The dummy variable indicating whether animal feces are present in the household is statistically significant and negative, implying that households with feces in their household may be less concerned about hygiene and potential water quality improvements. Finally, a dummy variable indicating that the household reported satisfaction with the taste and smell of their current drinking water is negative and statistically significant in this model, which suggests that preferences for taste and smell could confound preferences for the safety of drinking water, an issue which we investigate further below.

Columns 2 and 3 contain the results of the basic model for the sample split on the basis of satisfaction with taste and smell of current water. The second column shows the results for households that did not prefer the taste of their favorite treated water sample to their current water; for these households, satisfaction with current drinking water has a highly significant and negative effect on WTP. The third column corresponds to the remaining households that did prefer the taste of their favorite treated water sample to their current water; satisfaction with current drinking water is also negatively related to WTP for these households, although the relationship is not statistically significant. Most other coefficient estimates retain the same signs as in the full sample, although their significance varies. In particular, households that did not prefer the tasted water samples to their own and saw the choice sets before the WTP offer were more likely to accept it, suggesting possible anchoring bias from the choice experiment. Such households may have been more conscious that taste/smell and safety might be different, given the fact that each of these appeared separately in the conjoint exercise.

A similar estimation was conducted with perceptions of source water quality and yielded similar results (see Appendix, Table A1, http://www.iwaponline.com/jwh/011/212.pdf). The coefficient on perceptions of source water quality is only significant (at the 10% level) for the subsample that did not prefer the taste test to their own water sample. Thus, among households that preferred their existing drinking water to all of the taste test samples, respondents that believed their source water was of higher quality had a lower WTP.

We also estimated similar logit models using actual source and in-house water quality as the water quality measures in the single-stage regression model for WTP (see Appendix, Tables A2 and A3, http://www.iwaponline.com/jwh/011/212.pdf). The sample sizes for these models are small, but we find that the marginal effect of actual source water quality is small yet statistically significant and negative. An additional 100 *E. coli* cells in 100 mL of source water increases the probability of accepting the WTP offer by 0.25 percentage points. On the other hand, among households treating their drinking water, there is a slight positive relationship between water quality of in-house water and WTP, suggesting that the households who are most careful about their in-house drinking water may have particularly high WTP for improved water safety.

Two-stage WTP model

The model specified in Table 3 treats quality perceptions as exogenous to WTP for improved quality, which as described above, may be problematic. Table 4 presents results from the 2SLS model in Equation (3) that seeks to reduce the potential bias arising due to the endogeneity of perceptions. Table 4 shows that in both the full sample and split samples, perceived in-house water quality is statistically significant (Equation (3)). Primary water sources, adult education, respondent sex, respondent age, water handling variables, satisfaction with current water, and a binary variable for community were used to predict perceptions of in-house water quality. Water source, the community indicator, and current level of satisfaction with the taste and smell of the water are statistically significant indicators of water quality perceptions. Although the model fit is low ($R^2 = 0.04$), this is not an unusual finding for similarly heterogeneous perception measures that are likely related to many unobservable factors. (The Whitehead study provides a comparable R^2 value of 0.06 in the first stage.) Additionally, the R^2 is somewhat misleading since perceptions were measured on an integer scale, rather than as a purely continuous variable as assumed in the OLS model. Since the number of households that we were able to obtain water samples from is

Table 4 | 2SLS model, with in-house water quality perceptions

Variables	(1) OLS Quality perceptions (full sample)	(2) Logit Accept WTP offer (full sample)	(3) Logit Accept WTP offer (did not prefer sample)	(4) Logit Accept WTP offer (did prefer sample)
WTP offer		−0.66[a]	−0.64[a]	−0.69[a]
		(0.06)	(0.11)	(0.07)
Predicted perceptions of in-house water quality		−1.86[a]	−3.63[a]	−0.91[c]
		(0.46)	(0.94)	(0.47)
Primary source is piped water	−0.03	−0.54[a]	−0.36	−0.76[a]
	(0.12)	(0.19)	(0.31)	(0.28)
Primary source is rain water	0.28[c]	0.26	0.93[b]	−0.11
	(0.14)	(0.22)	(0.42)	(0.23)
Average years of adult education in household	0.02	0.11[a]	0.14[a]	0.08[a]
	(0.01)	(0.02)	(0.03)	(0.03)
Respondent gender (1 = female)	−0.06	0.03	0.16	−0.09
	(0.07)	(0.16)	(0.25)	(0.24)
Respondent age (years)	−0.00	−0.00	−0.00	−0.00
	(0.00)	(0.01)	(0.01)	(0.01)
Choice set section appeared first		0.33	0.50[c]	0.09
		(0.21)	(0.28)	(0.27)
Community indicator (1 = Site A)	0.20[a]	0.02	0.28	−0.08
	(0.07)	(0.24)	(0.24)	(0.26)
Observed feces in hh (1 = yes)	−0.04	−0.37[b]	−0.19	−0.47[b]
	(0.06)	(0.15)	(0.28)	(0.19)
Treats water daily	−0.06	−0.33	−0.56	−0.10
	(0.13)	(0.24)	(0.46)	(0.27)
Days of storage before consumption	−0.02	−0.03	−0.03	−0.02
	(0.04)	(0.05)	(0.10)	(0.06)
Soap observed in hh (1 = yes)	0.12	0.10	0.37	−0.03
	(0.13)	(0.33)	(0.35)	(0.38)
Satisfied with current drinking water taste/smell (1 = yes)	0.35[b]			
	(0.16)			
Predicted total earnings (natural log, dollars)		0.56[a]	0.45[c]	0.92[b]
		(0.20)	(0.24)	(0.38)
Constant	8.53[a]	14.52[a]	29.90[a]	4.88
	(0.27)	(4.46)	(8.25)	(5.51)
Observations	898	882	378	488
R^2	0.04	0.17	0.18	0.19

Robust clustered standard errors in parentheses.

[a] $p < 0.01$.

[b] $p < 0.05$.

[c] $p < 0.1$.

relatively low ($n = 79$), we do not include actual *E. coli* counts as a predictor of in-house water quality perceptions.

In the second stage of this full-sample model (column 2), the sign on the predicted perceptions coefficient is negative, which is consistent with the hypothesis that perceived high quality in-house water is related to lower household demand for improved water quality. In contrast to the finding from the single-stage model, the coefficient on predicted perceptions in the second-stage of this model is much larger and statistically significant, suggesting that perceptions may be endogenous in the basic model. Piped connections, education, observable feces, and income remain significant in this model, and the signs are the same as those in the basic model (Table 3). However, the community indicator loses its significance in this model compared with the basic model (Table 3), probably because its effect is captured in the first stage.

We note that the 2SLS strategy for estimating the effect of water quality perceptions on WTP is complicated by the role that satisfaction with current drinking water also plays in demand, and the fact that even the two-stage model does not allow us to definitively dismiss the endogeneity of perceptions. As shown in Table 3, the satisfaction measure is highly significant in the single-stage model. It is also highly significant in explaining in-house water quality perceptions. Thus, it should not be surprising that including it alongside perceptions in the second-stage of the 2SLS model results in only one of these two highly correlated variables being significant in the second stage. This serves as additional motivation for splitting the sample according to preferences for the taste of the water sampled by the household. If the two principal dimensions of satisfaction with the taste and smell of current water sources are related to quality and aesthetics, then splitting the sample in this way should more effectively reveal the relationship between perceptions of safety and taste. Also importantly, the coefficient on price is not significantly different from that found in the basic model specifications presented in Table 3 (which is consistent with the survey's randomization of prices to respondents).

Columns 3 and 4 in Table 4 display the results for the second stage obtained from the split sample analysis, where predicted perceptions used in this second-stage estimation are the same as those estimated for the full sample as shown in column 1. The marginal probability of accepting the price offer for a 1-unit change in in-house perceptions for those that did not prefer the water sample to their current water sample (−0.70) is much larger than the marginal probability for those that did prefer the water sample (−0.17). This result implies that perceptions of better in-house water quality were much more important in reducing demand among those who were already satisfied with the taste and smell of their water (those that did not prefer the taste test water sample to their own). Perceptions of in-house quality were 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). We also obtain similar results when considering source water rather than in-house drinking water in the model (see Appendix, Table A4, http://www.iwaponline.com/jwh/011/212.pdf).

Estimates of average WTP

For the purpose of comparing the WTP implied by each of these models, in this section we calculate four estimates of WTP. The mean WTP estimate obtained from the basic model using in-house perceptions (Table 3) is US$1.70 for 200 L of clean water. Since most other WTP measures are provided as a monthly amount, this amount is converted to similar units using the British Dietetic Association recommended drinking amount of about 2 L of uncontaminated water per day (National Institute of Health 2011). This calculation yields a monthly WTP for the average household of 5.3 people in rural Cambodia of US$2.70 per month. Table 5 provides similar WTP estimates across the different models using both source and in-house water perceptions as predictors of WTP. The values range from about US$2.20 to 4.40 per month, with an average of US$3.00 across models. This mean WTP is roughly 1.2% of the average income of respondents in our sample.

As indicated in the results presented above, the coefficient on the variable for whether the respondent saw the choice set experiment prior to the WTP experiment was significant in many of our models. Still, its effect is not large. We further split the sample to estimate WTP for those who saw the choice experiment first from those who did

Table 5 | Mean willingness to pay estimates (US$)

Sample	Model type	Source perceptions	In-house perceptions
Full sample	Basic model	$2.67	$2.64
		(0.12)	(0.12)
	2SLS	$2.88	$4.41
		(0.12)	(0.12)
Did not prefer taste test sample	Basic model	$2.22 (0.20)	$2.38 (0.20)
	2SLS	$2.93	$3.08
		(0.20)	(0.20)
Did prefer taste test sample	Basic model	$3.36 (0.17)	$3.28 (0.17)
		(0.17)	(0.17)
	2SLS	$2.82	$3.33
		(0.17)	(0.17)

Bootstrapped standard errors in parentheses.

Table 6 | WTP estimate ranges by subgroup (US$)

Subgroup categories	Mean WTP	WTP range
Piped users	$3.29	$2.34–4.68
Rainwater users	$3.09	$1.16–4.05
Other source users	$3.38	$1.35–4.40
Site A residents	$2.55	$1.22–4.43
Site B residents	$3.47	$2.70–4.70
Households that treat water daily	$2.86	$1.99–4.22
Households that do not treat water daily	$3.47	$2.91–5.01
Households that have soap	$2.99	$2.22–4.45
Households that do not have soap	$3.05	$2.22–4.21
Households that were satisfied with taste/smell of their current water	$2.78	$1.51–4.40
Households that were not satisfied with taste/smell of their current water	$3.69	$2.82–4.86
Households that had visible feces in home	$2.64	$2.15–4.01
Households that did not have visible feces in home	$3.45	$2.32–4.90
Households with high source perceptions (perceptions = 10)	$0.00	$0.00–4.40
Households with low source perceptions (perceptions = 0)	$5.24	$2.38–18.36
Households with high in-house perceptions (perceptions = 10)	$1.80	$0.00–3.37
Households with low in-house perceptions (perceptions = 0)	$14.97	$2.22–85.03

not. Those that saw the choice experiment first had a mean WTP of US$3.10 (1.23% of average monthly expenditures) while the remaining respondents had a mean WTP of US$2.80 (1.11% of average monthly expenditures). This difference is not statistically significant but does suggest that the choice experiment may have primed respondents to respond positively to higher prices in the CV exercise.

Table 5 also contains mean WTP estimates from the split sample models. As shown, households preferring the taste test water sample have a mean WTP of approximately US$1.00 higher than those that do not prefer the taste test water sample. Households preferring the taste test sample to their own drinking water appear more likely to want to switch away from their current water (perhaps for quality as well as taste reasons) and thus have a higher WTP for the water provided in the favored taste sample.

Table 6 summarizes the ranges of WTP estimates for different subgroups of the survey sample, obtained from the model specifications summarized in Table 5. The last four rows show the predicted average WTP obtained when source and in-house perceptions for all respondents are set at 0 (totally unsafe) or 10 (totally safe). Controlling for other factors, households rating source water quality at the highest level of 10 would theoretically have the lowest mean WTP and households with the lowest rating for in-house water quality (0) would have the highest mean WTP (although we remind the reader that no respondents indicated in-house perceptions to be lower than 6). This finding highlights the importance of perceptions of water quality in influencing demand for water quality improvements. It is logical that households with lower perceptions of in-house water quality have a high mean WTP for safe water, because these households are likely most concerned with the inadequate quality of drinking water they are consuming.

Table 6 also shows that households already displaying strong treatment and hygiene behaviors (e.g., treating water daily or having soap in the household) have a lower mean WTP than households that do not engage in such behaviors. Households that are not satisfied with the taste/smell of their current water have much higher mean WTP than households that are not satisfied.

DISCUSSION

This paper uses simple logit and two-stage models to explore the relationship between perceived and actual water quality and WTP for a water quality improvement. We determine the mean WTP for improved water quality to range from US$2.20 to 4.40 per month in a sample of 915 peri-urban households in Cambodia. The paper contributes a new data point on WTP to a relatively thin literature on the demand for improved water quality in low income countries. While our estimates are lower than the range of estimates (US$4.89–20.29 per month) cited in a recent meta-analysis for improved water supply in low income countries (Van Houtven *et al.* 2011), our study only considers WTP for improvements in quality, as opposed to quantity and access. The vast majority of consumers in the study site already had a water supply at the household level (through piped water, rainwater harvesting and storage, or private wells), and the survey scenario carefully explained that the improvement would only change the quality of their water.

The single-stage logit models estimated in this paper do not reveal a relationship between water quality perceptions and WTP for safe water. Such models are, however, problematic as it is likely that the unobservable factors related to WTP are also linked to such perceptions. Several of the estimated single-stage logit models that use actual water quality rather than perceptions as a predictor of WTP for improved water quality suggest that there may be a relationship between actual water quality and WTP. However, these results are not consistent across model specifications, only apply to a small sample, and appear to be driven by outliers with high *E. coli* counts. Furthermore, the coefficients on water quality variables have very small marginal effects on WTP. In addition, single-sample measures of *E. coli* may unreliably indicate safety of drinking water (Moe *et al.* 1991; Brown *et al.* 2008), since *E. coli* may proliferate in the environment under some circumstances and may even be indigenous to environmental media (Luo *et al.* 2011).

The 2SLS models for perceptions of water quality on the other hand lend tentative support to the hypothesis that impressions of high source and in-house water quality have a significant and negative relationship with WTP for safe water. This effect of perceptions is particularly strong among those households who preferred the taste of their current water to all of the three treated water samples (one commercial bottled water sample and two treated with different chlorine-based disinfectants) tasted by respondents during the survey. Among such households, the average WTP for improved water quality across models was US$2.60, which is 18% lower than the WTP among households who indicated a preference for one of the treated water samples. This support for the relationship between perceptions and WTP is, however, only tentative at this time because we could not identify a purely exogenous factor (e.g., an instrumental variable) that would influence WTP only through its effect on water quality perceptions. It is however important to note that the price coefficients in the 2SLS models and the significance of other explanatory variables included in the models remained stable relative to those obtained from the basic model logit predictions. This need not be the case in general, since omitted variables bias could affect estimates of WTP; however, the contingent valuation approach used here with random assignment of prices to different households appears to be robust to such confounding.

Another important result is related to the insights that can be gained from treating water quality perceptions as endogenous to WTP. At the most basic level, both source and in-house perceptions models provide support for the hypothesis that as perceptions of drinking water quality improve, the demand for better water quality decreases. This suggests that those planning interventions focused on improving water quality should pay attention to local perceptions lest they implement programs that are unlikely to be responsive to beneficiaries' preferences.

Perhaps even more importantly, taste preferences for samples offered during the survey were found to be strongly related to perceptions of water quality. Households who did not prefer the treated taste test samples to their own drinking water also tended to believe that their own water was much safer than those who did prefer the treated taste test samples. At the same time, household perceptions of water quality do not appear to correlate with the measure of water safety we used. We identified very low or negative correlations between perceptions and *E. coli* counts for water samples taken from the household water sources and storage containers holding the water they identified as drinking water at the time of the survey visit. In fact, although clearly insufficient as a measure of water quality, it does seem logical that households might equate safety with good taste if they do not have access to test results, given that contamination cannot readily be observed (Doria *et al.* 2009).

The data gathered concerning the link between perceptions of water quality and WTP lend support to the notion that future interventions to improve water quality should address the lack of connection between perceived and actual water quality. Since in-house water quality has been overestimated by many households, one way to increase demand for improved water quality may be through educational or informational campaigns. Informational campaigns have proven successful in the water and sanitation sector (Jalan & Somanathan 2008). However, educational interventions that explain the importance of water quality alone without changing misconceptions about the safety of existing water supplies may only have limited effect in increasing demand, if these misconceptions persist. Currently, there are no tools that are readily available to households to evaluate their own water quality, which makes it nearly impossible for households to accurately infer drinking water quality.

Additional studies on the determinants of demand for improved water quality are needed before the results presented in this paper can be considered general. Evidence of three types would be useful to advance the state of knowledge in this domain. First, additional work should be conducted on the relationship between perceptions and objective measures of water quality. In particular, it would be useful to understand what conditions (i.e., taste preferences) or characteristics of households (perhaps such as education), if any, are related to such perceptions being more accurate. Unfortunately, the dataset used in this paper only has actual water quality data for households with working piped water connections ($n = 79$ for in-house water quality) and therefore does not have a sufficient sample size or sufficiently general population to adequately explore this question. Second, research is needed to understand the factors that could change such perceptions when they are inaccurate. In this vein, recent studies on the role of water testing in influencing demand for water quality are useful but do not go far enough (Jalan & Somanathan 2008; Hamoudi *et al.* 2012). Third, interventions designed to influence perceptions should be combined with rigorous studies of the demand for water quality in an effort to uncover the extent to which such interventions may lead to actual and sustainable improvements in household water quality.

CONCLUSION

We examined how household perceptions of source and in-house water quality affect WTP for water quality improvements. We found that the average WTP for water quality improvements was about US$3.00 per month. Further, using a 2SLS model, we found that WTP is sensitive to perceptions of current drinking water quality, and that perceptions of water quality are not highly correlated with the actual count of *E. coli* in household water samples. Therefore, educational and informational campaigns targeting water quality perceptions may be effective strategies to increase demand for water quality improvements.

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