



Willingness to pay for cleaner water in less developed countries: systematic review of experimental evidence

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WILLINGNESS TO PAY FOR CLEANER WATER IN LESS DEVELOPED COUNTRIES: SYSTEMATIC REVIEW OF EXPERIMENTAL EVIDENCE

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Summary

Background:

Diarrheal diseases kill two million children every year despite the availability of effective and inexpensive technologies to improve water quality and limit the spread of pathogens. There is a growing literature on the effectiveness of such technologies but important gaps remain in understanding the demand for these products and the adoption decision.

Methods:

This review expands upon and complements several existing summary articles by focusing on willingness to pay for cleaner water. Willingness to pay can be measured by price randomizations that induce people to reveal their valuation in real purchase decisions or by other methods such as contingent valuation exercises in hypothetical situations and discrete choice analysis. The review conducts a systematic search for experimental evidence on willingness to pay for cleaner water.

Results:

This review finds few studies that have used randomized approaches or even attempted to measure households' willingness to pay for cleaner water, but a very clear picture emerges from the existing evidence: willingness to pay is often less than the cost of these technologies and demand is very sensitive to price. Existing evidence suggests that positive prices do not effectively target products to those who need them the most and that positive prices are a key barrier to realizing potential gains associated with water treatment.

Implications:

Given the evidence of low valuation for water quality, despite the impact of water-borne disease on child health, the challenge for research and policy is to identify innovative service delivery models and technological innovations that drive prices down and make public subsidies more feasible.

Future willingness to pay studies should be based on real purchases and use. Experimental methods to collect estimates of willingness to pay are easily justified as promotional discounts and could be implemented via coupon programs that make it possible to assemble large datasets quickly and cheaply.

1. Introduction

This paper provides the first systematic review of experimental evidence on willingness to pay for cleaner water in less developed countries. We focus on studies in which prices are randomized and demand is based on real purchase decisions, and compare this to results from contingent valuation in hypothetical situations from diarrhea efficacy trials. We find that willingness to pay is often less than the cost of technologies to improve water quality in the home or at the source. We draw lessons from the existing literature to point the way forward on this important topic.

The remainder of this paper is organized as follows: In section 2, we discuss the background for our review. We then outline our objectives (section 3) and methods (section 4). In section 5 we present the results of experimental studies examining willingness to pay for cleaner water, and reference results from non-experimental studies that use contingent valuation methods. We also describe household characteristics correlated with willingness to pay for cleaner water. In Section 6, we consider market inefficiencies, including health and knowledge externalities and incomplete property rights, which may lead to underinvestment in water quality improvements. Since legal institutions can determine whether or not there will be externalities, we also address relevant research on private sector participation and decentralization. In the final section, we conclude.

2. Background

2.1 Motivation for the review

Over one billion people worldwide lack access to safe drinking water, and every year roughly two million children die of diarrheal diseases caused in large part by contaminated water (WHO, 2007). The gold standard of infrastructure solutions such as increasing in-home access to piped water supplies is often too expensive to develop, particularly in rural areas where households are dispersed over large geographic areas, and are often difficult to maintain (Clasen and Haller, 2008). A variety of technologies have been developed to address the problem of unsafe water in areas where piped water from a central supply is not available, such as urban slums or rural areas with dispersed settlements.¹ Point-of-use (POU) water treatment methods including locally-produced ceramic filters, dilute chlorine, solar disinfection, combined flocculation-disinfection systems, and the age-old practice of boiling are intended to make water microbiologically safe to drink. Especially when combined with safe storage containers that prevent recontamination by allowing users to access water without actually touching it (such as by opening a tap instead of using a dipper), POU water treatment methods can substantially improve the quality of drinking water.

¹ In this paper we focus on water quality improvements rather than increases in the available quantity of water, which might also be important for child health. In some cases, such as when a new borehole well is sunk or piped systems are extended to new users, improvements in quantity and quality go hand-in-hand. We include such cases in this paper.

Safer drinking water should in theory lead to better health. POU water treatment methods have been shown to reduce diarrhea among children by anywhere from 20-70 percent.² Since diarrhea is the second leading cause of death for children under-5 worldwide (UNICEF/WHO, 2009), improved water quality could play an important role in achieving progress toward the Millennium Development Goal of reducing the under-five child mortality rate by two-thirds.

In practice, the health benefits of POU water treatment methods will depend on private demand for health and health products, which will ultimately determine whether or not those who could benefit from POU water treatment will adopt and consistently use these methods. The epidemiological studies that have established the benefits of these products use frequent field staff visits to keep product use high through frequent reminders and free product distribution in the home. As noted by White and Gunnarsson (2008), such impact evaluations do not provide actionable guidance to policymakers about how to implement apparently beneficial interventions.

In contrast to the science behind POU water treatment, which is fairly well-established, the factors that influence demand for cleaner water are not well understood. While we focus on price as the key determinant of demand in this paper, it is important to recognize that POU technologies which produce cleaner water often lead to changes in other attributes of the treated water, such as taste, turbidity (clarity), or even temperature, and that these qualities might also affect demand for POU products. Indeed, in some cases social marketing of POU technologies purposefully focuses on attributes other than water quality, and attempts to increase demand based on user's associations of POU technologies with social status or good motherhood or a number of other positive images, especially in contexts where germ theory is not well understood. In this paper we focus on willingness to pay for a POU technology as the best measure of willingness to pay for cleaner water, even though in practice water quality improvements are bundled with changes in other attributes.³ A better understanding of the valuation of cleaner water, and health more broadly, can inform policy decisions about how to increase use rates of these biomedically effective products.

2.2 Estimating willingness to pay for cleaner water

A number of papers have considered willingness to pay for water in less-developed countries, but the focus has primarily been on quantity of water rather than quality, though the two are often intertwined as in the case of increasing access to a centralized piped

² The large literature on the epidemiological efficacy of point-of-use water treatment technologies has been summarized by a number of review articles, including the International Initiative for Impact Evaluation (Waddington et al., 2009). See also Arnold and Colford (2007), Clasen et al. (2007), Fewtrell et al. (2005), White and Gunnarsson (2008), and Zwane and Kremer (2007). Recently these conclusions have been questioned, however, by Schmidt and Cairncross (2009), who argue that the results of efficacy studies could be strongly biased by a reliance on self-reported outcomes.

³ We use the term "willingness to pay" in the economic sense, which incorporates the resource constraint, rather than distinguishing between ability to pay given the household's budget and an unconstrained notion of valuation for cleaner water. While there are many interesting questions that relate to the issue of unconstrained valuation of cleaner water, our focus in this paper is on policy-relevant evidence, which necessarily incorporates the budget constraint.

system. Willingness to pay for cleaner water generated by POU water treatment methods has received much less attention, even as there has been increasing enthusiasm about this approach in the development community (WHO, 2002). Three methods are used to infer willingness to pay in the literature: contingent valuation, discrete choice models and experimental methods.

Research on demand for increased quantities of water has traditionally relied on stated preference data from hypothetical situations to identify the price that households would be willing to pay, a method known as contingent valuation (CV). While CV data from such studies may be the most practical solution when estimating valuation of a non-rival good or one that is costly to offer in a real transaction, it is also subject to a number of pitfalls stemming from the fact that choices in hypothetical situations might not be the same as those that the respondent would make in the real world, facing real budget constraints and real benefits (Diamond and Hausman, 1994). In addition, it may be difficult for individuals to know beforehand how they will value a good *ex post* and survey respondents may strategically overstate their willingness to pay (Whittington, 2002).

A second approach is to use discrete choice models to analyze cross-sectional survey data on households' decisions about water quality improvements.⁴ Most discrete choice models use cross-sectional survey data to assess the relationship between a water quality improvement (or a deterioration) or price change in the product on the demand for the water treatment (sometimes measured indirectly by the observed probability of illness), usually based on a utility function. The models then use the predicted probabilities of demanding or using clean water technology and the cost of the water treatment to estimate a lower bound of willingness to pay for the products. This avoids some of the problems of CV by evaluating real water-related household choices, such as the decision to purchase a water filter, boil household drinking water, or use dilute chlorine. By using household choices between various actions that provide differing levels of safe drinking water, discrete choice methods provide information on a part of the preference function (McConnell and Rosado, 2000). The problem with this type of method is that there may be unobservable household characteristics correlated with households' choices, which will lead to biased results if it is the unobservable factors which are driving the demand decisions (or observed disease occurrence).

A third approach is to infer willingness to pay for cleaner water using experimental methods, since the inputs can be offered for sale at different prices and real purchase decisions can be observed. Variation in the costs of cleaner water, including time costs, can be induced in randomized evaluations that make it possible to identify the effect of price on demand for cleaner water. Households' valuations of cleaner water from source water quality improvements can also be assessed using revealed preference data, such as the number of

⁴ There are a number of papers, including Mu et al. (1990) which estimate more general demand functions for water from various sources. Nauges and Whittington (2011) provide an overview of the literature on estimation of water demand in developing countries. We do not focus on these papers here, since they do not explicitly deal with water quality as a measurable attribute in the decision process.

trips made to the improved source relative to an unimproved source, as long as source water quality improvements are randomly assigned.

Experimental techniques are a preferable approach to CV and discrete choice models for a number of reasons, including the observation of actual decisions in real market situations, the potential to target populations of interest, and the ability to isolate specific channels of causality. In addition, although randomized efficacy trials of locally-available clean water technologies often include a coarse price randomization in the sense that households in the treatment group receive a free supply of the water quality improvement method and households in the comparison group have access to the water quality improvement method at retail prices, this variation in price is often confounded by intensive promotion of the water quality improvement method that is intended to generate high uptake for the purposes of measuring biomedical effects. In these cases, the effect of price cannot be separated from the effect of intensive promotion.

The reliability of willingness to pay estimations is also likely to be affected by more than just the estimation method. Whether the participants have experience in using the cleaner water technology and in observing its effectiveness in terms of important outcomes would seem to be key issues. For example, individuals are more likely to show a more reliable willingness to pay when they are exposed over a longer period of time and can observe the benefits and costs of the intervention.

3. Objectives

Our review expands upon and complements several existing summary articles on the medical efficacy of water quality interventions by focusing on willingness to pay for cleaner water, an outcome that is rarely addressed in the efficacy literature but which may affect optimal public policy.

This paper provides the first systematic review of experimental evidence on willingness to pay for cleaner water in less developed countries. We focus on studies in which prices are cost-randomized and demand is based on real purchase decisions. We compare these results with evidence from high quality randomized and quasi-randomized diarrhea efficacy trials using non-experimental methods to infer willingness to pay. We draw lessons from the existing literature to point the way forward on this important topic.

4. Methods

4.1 Inclusion criteria

Population: We include studies of water quality interventions that assess willingness to pay in less developed countries, as defined by the World Bank's list of low- and middle-income countries. We focus on these countries because this is where the burden of diarrheal diseases is the highest. In less developed countries governments very often have paid for

improvements to water infrastructure but have typically not paid for programs at scale that treat water. Point-of-use water treatment systems have been designed to address this need in less developed countries, but in most cases users are expected to bear the costs.

Intervention: The interventions considered in this review offer households the opportunity to purchase or use various technologies for improving drinking water quality, with exogenous variation in the price of the technology. All methods of improving water quality will be included, ranging from point-of-use technologies such as filtration, chemical treatment (chlorination), solar disinfection, and flocculants to source water quality improvements such as spring protection, or the expansion of piped water systems to households.

Outcome: The interventions included are intended to affect the proportion of households who choose to purchase or use a water quality improvement technology at different prices, thus making it possible to measure willingness to pay for cleaner water. Therefore, the primary outcome is the willingness to pay. Special attention will be paid to whether or not a price randomization or data collection method could have had direct or secondary effects on willingness to pay estimates. Such effects could be in the form of courtesy or social desirability bias, which can be caused by putting a household's decisions under unusual scrutiny.

Study design: We include studies that make use of randomized variation in prices (either across groups or across time for a single group, but ideally both), real purchase decisions, and objective measures of use of water quality treatment methods (such as checking for the presence of chlorine in the water or measuring contamination levels in the drinking water supply).

We include any duration of follow-up from the point at which subjects are exposed to random variation in costs. Studies are not required to have a control group per se, but there must be at least two different prices to which subjects are randomly assigned. For example, we would include a study that described the results of a distribution of coupons for either 50 per cent or 100 per cent off the market price of a water quality improvement, as long as the coupons were randomly distributed, even if there were no data from a control group who did not receive a discount.

This methodology excludes contingent valuation studies, which are based on decisions in hypothetical situations, and discrete choice analyses. Some examples of studies that are excluded from our analysis on these bases are McConnell and Rosado (2000), Mu, Whittington, and Briscoe (1990), Jalan, Somanathan and Chaudhuri (2003) and Dasgupta (2004).⁵ However, to facilitate the comparison of experimental willingness to pay and the

⁵ McConnell and Rosado (2000) and Jessoe (2011) both estimate willingness to pay for cleaner water based on household decisions of whether or not to treat water in the home in response to improvements in source water quality. Using data on defensive expenditures that improve drinking water quality (boiling water and purchasing filters or bottled water) from a survey of Brazilian households, McConnell and Rosado (2000) estimate the willingness to pay for boiling water, which they consider to be a lower bound of willingness to pay for safe drinking water, to be \$3 per month on

contingent valuation and discrete choice methods which are more commonly used to estimate willingness to pay, we also summarize the willingness to pay evidence from contingent valuation and discrete choice studies that have been conducted in the context of high quality randomized and quasi-randomized efficacy trials evaluating impacts on diarrhea prevalence, as synthesized in a recent systematic review of this literature (Waddington et al., 2009).

4.2 Search

The literature search for this review included four methods of locating relevant studies, including: keyword searches in various academic literature databases, a review of articles addressing the efficacy of different water treatment technologies, contact with researchers in the field to inquire about existing unpublished studies or ongoing work with upcoming results, and an examination of references listed in bibliographies of published works. In addition, towards the end of the review process, we updated the search by carrying out a citation tracking of studies included. The databases listed in Table 1 below were searched using all combinations of the search terms.

average. Jessoe (2011) examines the tradeoff between source quality improvements (taps, tube wells, hand pumps, and bore wells) and point-of-use treatments in rural India. To mitigate the potential biases caused by the correlation of household choice of primary water source and unobservables, Jessoe uses hydrological data, such as tube well depth discharge rate, percent of district allocated to dug wells and tube wells, and percent of district characterized by hilly topography, as instruments to measure the price and supply of improved water sources. She finds that the probability of in-home treatment is reduced by the presence of improved water sources.

Jalan *et al.* (2003) and Dasgupta (2004) also use discrete choice analysis to identify household characteristics that are correlated with the decision to use a POU water treatment method, though the focus of the latter paper is actually on estimating the value of the costs of diarrheal illness. Jalan *et al.* (2003) use data from a national survey covering urban areas in India to estimate the probability of different purification methods, such as straining water with ordinary cloth, using alum (flocculant) tablets, using an ordinary filter, boiling water, or using an electronic filter, while controlling for household characteristics. They use these predicted probabilities, along with data on average costs of the purification method, to estimate a lower bound of willingness to pay for safe drinking water, conditional on explanatory variables. Jalan *et al.* (2003) find that even more than income, awareness, as proxied by schooling and exposure to mass media, significantly impacts adoption of purification methods and household's willingness to pay for such methods. Using a different dataset but a similar method of regressing an indicator for the decision to purify water (most commonly with chlorine) on a variety of household characteristics, Dasgupta (2004) finds that households with higher income and education are significantly more likely to purify their water. However, the author acknowledges that these correlations might also reflect unobserved characteristics, particularly in the case of sewer connections which are positively correlated with water treatment, i.e. households at high socio-economic levels are more likely to have sewer connections and treat their water but this is not to say that it is the sewer connections that are causing them to take defensive actions against contamination, but rather than some unobserved characteristic is likely leading to both the sewer connections and the decision to treat the water.

Table 1 Databases and search terms

Databases	Search Terms
Cochrane Library, Google Scholar, IDEAS, LILACs, Medline, PubMed, Web of Science,	<p>ONE OF: clean water, drinking water, clean drinking water, drinking water quality</p> <p>AND ONE OF: willingness to pay, willingness-to-pay, valuation, demand,</p>

In addition to the literature search described above, we accessed all of the papers on water quality improvements identified for inclusion in an updated systematic review of diarrhea prevention interventions in less developed countries (Waddington et. al, 2009).

4.3 Data collection and analysis

Data collection was determined based on the search method utilized. Paper titles identified through the database searches were examined for appropriateness and if the paper was deemed appropriate, then it was downloaded into our shared directory. Papers were then examined for discussion on whether the study did indeed measure willingness to pay and the method of eliciting willingness to pay (experimental or non-experimental). A similar process was implemented in cross-checking bibliographies for additional relevant papers.

For experimental and efficacy studies assessing willingness to pay, further data was collected on the study location, the water quality improvement, sample size (number of households), length of exposure to water quality improvement prior to willingness to pay measurement, any additional details specific to the experimental design, the willingness to pay results, and the unit cost of the intervention.

We provided a narrative summary of the studies. In addition we collected willingness to pay information, and compared these to unit costs of the intervention. We standardized units across studies to measure willingness to pay for 1000 liters of water and per household per year (taking into account differences in water consumption per person and household size across countries). The results are reported in US dollars. When the mean willingness to pay is not reported in the study, but the study reports the demand for the product at different sizes, we computed the willingness to pay through the following approach:⁶

$$WTP = \sum_{i=1}^n x_i p_i$$

where x_i is the different range of prices or willingness to pay in the population and p_i is the share of the sample that would be willing to pay or buy the product at this price but not at a bigger one. The estimation of p_i rests on three important assumptions: first, the whole population has a willingness to pay in the range of prices provided in each study (none of the individuals would buy the product at a higher price than those included in the studies); second, all the groups are assumed to have identical preferences on average; and third, the

⁶ Information on the computation of the mean willingness to pay and cost for each included study and their standardization is available upon request to the author.

individuals who are willing to pay a given price for the intervention would be also willing to pay a lower price.

It is important to understand that the accuracy of the mean willingness to pay calculations depends not only on the reliability of the estimation method and the willingness to pay stated but also on other operational aspects related to the study design. In some of the experimental studies, surveyors offer randomly a price or discount among a set of pre-established prices. If the set of prices at which the price is offered contains few possibilities or does not cover all the prices, the mean willingness to pay computation is likely not to be accurate. Particularly, if high prices are not offered, the mean willingness to pay estimation will be biased downward.

The table in Appendix 3 includes a column with information on the methodological caveats for the computation of the mean willingness to pay in the experimental studies. The assessment looks at aspects of the study design such as the presence of few intervals but also to other potential problems that might affect willingness to pay calculations such as the length to the treatment exposition or non-compliance in studies using an auction design.

5. Findings from the review

5.1 Search results

The databases searches yielded a total of 421 papers, of which 164 were excluded on the basis of country income level, 205 were excluded on the basis of content that did not match the topic of the review, and 50 (18 unique papers, once duplicates from different searches are accounted for) which appeared to be relevant for the review. Upon closer review, however, none of these 18 papers used an experimental methodology: 12 used CV methods rather than real purchase decisions,⁷ two were based on a discrete choice analysis of non-experimental data,⁸ two used both CV and discrete choice analysis,⁹ and one was purely descriptive.¹⁰

Through conversations with researchers known to be working on projects related to water quality, we identified five studies, all of which met our inclusion criteria.¹¹

In addition to the literature search described above, we also accessed all of the papers on water quality improvements identified for inclusion in an updated systematic review of

⁷ Contingent valuation studies include: Ahmad *et al.* (2005); Ahmad *et al.* (2006); Asthana (1997); Goldblatt (1999); Hardner (1996); Jalan *et al.* (2003); Maddison *et al.* (2005); Nyarko *et al.* (2007); Rosado *et al.* (2006); Shultz and Soliz (2007); and Whittington *et al.* (1990). In addition, some of the efficacy studies also include CV components; greater detail on those studies is included in Section 2.3.

⁸ Jalan *et al.* (2003); Harapap and Hartono (2007)

⁹ Haq *et al.* (2008); World Bank Water Demand Research Team (2003)

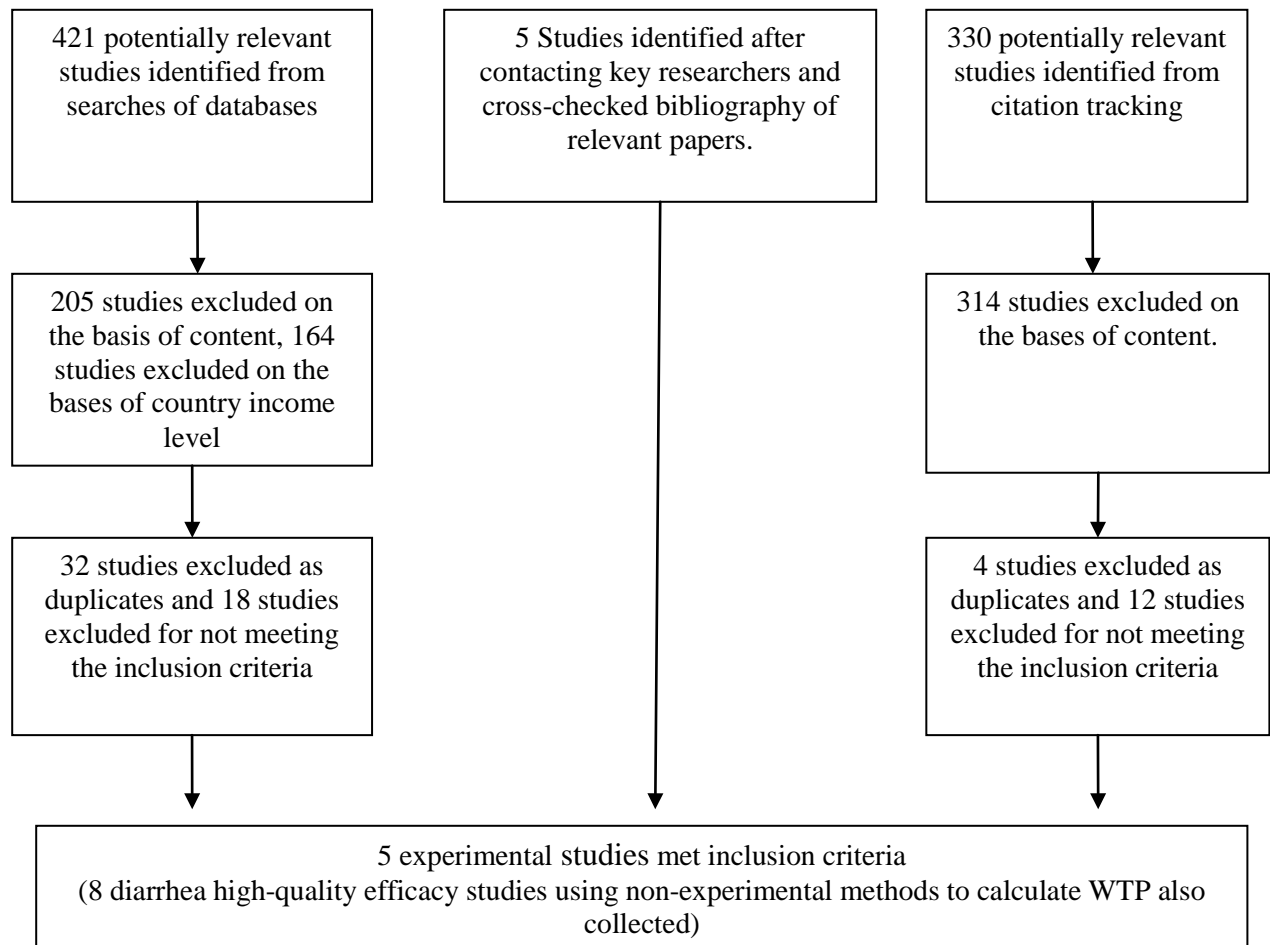
¹⁰ Spencer (2008)

¹¹ Ashraf *et al.* (2010), Berry *et al.* (2011), Kremer *et al.* (2009), Kremer *et al.* (2011), Luoto *et al.* (2011).

diarrhea prevention interventions in less developed countries (Waddington *et al.*, 2009). Although there have been many rigorous impact evaluations of various water quality interventions, relatively few have considered willingness to pay as an outcome variable. In fact, of the 35 studies of water quality interventions identified for inclusion in Waddington *et al.* (2009), only 6 studies of water quality improvements incorporated some measure of willingness to pay among their outcome variables, and even among several of these many of the concerns about CV data quality raised by Whittington (2002) apply.¹²

In a final step and before concluding the paper, we carried out a citation tracking of the relevant studies included so far to update the search. This process did not identify any additional studies that met the inclusion criteria.

Figure 1. Search and review process



¹² Including Clasen *et al.* (2004), Garrett *et al.* (2008), Kremer *et al.* (2009), Kremer *et al.* (2011), Luby *et al.* (2008), and Semenza (1998). More discussion of these papers is provided in the following sections. We were unable to obtain three of the papers identified in Waddington *et al.* (Blanton, 2008; Xiao, 1997; and Universidad Rafael Landivar, 1995) and thus were not able to determine whether or not they included any mention of willingness to pay for the interventions.

5.2 Summary of evidence from experimental studies

The review includes evidence from five studies exploring willingness to pay for cleaner water in Kenya, Bangladesh, Zambia and Ghana. Experimental studies include evidence on willingness to pay for both POU water treatments (including provision of chlorine, filters, flocculant disinfectant) and point-of-collection clean water interventions (spring protection).

By randomizing the price households have to pay for cleaner water, it is possible to observe directly how price affects demand and avoid the concerns associated with contingent valuation data. Only five completed studies have made use of explicit price randomizations, but this strategy is gaining appeal and several projects currently underway will soon add to this literature (including Dupas, Hoffman, Kremer, and Zwane's ongoing study of chlorine distribution through health clinics in Kenya; Hoffman, Lapeyre, Null and Rostapshova's study of community-financed chlorine dispensers in Kenya; and Guiteras, Kremer, Levine, and ICDDR,B researchers' study of shame and disgust as determinants of willingness to pay for chlorine dispensers).

In their study of willingness to pay for dilute chlorine (Clorin) in peri-urban Zambia, Ashraf, Berry, and Shapiro (2010) use a two-stage price randomization that allows them to test whether higher prices increase use via two specific mechanisms: targeting the product to households who will value it more and by inducing a sunk-cost effect that leads households who pay more for chlorine to use it more.¹³ In a door-to-door marketing campaign, roughly 1000 households in the study were first asked if they wanted to purchase a bottle of dilute chlorine at a randomized *offer* price ranging from less than 40% to 100% of the retail price. If a household agreed to purchase and was able to come up with the cash needed for the transaction, they were then offered an additional randomly-assigned discount which determined the *transaction* price. Transaction prices ranged from free to almost 90% of the retail price. Variation in offer prices is used to analyze whether households who are willing to pay a higher price are more likely to use chlorine, controlling for the price the household ultimately did pay, whereas variation in transaction prices is used to test for a sunk-cost effect that might lead households who did actually pay more for chlorine to be more likely to use it, controlling for willingness to pay. Approximately two weeks after the marketing campaign had begun, the survey team reached almost 900 of the households who received the marketing intervention to test for the presence of chlorine in stored drinking water supplies and administer a follow-up study.

Combining their data on randomized prices, real purchase decisions, and an objective measure of use, the authors find that higher prices do depress take-up rates (with an estimated price elasticity of demand of -0.6, or a 7% increase in the probability of purchase for each 100 Kwacha discount from the maximum of 800 Kwacha), and that households who agreed to pay a higher offer price are also significantly more likely to use the chlorine they purchased, controlling for transaction price (with an estimated price elasticity of use of 0.3

¹³ Karlan and Zinman (2008) pioneered this strategy in their study of the consumer credit market.

to 0.4, or 3-4% increase in the probability of use for each 100 Kwacha increase in the offer price).¹⁴

The screening effect that the authors identify does not lead to more effective targeting to those households with higher potential health gains, those households with children under age five or pregnant women. Thus, while willingness to pay for chlorine seems to include information about a household's propensity to use that cannot be predicted by demographic characteristics alone, it is uncertain that charging positive prices would lead to improve community wide health outcomes relative to a free distribution strategy. This is especially true for a product that is as cheap to produce as dilute chlorine. The failure of price to target to households in need has been found in other settings as well, including bednets (Cohen and Dupas, 2008; Hoffman et al., 2009).¹⁵

Whereas the screening effect of higher prices does seem to lead to higher use among those who purchase chlorine, the sunk-cost of the product does not appear to make households any more likely to use chlorine that they have purchased. Nor do the authors find evidence that paying any positive amount makes a household more likely to use the chlorine for their drinking water than if they had received it for free, a hypothesis that is often cited by NGO managers as a reason to charge something for goods and services (e.g. Population Services International, 2003). The Ashraf *et al.* experimental design has many attractive features that should be common practice in research on willingness to pay for cleaner water: prices are randomized, willingness to pay is based on real purchase decisions, and use of the clean water technology is defined by objective tests rather than self-reports. However, there are still some concerns with their approach. Purchase decisions during a house-to-house marketing campaign might not be representative of a more natural setting in which households purchase chlorine in shops for a number of reasons, including the convenience value of having chlorine delivered to the house and the potential for social desirability bias when the marketer is observing the purchase decision.

There is also the question of whether households who do not have evidence of chlorine in their water are rightly characterized as not using the product. Anecdotal evidence from other settings suggests that households might treat their water intermittently, perhaps saving chlorine for times when they anticipate it will be most beneficial, since the product can be stored. If this were the case, then the screening effect of higher prices might only indicate that households who are willing to pay more for chlorine are more likely to use it sooner, or more often, rather than never. Future research using similar methods, as is recommended by the authors of this review, should give special consideration to the potential for social desirability bias and address intertemporal substitution of water treatment methods and care-taking more generally.

¹⁴ Elasticities have been evaluated at the mean offer prices and purchase and use rates.

¹⁵ Cohen and Dupas (2008) study willingness to pay for long-lasting insecticide treated bednets to prevent malaria in rural Kenya using an approach similar to that employed by Ashraf *et al.* (2010). In that case, the authors find no evidence that women with a higher willingness to pay for a bed-net are more likely to need it or use it, though higher prices do dampen demand. Hoffman *et al.* (2009) also find that willingness to pay for bednets is far below the market price, although very few households are willing to sell nets that they receive for free, again suggesting that targeted distribution of free or highly subsidized health products like nets might be a viable strategy for increasing use.

Kremer *et al.* (2009) also use randomly-assigned discounts to investigate willingness to pay for dilute chlorine. In a set of impact evaluations that tested both price and non-price interventions to increase take-up of chlorine, households were randomly assigned to either a comparison group or to treatment arms in which they received a free supply of individually-packaged chlorine, coupons for free or half-priced chlorine that could be redeemed at local shops, or access to an unlimited supply of chlorine at no cost provided via a dispenser installed at the communities' water source.¹⁶

Although 70-90 percent of households in the study region had heard of the local brand of point-of-use chlorine and roughly 70 percent volunteered that drinking "dirty" water is a cause of diarrhea, only 5-10 percent of households reported that their main supply of drinking water was chlorinated prior to the interventions. Access to free chlorine, either via the individually-packaged bottles that were distributed or a dispenser at the point-of-collection increased take-up rates to over 60 percent, whereas coupons for even a 50 percent discount hardly affected take-up. With a local chlorine promoter to remind households to redeem their coupons for free chlorine and use it to treat their water, take-up rates were similar to free distribution in the short-run (3-weeks after the intervention) but fell to a still-respectable 40 percent over the medium term (3-6 months after the intervention). The authors conclude that high take-up rates can be achieved at sufficiently low prices, particularly when non-price mechanisms such as the convenience factor of the dispenser or social networks are harnessed, but that demand for chlorine among their rural sample is extremely sensitive to price even at levels that are near zero.¹⁷ Moreover, the authors find no evidence that households who stand to benefit most from cleaner water have a higher willingness to pay, as did Ashraf *et al.*

Although the interventions and data collection in the Kremer *et al.* study were implemented during household visits that could have conceivably influenced willingness to pay for cleaner water, coupons for discounts at local shops have several advantages over the door-to-door marketing approached used by Ashraf *et al.* By marking each coupon with a household identifier and collecting redeemed coupons from shopkeepers, the authors are able track take-up at different price levels without the direct observation of a marketer that could lead to social desirability bias while preserving the simple justification of random variation in prices as promotional discounts.¹⁸ From a logistical point of view, this data collection method is also much less expensive since data on a number of household can be collected

¹⁶ The free bottle and half-price coupon treatments were randomized at the household level, whereas the free coupon and dispenser treatments were randomized at the community level. In addition to changing the price of chlorine, the community treatments also involved a persuasion component in which a local chlorine promoter was elected by the community and paid by an NGO to encourage others to chlorinate drinking water.

¹⁷ One bottle costs, roughly a quarter of the agricultural daily wage and is enough to provide an average household with a month's supply of safe drinking water.

¹⁸ Although trading or even resale of coupons could undermine analysis of household characteristics that are correlated with coupon redemption decisions, in practice very few households in that study reported giving coupons away despite the fact over half the subjects who were given a free supply of individually-packaged bottled chlorine reported re-gifting at least one of the bottles they received. While households clearly understood that the bottles could be shared with others, they seemed not to realize that the same was true of the coupons.

from a single shop, a consideration that is especially relevant in rural areas where willingness to pay for improved water quality is not well understood and household visits can be remarkably expensive among dispersed populations without good roads. Coupons are also being used by Dupas *et al.* in their ongoing study of ways to increase take-up of chlorine distributed to mothers through health clinics and by Dupas (2009) for long-lasting insecticide treated bed-nets to prevent malaria, but this promising data collection method is currently underutilized.

Households' responses to random variation in the price of cleaner water can also be used to estimate structural models of demand, though we are aware of only one example of this to date. Kremer *et al.* (2011) exploit exogenous changes in the trade-off that households face when choosing between multiple water sources, some of which are close but contaminated and others of which are far away but clean. This variation in the distance / water quality trade-off is generated by a spring protection intervention that was randomly phased in to almost 200 communities in rural Kenya. Spring protection reduces contamination by sealing off the eye of the spring so that it is no longer vulnerable to surface-water runoff.

The authors compare how many trips households make to protected springs and other sources, controlling for differences in the time it takes to walk to each source. After converting extra time walking into monetary terms, the estimated median valuation for spring protection is equivalent to 18.5 workdays, or approximately US\$2.96 per household per year using their best measure of the time value of local water collectors.

They also contrast this revealed preference estimate of willingness to pay for spring protection with two different stated preference methodologies: stated ranking of alternative water sources, and contingent valuation. Their paper is one of the few cases in which stated preference estimates have been validated against reliable revealed preference benchmarks. They find that the stated preference approaches generate much higher valuation estimates than the revealed preference approach, by a factor of three, with the contingent valuation survey approach yielding especially imprecise estimates, casting doubt on the reliability of stated preference methods in this setting.

Luoto *et al.* (forthcoming) estimate and compare willingness to pay and costs for different POU water treatment methods randomly allocated within poor neighbors in urban Bangladesh. In this study, 800 households were randomly selected among targeted neighbors and split into a control group and four treatment groups to receive one out of four water Point-of-Use treatment products including dilute liquid chlorine (WaterGuard), sodium dichloroisocyanurate (NaDCC) tablets (Aquatab), a combined flocculant-disinfectant powdered mixture (PUR) and a siphon filter. After a two months free trial, the households that participated in the trial were tested for their use of the product and asked for their willingness to pay for the technologies through a Becker-DeGroot-Marschak (BDM) auction¹⁹ with real money. In this mechanism, each participant makes a bid and after the bid is done, the price is randomly generated. The participant purchases the product when the price generated is lower than or equal to the bid offered. If appropriately understood, the BDM

¹⁹ For more information on the functioning of the auction, please see Becker *et al.* 1964

auction provides incentives for revealing truthful willingness to pay for a product (Luoto et al. forthcoming).

The results of the auction revealed a high dispersion of willingness to pay across participants and technologies. Approximately 47 percent of the households are willing to pay at least a price equal to the cost of NaDCC (Aquatap), while the share of participants that are willing to pay at least a price equal to the cost of the dilute chlorine (WaterGuard) is approximately 33 percent. Willingness to pay for the flocculant (PUR) treatment and the filter are lower without any participant offering a bid equal to the cost of the PUR treatment and just 1 percent of participants making a bid equal to the cost of the filter. The share of participants bidding 0 is around 40 percent for NaDCC, chlorine, and the filter, and this share is up to the 80 percent for the flocculant.

Berry et al. (2011) examine the willingness to pay for Kosim ceramic filters in Northern Ghana using two different strategies: the BDM auction and the "Take it or leave it" (TIOLI) strategy. Surveyors and local volunteers visited selected villages in Northern Ghana, carried out demonstrations of the filter and installed the filter in the health liaison's home, opened to the use of all the community members. Two weeks later, surveyors returned to the village. They visited demonstration attendees and collected information on their willingness to pay using the TIOLI and BDM strategies. For the former strategy, the surveyors offered the product at a price randomly determined of 2, 4 or 6 GHS. The authors estimate the demand for the product for each of the prices offered. For the BDM approach, the surveyors asked the attendees to make a bid for the product. The purchase is carried out when the offered bid is larger than a randomly determined price.

The BDM approach yields an average willingness to pay of 3.1 GHS. When the TIOLI mechanism is considered, the share of participants willing to buy the filters at the prices of 2, 4 and 6 GHS are 90 percent, 48 percent and 22 percent. For each of these prices, the results suggest that the BDM mechanism predicts lower willingness to pay in comparison to the TIOLI method. The authors test and reject the argument that these differences might be created by strategic bidding to influence future price of the product and anchoring created by the stated price in TIOLI. Additionally, the authors failed to find evidence of screening and sunk-cost effects of prices in product use.

5.3 Summary of evidence from efficacy studies

The review includes evidence from eight diarrhea efficacy trials exploring willingness to pay for cleaner water or other water improvements interventions in Latin-America, North Africa and Central, South and South-East Asia. These efficacy studies assess the impact on diarrhea prevalence of a wide set of water quality improvements interventions including the provision of flocculant disinfectant, chlorine, filters and water infrastructure. Five of these studies use either a contingent valuation method or discrete choice models to assess willingness to pay for cleaner water. As noted above, this evidence is vulnerable to the critique of stated preference approaches and thus should be treated with caution. Three studies are able to make clearer inference about valuation because they study interventions where actual payments were required to receive services. We begin with a review of the

results from these papers, two of which estimate the diarrhea impacts of water infrastructure interventions, and which both briefly discuss willingness to pay in terms of the amounts that study households were required to pay for the improved services.²⁰ The third is based on inferred purchases of a POU technology since the intervention included only encouragement to treat water and did not provide it to study households.

Devoto *et al.* (2009) find that households in urban Morocco who purchased a private connection to the municipal piped water system as a result of being randomly chosen to receive logistical assistance with their application paid on average twice as much per month than households without the piped connection. At the same time, households who got connected experienced important time savings, as they no longer spent any time collecting water from communal sources compared to almost 18 hours per month among the control group. Importantly, however, these costs and time-savings seem to be entirely a function of convenience and water quantity, as there were no detectable improvements in water quality between those who got connected and those who continued to rely on communal sources. In a combined water quality and quantity infrastructure health impact evaluation, Duflo *et al.* (2010) note that households in rural India were able to meet the financial prerequisite to enroll in an NGOs program of providing communal water tanks and private toilets and bathing facilities, with each household in participating villages contributing approximately \$20 prior to receiving any services from the NGO.²¹

Turning to the studies of POU technologies, the only one to say anything about willingness to pay which is based on real purchase decisions is Garrett *et al.* (2008). Forty-three percent of households in their sample who are observed to have residual chlorine in their stored drinking water in the follow-up survey round must have been willing to pay the \$0.33 for a two-month supply of the product, since it was not distributed for free as part of the intervention which was based solely on encouragement to purchase.

Among the efficacy studies that use contingent valuation methods, Clasen *et al.* (2004), report that for a sample of 50 households in rural Bolivia who participated in a randomized control trial of ceramic water filters, the mean willingness to pay for a filter was less than 40 percent of the cost.²² This is despite the fact that diarrhea risk among treatment households was 70% less than for comparison households and respondents' mean estimate of how much a filter system cost was remarkably close to the actual cost of \$25.^{23,24}

²⁰ Neither of these new working papers were in circulation at the time Waddington *et al.* was written.

²¹ Wealthier households subsidized poorer households within the same village, but no exact data on how much each household contributed are available.

²² It is important to note that ceramic filters are a durable good, in contrast to most other POU water treatment methods such as chlorine which get used up and need to be replenished. As such, willingness to pay for an expensive filter that will last a long time might be more difficult to quantify since credit constraints could make it difficult for poor households to finance the purchase.

²³ Baseline diarrhea prevalence in this study was around 20%; it is possible that households might not be able to recognize absolute reductions in diarrhea prevalence even if they are statistically significant and large in medical terms.

²⁴ Nonetheless, the authors conclude that "While data on willingness to pay should not be generalized beyond the economic conditions under which it was collected, since Bolivia is one of the poorest countries in Latin America, these results suggest that a significant proportion of vulnerable populations may be able to afford a ceramic water filter system." It is not clear what these authors mean by "able

Similarly, Brown (2007) investigated the efficacy of and willingness to pay for ceramic filters in Cambodia. The author reports willingness to pay results separately for households that are using the filters daily (156 households) and those disusing the filter (281 households). When households regularly using the filter were asked how much they were willing to pay for additional or replacement ceramic filter inserts, 72 percent said US\$ 2.50, 29 percent said US\$ 4 and 26 percent said US\$ 5. In contrast, of those households disusing the filters, 43 percent were reportedly willing to purchase another filter. When asked to state an appropriate price, the mean non-zero response ranged between US\$ 1.48 and US\$ 2.95, depending on the province. The actual cost of replacement filter elements in Cambodia is between US\$ 2.5-4.

Luby *et al.* (2008) find that take-up of flocculant-disinfectant sachets among roughly 500 households in rural Guatemala is quite low six months after an efficacy study in which a random subset of participants were given a free supply of the product. Specifically, only 14 percent of surveyed households reported using flocculant-disinfectant in the past week and fewer than 2 percent of households' drinking water supplies tested positive for chlorine (the disinfectant in the sachets). The authors identify price as a major impediment to take-up, since price was the most commonly cited negative characteristic of the product (given by 41% of households), but they also recognize the time required for treatment and households' potential inability to recognize reductions in diarrhea as other barriers. Only 12 percent of households report having purchased the flocculant-disinfectant at the market price in the past two weeks, whereas 93 percent of households said they would use the product if it were one half of its marketed price (the authors do not provide any description of how these willingness to pay data were collected, or whether the survey asked about other prices).

Semenza *et al.* (1998) implemented a home chlorination intervention in one region of Uzbekistan, by providing chlorination training, 1.5 percent chlorine stock solution, and narrow-necked water containers with spouts to households without access to piped water. Although the authors found take-up of the chlorination procedure to be relatively high, with 73 percent of households having detectable chlorine residual in their water at the time of follow-up visit, residents stated a mean value of approximately US\$ 0.20 per 20 liters of clean drinking water as their willingness to pay. The residents also stated a mean value of approximately US\$ 0.30 as the amount they would be willing to pay for the container used in home chlorination.

Venczel (1997) implemented a contingent valuation study in Bolivia to assess the willingness to pay for a mixed oxidant disinfection system.²⁵ The author asked willingness to pay questions in two sample populations: (1) treatment households who were participating in the larger efficacy study and therefore had already received the disinfectant for free, and (2) control households from the same communities. Households in both groups were

to afford," which seems difficult to reconcile with the low willingness to pay that they report among study participants.

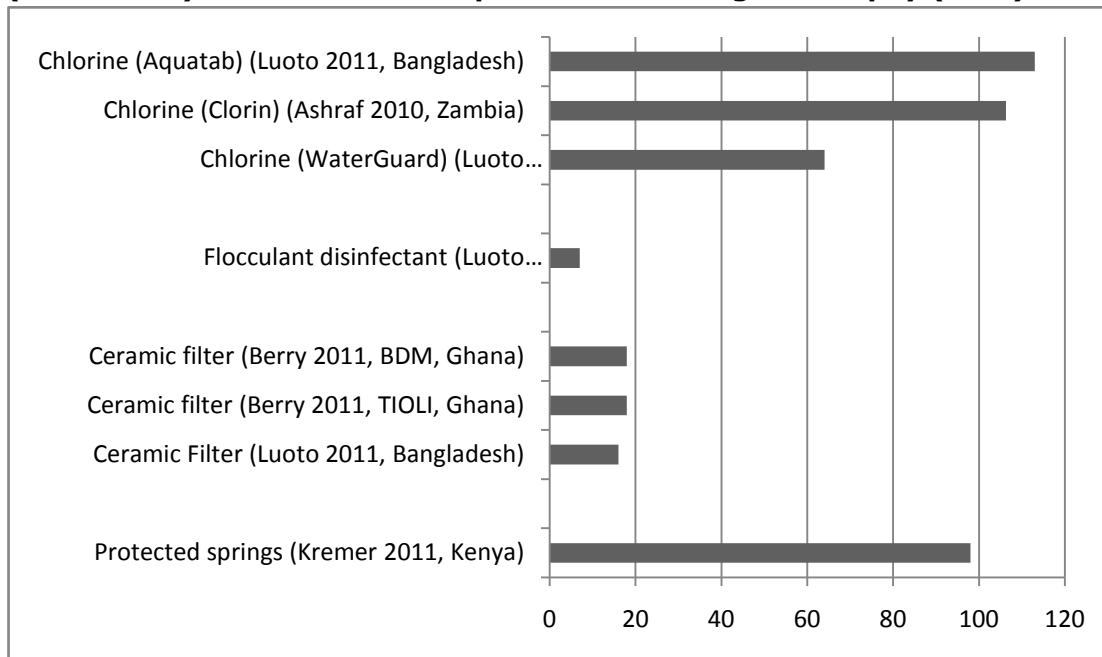
²⁵ This paper is not included among the Waddington *et al.* inventory, but we located it through bibliographic checks of the included papers (it was cited by Sobsey, 2003).

randomly asked whether they were willing to pay either 0.20 Bolivianos or 1 Boliviano (5 Bolivianos = US\$1) for a 500 ml bottle of the disinfectant. Venczel found that 97 percent of respondents from the treatment group and 100 percent from the control group were willing to pay 0.20 Bolivianos, whereas 78 percent of respondents from the treatment group and 90 percent from the control group were willing to pay 1 Boliviano.

5.4 Comparing average willingness to pay and cost of cleaner water

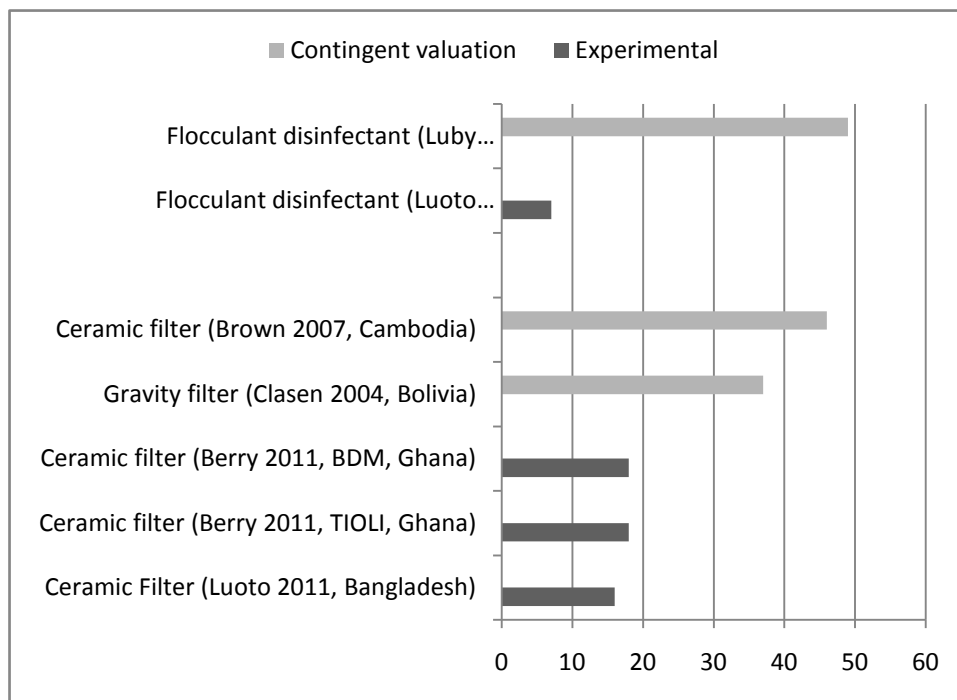
Annex B summarizes the mean willingness to pay and costs for each water treatment in US\$ for those studies which report either the mean willingness to pay or enough information to compute it. Figures 2 and 3 show the ratio of mean willingness to pay to costs of the clean water intervention for experimental and contingent valuation studies, for groups of interventions. The results need to be taken with caution because in most cases the mean (and variance in) willingness to pay was not reported, but had to be approximated from other information about the distribution of prices. Figure 2 suggests that, overall, from the very limited information available on willingness to pay for cleaner water, chlorine provision interventions yielded the largest willingness to pay/cost ratio. For the same intervention type, Figure 3 suggests that contingent valuation estimations yield larger willingness to pay/cost in comparison to those reported when experimental techniques have been applied. This is consistent with the conclusion that contingent valuation techniques are likely to overstate willingness to pay and thus yield biased estimates.

Figure 2 Percentage of costs that households are willing to pay for cleaner water (1000 liters): evidence from experimental Willingness to pay (WTP) studies²⁶



²⁶ Kremer et al. 2011, reported the annual cost and WTP for spring protection and unlimited clean water. Although the cost and WTP for 1000 l is irrelevant in an intervention with only fixed costs, the WTP/Cost ratio per 1000 l is equivalent to the ratio of mean WTP for unlimited water annually with annual costs, which is reported in Figure 2.

Figure 3 Percentage of costs that households are willing to pay for cleaner water (1000 liters): comparison of evidence from experimental WTP estimates and contingent valuation studies²⁷



5.5 Determinants of willingness to pay for cleaner water

Ultimately, in addition to understanding willingness to pay for cleaner water, we would also like to know what factors influence valuation since that might make it possible to design interventions that could increase willingness to pay and thereby increase adoption of clean water technologies. Willingness to pay may result from many factors such as household income, beliefs, and knowledge of the benefits and costs of using the product.

In the previous subsection, we noted that neither Ashraf *et al.* (2010) nor Kremer *et al.* (2009) find that households who stand to benefit more from cleaner water seem to have a higher valuation for it. Indeed, evidence from the efficacy literature has suggested that even with clinically large reductions in diarrhea morbidity, households may not be able to observe the health improvements from non-outbreak baseline conditions (e.g. Quick *et al.*, 2002; Luby *et al.*, 2008). Several studies note rather a connection between beliefs and willingness to pay. In the Kremer *et al.* (2009) study, households who were able to volunteer that “dirty” water could cause diarrhea were significantly more likely to redeem coupons for free chlorine. From the efficacy literature, Luby *et al.* (2008) note that

²⁷ Semenza *et al.* (1998) and Venczel (1997) are excluded from the Figures 2 and Figure 3 since they do not report data to estimate the cost of the intervention. Kremer *et al.* (2009), Garrett *et al.* (2008), Duflo *et al.* (2010) and Devoto *et al.* (2009) are excluded from the Figure 2 and Figure 3 since they do not report data to estimate the average mean willingness to pay for the clean water intervention,

households they identified as active repeat users were more likely to believe that their water was dirty and caused illness and Quick *et al.* (2002) find a positive relationship between existing knowledge and compliance with the intervention which the authors attribute to enhanced “self-efficacy”.²⁸ Berry et al. 2011 use a regression framework to explore which factors can affect the valuation of clean water. While the factors seem to differ depending on the strategy used to estimate the willingness to pay (TIOLI vs BDM), partial evidence suggest that a recent diarrheal illness among young children increases the willingness to pay for cleaner water. On the other hand, there is not conclusive evidence supporting any significant association between wealth indicators and willingness to pay for cleaner water.

While we have focused on the role of price as a determinant of demand for cleaner water in this paper, additional research is also needed to understand the roles of the other three “P”s in the social marketing approach: product (attributes), place (distribution), and promotion. As mentioned previously, other attributes of the water treatment process are likely to influence users’ demand for POU technologies, and these trade-offs are not well documented. Accessibility of POU produces in local markets, and the role of promotions to provide information as well as influence users’ perceptions of POU products, are also likely to be important determinants of demand, but at present we have a very limited understanding of how beliefs are updated and perceptions can be manipulated. Based on Kremer et al. (2009), Ashraf et al. (2010), and Luoto et al. (forthcoming) the balance of evidence suggest that price considerations dominate these other elements of social marketing.

6. Discussion: market inefficiencies

This section reviews a series of considerations that affect decisions about whether to subsidize the price of clean water, whatever private valuation is. This discussion draws on further evidence in addition to the evidence collected systematically on willingness to pay.

6.1 Externalities

Traditional public finance approaches recommend subsidies for goods and services that have positive externalities associated with them. When there are such externalities, private valuation, and thus adoption, is inefficiently low relative to the social optimum. There are two sources of such externalities in the case of safe water which support a policy of subsidized prices - those that affect the local disease environment and those that affect knowledge through social networks. To the extent that one household’s use affects either the disease environment or other households’ knowledge of the water quality improvement

28 Two additional papers have been able to identify causal effects of information about source water quality on households’ willingness to invest in cleaner water. Using similar randomized information provision campaigns, Madajewicz et al. (2007) and Jalan and Somanathan (2008) both find that households with better information about contamination respond by taking costly measures to improve their water quality, suggesting that willingness to pay for cleaner water likely depends on how much households think they need it.

method in question, if private benefits of use are smaller than the social benefits, inefficiently low levels of adoption can be expected even at subsidized prices. Moreover, while disease externalities might be apparent during times of outbreak, at normal diarrhea prevalence rates it is unlikely that households will be able to recognize the consequence their water treatment decisions have on their neighbors. Certainly, the health externalities of any water quality improvement method will be context specific, depending on the local population density and sanitation environment among a host of other characteristics, but since disease externalities can be expected to affect private valuation for water quality improvements, attempts to understand willingness to pay for cleaner water will greatly benefit from more evidence on the potential for health externalities. It is also important to note that it is generally not possible to quantify externalities using experimental designs that randomize participants into treatment and comparison groups at the individual level, since such a design will not lead to exogenous variation in the degree of exposure.

The possibility of externalities in the form of knowledge spillovers through social networks has also been explored by Kremer *et al.* (2009) in the case of water, building on earlier work by Kremer and Miguel (2007). Kremer *et al.* (2009) generate exogenous variation in the number of a household's close social contacts who were in the free chlorine treatment group. Although the randomization into their free chlorine treatment was done at the household level, communities were first randomized into high or low program intensity, with 6 of 8 sampled households in the treatment group in high intensity communities and 2 of 8 sampled households in the treatment group in low intensity communities. In this study, the authors find weak evidence for social network effects; more contacts in the treatment group led to more conversations about water and health, but small effects on the use of chlorine, as measured by detectable chlorine in drinking water at follow-up. Further investigation of the role of networks in water treatment and handling decisions should continue to explore this potential influence on the uptake decision.²⁹

6.2 Intra-family inequities

Young children are most at risk of death from unsafe water, and women and children are typically responsible for most water collection. Thus, the benefits of water quantity may flow particularly to women. However, women may not be able to allocate resources towards water resources or time savings because of intra-family inequities. This suggests a distributional case for public engagement in the distribution of water quantity, or subsidizing its supply, if there are systematic differences between valuation by women and men. Some recent empirical research has shown differences in intra-household preferences for health products (Ashraf, Field, & Lee, 2009). A very clear recent example is provided by Miller and Mobarak (2011) who demonstrate that women have much greater preferences for improved cookstoves in Bangladesh than men do, mostly out of consideration of their own health, not for child or family health more generally. On the other hand, as previously

²⁹ The randomization into different treatment intensities might have also affected the rate of technology diffusion through social networks, as predicted by Rogers' (2005) theoretical framework, by making it more likely that those with the potential to become early adopters would be randomized into the treatment group in high-intensity communities. Luby *et al.* (2004) also discuss technology diffusion through social networks in the case of POU chlorination.

discussed, several of the papers reviewed in the main section of this document find that not only is willingness to pay for improved water quality low, but also that households with young children did not behave differently from other households. This implies that willingness to pay is not correlated with vulnerability to illness or “need” for water treatment.

There is evidence that women have different preferences over public goods in addition to technologies used in the home. For example, Duflo and Chattopadhyay (2004) found that village councils led by women were more likely to invest in public goods (in this case, drinking water infrastructure) in rural India. The authors exploited a policy change in India that reserved one-third of all village council seats for women. The rules of this policy ensured that the reservations were randomly assigned.

6.3 Institutions

In addition to both disease and knowledge spillovers between households, legal institutions can also be a source of market inefficiencies and provide a case for interventions that affect prices as well as context that informs how observed valuation should be interpreted. Private supply of water services appears to be a means by which a vicious cycle of low service quality and low valuation can be broken, improving service levels and thus potentially increasing willingness to pay. Kremer *et al.* (2011), Galiani *et al.* (2005), and Kosec (2011) provide evidence on the questions as to whether private property rights over water resources can lead to under-investment in source water quality improvements or inadequate maintenance of existing infrastructure.

In their randomized evaluation estimating the impacts of source water quality improvements and household valuation of spring protection in rural Kenya, Kremer *et al.* (2011) assess the welfare impacts of alternative water property rights institutions. Through privatization policy simulations based on the willingness to pay results discussed earlier, the authors can compare a number of potential scenarios with varying degrees of private property rights and public investment. In each of these scenarios, decisions made by the landowners of the springs are followed by households’ decisions regarding their water collection. In the status quo with currently existing institutions, landowners can not restrict access to springs or charge for water collected, and thus have little incentive to invest in spring protection infrastructure. The simulations show that a social planner would only protect springs used by a relatively large number of households, which results in approximately one quarter of springs being protected. A hypothetical case of pure privatization, in which landowners could restrict access to the spring and charge for water, results in relatively little spring protection since households’ willingness to pay for cleaner water is low, but leads to large static losses since landowners can extract consumer surplus by charging for even unprotected spring water even though the marginal cost of provision is zero. A better alternative would combine private property rights over protected spring water with common property rights over unprotected spring water by requiring that runoff water from protected springs be allowed to pool for users to collect without charge. Such an arrangement could incentivize landowners to provide socially-optimal protection and at the same time limit welfare costs to spring users. This paper provides insights into the

tradeoffs between institutions designed to generate efficient investment incentives, such as property rights institutions, and those that promote alternative goals, such as health or equity.

Galiani *et al.* (2005) evaluate whether the privatization of water provision in Argentina improved the service of safe water and thus reduced child mortality from water-related diseases. The authors find evidence against the commonly-voiced criticisms of privatization. These include fears that unregulated private providers will undersupply the socially optimal water quality in the presence of positive health externalities or that they may exclude the poorest households from formal water provision through policies such as price increases, strict payment collection methods, or targeting network infrastructure investments on wealthier areas. Using variation in local water company ownership over time and space, the authors find that child mortality decreased by approximately 8 percent in locations where water systems underwent privatization and the largest effects occurred in the poorest areas. This is evidence in contradiction with concerns that privatization harms the poor and thereby addresses whether privatization can increase social welfare. The well identified evidence provided by Galiani *et al.* is contradicted by evidence provided by Clarke *et al.* (2004) who find no evidence that private sector participation in the water sector improves coverage using household-level data on pre/post and cross-sectional variation between cities that did and did not introduce private sector participation. However, this work is vulnerable to concerns about omitted variable bias. Moreover, of course, the pre-existing extent of service coverage and the regulatory environment are both likely to influence the effects of privatization.

In a related paper, Kosec (2011) investigates the effects of privatization in twenty-six African countries on child health outcomes in urban areas and addresses the relative importance of international development loans and private-sector participation. To do so, she constructs datasets on sub-national region private-sector participation, diarrheal disease prevalence, and fraction of the urban population reporting that their primary water source is piped. To deal with the endogeneity of private sector participation in a given country, the author employs two instruments for private sector participation in a given country: the fraction of the world water market controlled by the country that originally colonized an African country and the fraction of the population in the former colonizer country that currently obtains water from a private provider. Instrumental variables results indicate that private sector participation is associated with an approximately twenty to twenty-four percentage point decrease in diarrheal disease. Similar to Galiani *et al.* (2005), Kosec finds that the effect of private sector participation is greatest among the lower and middle classes (as proxied by household head educational attainment). Hypotheses on the potential causal channels of these effects are supported by evidence that private sector participation decreases diarrheal disease by increasing access to piped water. However, the results are not able to ascertain whether this occurs through a reduction in prices, an increase in water quality, or lower barriers to connection, or some combination of these effects.

Some supporters of decentralization argue that communities often develop efficient institutions for managing common property resources. In other words, there may be other

ways to break a vicious cycle of low service quality and low valuation in water quality besides formalization and privatization. Two studies that raise concern regarding the impacts of decentralized management on water quality are Lipscomb and Mobarak (2011) and Miguel and Gugerty (2005).

Miguel and Gugerty (2005) examined the role of ethnic diversity and social sanctions in the provision of public goods, one of which is community-maintained well water, in rural western Kenya. Miguel and Gugerty (2005) find that areas with average levels of ethnic diversity are six percentage points less likely to have a functioning well than homogeneous areas, highlighting the potential disadvantages of decentralization. The authors construct a stylized model of the role of social sanctions in preventing free-riding and the channel through which ethnic diversity affects local collective action. The model is based on the assumption that social sanctions are better functioning within ethnic groups than between them. The authors use land settlement patterns from the nineteenth century as an instrument in evaluating the impact of ethnic diversity on the maintenance of community wells (as measured by water flow and working well parts).

Lipscomb and Mobarak (2011) assess the impact of decentralization on another form of water quality: river pollution. Although this is not specific to the discussion on improvements to drinking water quality, the insights on decentralization are highly relevant. Using a panel dataset of monthly water quality measures (biochemical oxygen demand, or BOD) collected at monitoring locations on eight major Brazilian rivers, the authors exploit changes in county boundaries with each election cycle to isolate the impacts of changes in proximity to borders and decentralization on changes in water quality. Three types of variation (distance river travels in upstream county, distance river travels in downstream county, and number of county boundary crossings between any pair of monitoring stations) are employed to assess strategic pollution spillovers and isolate the net effect of decentralization on water quality. The authors find evidence of counties' strategic pollution close to the river's downstream exit from the county; however, they find no evidence that decentralization leads to water quality deterioration on the whole. The authors suggest that this could be due to some of the positive impacts of decentralization, such as potential increases in spending towards environmental or sanitation efforts.

Two additional policies promoted as methods by which to attain improved water infrastructure management, that might affect service quality and willingness to pay are female participation and financial support during the development of local management capabilities. Through the evaluation of a randomized field experiment, Kremer *et al.* (2008) provide evidence of the impacts of such policies on actual management outcome measures relevant for protected springs (e.g. time since storm drains or drainage trenches were cleaned and measures of source water quality). The intervention compares outcomes from two forms of financial support to water committees, payments to private contractors for spring maintenance and ongoing grants to user committees, with the outcomes of a control group. Additionally, half of the communities received messages encouraging women to take leadership roles in their water user committees. Results suggest that financial support made a substantial impact on the infrastructure maintenance activities that are most labor-intensive and paying contractors to perform the maintenance had a significantly larger

effect than providing user committees with grants. Monitoring by government officials impacted the maintenance performed by contractors but not the performance of committees that were grant recipients. Communities that received the female participation intervention were twice as likely to have women in the role of water committee chair; however, this did not lead to differences in the effectiveness of the user committees in the public good provision. Thus, the authors conclude that advocacy for female participation can increase women's involvement without any impact (either positive or negative) on project outcomes.

7. Conclusion and suggestions for future research

In recent years there has been a major push to expand access to safe water by promoting water quality improvements, particularly point-of-use water treatment technologies such as filtration and chlorination. Adoption of new technologies has been slow to catch on, however. A number of efficacy trials have demonstrated the potential for these methods to improve water quality and reduce childhood diarrhea, but to translate these results into real health gains, ultimately households have to choose to use these technologies. A consistent trend emerges from the existing, though limited evidence – even with major documented health improvements, willingness to pay for water quality improvements is less than the cost of the technology, perhaps in part because it is difficult for households to observe the private benefits in terms of improved health.

In this systematic review we have documented the existing evidence on willingness to pay for cleaner water focusing on the evidence from the studies in which price randomizations have been used to provide credible estimates of willingness to pay for cleaner water, and, for completeness, summarized results from other estimates of willingness to pay conducted in the context of randomized diarrhea efficacy trials which have significant methodological shortcomings.

Given the body of evidence suggesting low willingness to pay for water quality, future research is needed to design service delivery models and technological innovations that support take-up despite low private valuation. Innovations need not be limited to point of use technologies or purely private delivery. As discussed in this paper, point of collection treatment appears to be a promising means of reducing service delivery costs for chlorine, for example. There is reason to believe that public support is warranted, given the a priori case to suspect significant disease externalities and intra-family distributional inequities. Future research to further understand valuation and ways to influence take-up will be most valuable when it is based on actual purchases. Future evaluations should incorporate randomized prices (which are easily justified as promotional discounts and could be implemented via coupon programs that make it possible to assemble large datasets quickly and cheaply), real purchase decisions rather than contingent valuation scenarios, and objective measures of use rather than self-reports.

Practical solutions to low valuation will also need to be complemented by work that unpacks the observed low levels of valuation, by purposefully seeking to understand the costs and benefits that households weigh against one another when deciding whether or not to invest

in cleaner water. Understanding how low values are arrived at psychologically, whether people accurately calculate the links between technology and health, and are able to perceive the health improvements that have been documented in the epidemiological literature, or make systematic errors in any of these elements of the decision process, will also be important.

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Annex A: Studies included in the paper

Experimental willingness to pay (WTP) studies							
Study	Study Location	Water quality improvement	Estimation Methods	Study design/Details on the estimation methods	Sample Size	Length of exposure to water quality improvement (prior to WTP measurement)	Main Findings
Ashraf <i>et al.</i> (2010)	Zambia	dilute chlorine (Chlorin)	Experimental design: randomized price	Two-stage price randomization (offer price and transaction price randomly assigned) during door-to-door marketing campaign was used to differentiate between sunk cost and screening effects.	1,260	Depends on households' prior exposure to Chlorin	Price elasticity of the demand for the product is -0.6. Study found evidence of screening effects but not of sunk-cost effects.
Berry <i>et al.</i> 2011	Ghana	Kosim ceramic filters	Experimental design: Becker-DeGroot-Marschak (BDM) auction and "Take it or Leave it" (TIOLI) approach	Surveyors visited targeted communities in Northern Ghana. They performed a demonstration of the filter and install a filter at the health liaison's house for public use. Two weeks later, the surveyors returned to the community and carried out the auction.	603 (BDM) 645 (TIOLI)	2 weeks	The average bid is 3.1 GHS, estimated through the BDM. The BDM approach under-predict the WTP in comparison with the TIOLI approach. There is no evidence that the latter difference is caused by anchoring or strategic behavior in the BDM auction.
Kremer <i>et al.</i> (2009)	Kenya	dilute chlorine (WaterGuard)	Experimental design: randomized discounts and non-price interventions	Households randomly assigned to either control group or treatment group, in which they receive a free supply of individually-packed bottles of chlorine, coupons for free or half-priced chlorine to be redeemed at local shops, or access to an unlimited supply of free chlorine via a dispenser installed at the communities' water source.	2,786	Depends on households' prior exposure to WaterGuard; roughly 30% of study households reported using WaterGuard at some point prior to the study.	The mean value disability-adjusted life year (DALY) saved is \$20. Adoption rate is very high when price is 0. However, demand is very sensitive to price change for low levels of price

<p>Kremer <i>et al.</i> (2011)</p>	<p>Kenya</p>	<p>protected springs</p>	<p>Experimental design: random variation in distance to cleaner water</p>	<p>200 springs were randomly assigned to be protected, with the intervention phased in over 4 years due to financial and administrative constraints. All springs were stratified geographically and by treatment group, before being randomly assigned to an activity wave.</p>	<p>1,354</p>	<p>Travel costs were calculated with several waves of data collected at households over several years.</p>	<p>WTP for cleaner water at point collection is \$2.96 per household per year. \$23.68 is the average value of DALY saved. The mean value of an averted diarrhea episode is \$23.68. The mean value of averting one statistical child death is \$7.69.</p>
<p>Luoto <i>et al.</i> (Forthcoming)</p>	<p>Bangladesh</p>	<p>dilute chlorine (WaterGuard) chlorine tablets (Aquatab) flocculant-disinfectant (PUR) ceramic filter</p>	<p>Experimentall design: Becker-DeGroot-Marschak (BDM) auction</p>	<p>800 households in communities with no access to pipe water were randomly split in 4 treatment groups and a control group. In each of the groups, the participants received a different water treatment product.</p>	<p>800 households</p>	<p>2 months</p>	<p>47% and 33% of participants are willing to pay at least the cost of Aquatab and WaterGuard. On the other hand, none of the participants is willing to pay the price of the POU and only 1% is willing to pay the cost of the ceramic filter.</p>

Additional CV or discrete choice WTP estimates from randomized and quasi-randomized diarrhea efficacy studies

Study	Study Location	Water quality improvement	Estimation Methods	Study design/Details on the estimation methods	Sample Size	Length of exposure to water quality improvement (prior to willingness to pay (WTP) measurement)	Main Findings
Brown (2007)	Cambodia	Locally-produced ceramic water filters	Contingent valuation	Study collected information on a random sample of beneficiaries of a project that deliver ceramic filters. Individuals using and disusing the filters were separately asked to state an appropriate cost or their WTP for a filter replacement.	506	0 to 48 months	Among those which use filters regularly: 72% are willing to buy at \$2.50, 29% at \$4 and 26% at \$5. The average WTP of those disusing the filters that are willing to buy one with non 0 response is \$2.38. Cost of filter replacement varies between \$ 2.5 and \$4 depending on the place.
Clasen <i>et al.</i> (2004)	Bolivia	Gravity water filter system	Contingent valuation	Intervention randomly provides a gravity water filter system to a treatment group within a community. Six months after the start of intervention, authors asked participants and control group the maximum price of the filter they would pay.	50	not stated	Mean WTP for the ceramic water filters is \$9.25. The retail price of the filter is \$25.
Devoto <i>et al.</i> (2009)	Morocco	Household connections to piped water system	Utility payments	The intervention provides randomly a subsidized interest free loan to install a water connection directly to point of use. Note the intervention does not improve water quality. Study reports the water bill from both control and treated households.	845	On average 5 months after installation of connection	Household who received piped water spend in their water bill in average \$24 per month compare to \$9 in the control group. They save 18 hours per month in collecting water and the price for the connection is \$500.
Duflo <i>et al.</i> (2010)	India	Communal water tanks, private toilets and bathing facilities	Required financial contribution to program	Households are required to contribute approximately \$20 as a pre-requisite to get access to communal water tanks and private toilets	5,999 (village-year observations)	prior to service provision	Households in rural India contribute \$20 as a pre-requisite for a program to provide communal water tanks and private toilets and bathing facilities.

Garrett et al. (2008)	Kenya	Home chlorination treatment	Inferred purchases	Community health workers sold 500 ml Chlorine bottle in project villages, where hygiene and Safe Water System promotion campaigns have been carried out.	720	only available for households that purchased the product	43% of the households seem to buy the bottle of chlorine disinfectant at the retail cost (\$0.33).
Luby et al. (2008)	Guatemala	Flocculant-disinfectant sachet	Contingent valuation	Intervention provides for 3 months to a random sample of individuals flocculant-disinfectant sachets. Six months after finishing the intervention, a follow up survey collected reported information on whether participants and control group use and buy the product. Study reports also information on the hypothetical use of the product at half of its price.	500	6 months	12% of the households use frequently the product after six months (purchased the disinfectant in the past two weeks). 93% of household state that they would buy it if price reduce to half
Semenza et al. (1998)	Uzbekistan	Home chlorination treatment for households without piped water supplies	Contingent valuation	Intervention provides randomly chlorine solution and training on how to use chlorine to clean water to half of the selected households without piped water in the district.	240	not stated	The WTP for 20 liters of clean water is \$0.20. The WTP for container used in home chlorination is \$0.30.
Venczel (1997)	Bolivia	Mixed oxidant disinfection system	Contingent valuation	Intervention provides free disinfectant randomly to half of the households with no access to pipe water in the community. During the follow up survey, both participants and control group are either asked whether they would buy a bottle of 500 ml of disinfectant if the price were 0.20 or if the price were 1 boliviano. Finally, they were asked for their maximum WTP for 500 ml disinfectant.	123	not stated	The WTP for a 500 ml disinfectant bottle is in average \$0.199 among those receiving the disinfectant and \$0.267 among those not receiving the disinfectant

Annex B: Estimates of WTP, Costs and WTP/Costs3031

Study	Study Location	Water quality improvement	Estimation Methods	Mean WTP for cleaner water intervention (\$ per 1000l) *	Cost of the intervention (\$ per 1000 l)	Mean WTP for cleaner water intervention (\$ per household per year)	Cost of the intervention (\$ per household per year).	WTP/Cost of the intervention (1000 l)	Methodological assessment of the WTP calculation:
Experimental WTP studies									
Ashraf <i>et al.</i> (2010)	Zambia	dilute chlorine (Chlorin)	Experimental design: randomized price	0.40	In retail outlets: 0.66 In health clinics: 0.38	4.79	In retail outlets: 7.93 In health clinics: 4.41	In retail outlets: 0.61 In health clinics: 1.06	Mean WTP estimated with the demand at only three different prices.
Berry <i>et al.</i> (2011)	Ghana	Kosim ceramic filters	Experimental Design: Becker-DeGroot-Marschak (BDM) auction and "Take it or Leave it (TIOLI)" approach	TIOLI: 0.23 BDM: 0.22	1.28	TIOLI: 2.79 BDM: 2.68	15.19 ³²	TIOLI: 0.18 BDM: 0.18	Participation in the programme is not randomly assigned. Exposure to the treated water before the auction is 2 weeks. TIOLI based mean WTP estimated with the demand at only three prices.
Kremer <i>et al.</i> (2009)	Kenya	dilute chlorine (WaterGuard)	Experimental design: randomized discounts and non-price interventions	NA	0.58	NA	7	NA	NA

³⁰ For better comparability, WTP and Costs are reported in Parity Purchasing Power (ppp) US dollars in the year 2009. Conversion of ppp US dollars across time is done using Consumer Price Index.

³¹ Devoto *et al.* (2009) and Duflo *et al.* (2010) are excluded from the table since none of them report enough data to estimate the mean willingness to pay or cost of the clean water intervention.

³² Price obtained from Swanton *et al.* 2008 pp 35. I use the average value of the interval reported and assumed filter last for three years (Swanton, pp 23) and water consumption per household is 1000 l per month (Ashraf *et al.* 2010) to estimate WTP and cost of the intervention per household per year and per 1000 l. Finally WTP and costs are converted into ppp \$ of year 2009.

Study	Study Location	Water quality improvement	Estimation Methods	Mean WTP for cleaner water intervention (\$ per 1000l) *	Cost of the intervention (\$ per 1000 l)	Mean WTP for cleaner water intervention (\$ per household per year)	Cost of the intervention (\$ per household per year).	WTP/Cost of the intervention (1000 l)	Methodological assessment of the WTP calculation:
Kremer <i>et al.</i> (2011)	Kenya	protected springs	Experimental design: random variation in distance to cleaner water	NA	NA	5.61	5.73	0.98 ³³	Spring protection is a fixed cost independent of quantity of water consumed; WTP per 1000l is irrelevant.
Luoto <i>et al.</i> (2011).	Bangladesh	dilute chlorine (WaterGuard) chlorine tablets (Aquatab) flocculant-disinfectant (PUR) ceramic filter	Experimental design: Becker-DeGroot-Marschak (BDM) auction	Aquatab: 2.15 WaterGuard: 1.39 PUR: 1.82 Ceramic filter: 0.57	Aquatab: 1.9 WaterGuard: 2.17 PUR: 27.17 Ceramic filter: 3.61	Aquatab: 7.82 WaterGuard: 5.03 POU: 6.66 Ceramic Filter: 2.09	Aquatab: 6.96 WaterGuard: 7.93 POU: 99.17 Ceramic Filter: 13.12	Aquatab: 1.13 WaterGuard: 0.64 POU: 0.07 Ceramic Filter: 0.16	The study does not report the share of individuals that after bidding a higher amount than the price, did not buy the product (non-compliers).

³³ Although the cost and WTP for 1000 l is irrelevant in an intervention with only fixed costs, the WTP/Cost ratio per 1000 l is equivalent to the ratio of mean WTP for unlimited water annually divided by the annual fixed costs for the intervention. WTP and costs are converted into ppp US \$ of year 2009.

Study	Study Location	Water quality improvement	Estimation Methods	Mean WTP for cleaner water intervention (\$ per 1000l) *	Cost of the intervention (\$ per 1000 l)	Mean WTP for cleaner water intervention (\$ per household per year)	Cost of the intervention (\$ per household per year).	WTP/Cost of the intervention (1000 l)
Efficacy studies								
Brown (2007)	Cambodia	Locally-produced ceramic water filters	Contingent valuation	Those which use filters regularly: 0.24 Those disusing the filter: 0.07	0.31	Those which use filters regularly: 2.16 Those disusing the filter: 0.8	2.79	Those using the filters regularly: 0.77 Those disusing the filters: 0.28
Clasen <i>et al.</i> (2004)	Bolivia	Gravity water filter system	Contingent valuation	0.34	0.94	3.17	8.6	0.37
Garrett <i>et al.</i> (2008)	Kenya	Home chlorination treatment	Inferred purchases	NA	0.77 ³⁴	NA	5.84	NA
Luby <i>et al.</i> (2008)	Guatemala	Flocculant-disinfectant sachet	Contingent valuation	22.50	46	118 ³⁵	240	0.49
Semenza <i>et al.</i> (1998)	Uzbekistan	Home chlorination treatment for households without piped water supplies	Contingent valuation	25.5	NA	232 ³⁶	NA	NA
Venczel (1997)	Bolivia	mixed oxidant disinfection system	Contingent valuation	Those already receiving treatment: 3.04 Those who do not receive treatment: 4.06	NA	Those already receiving treatment: 27.2 ³⁷ Those who do not receive treatment: 36.6	NA	NA

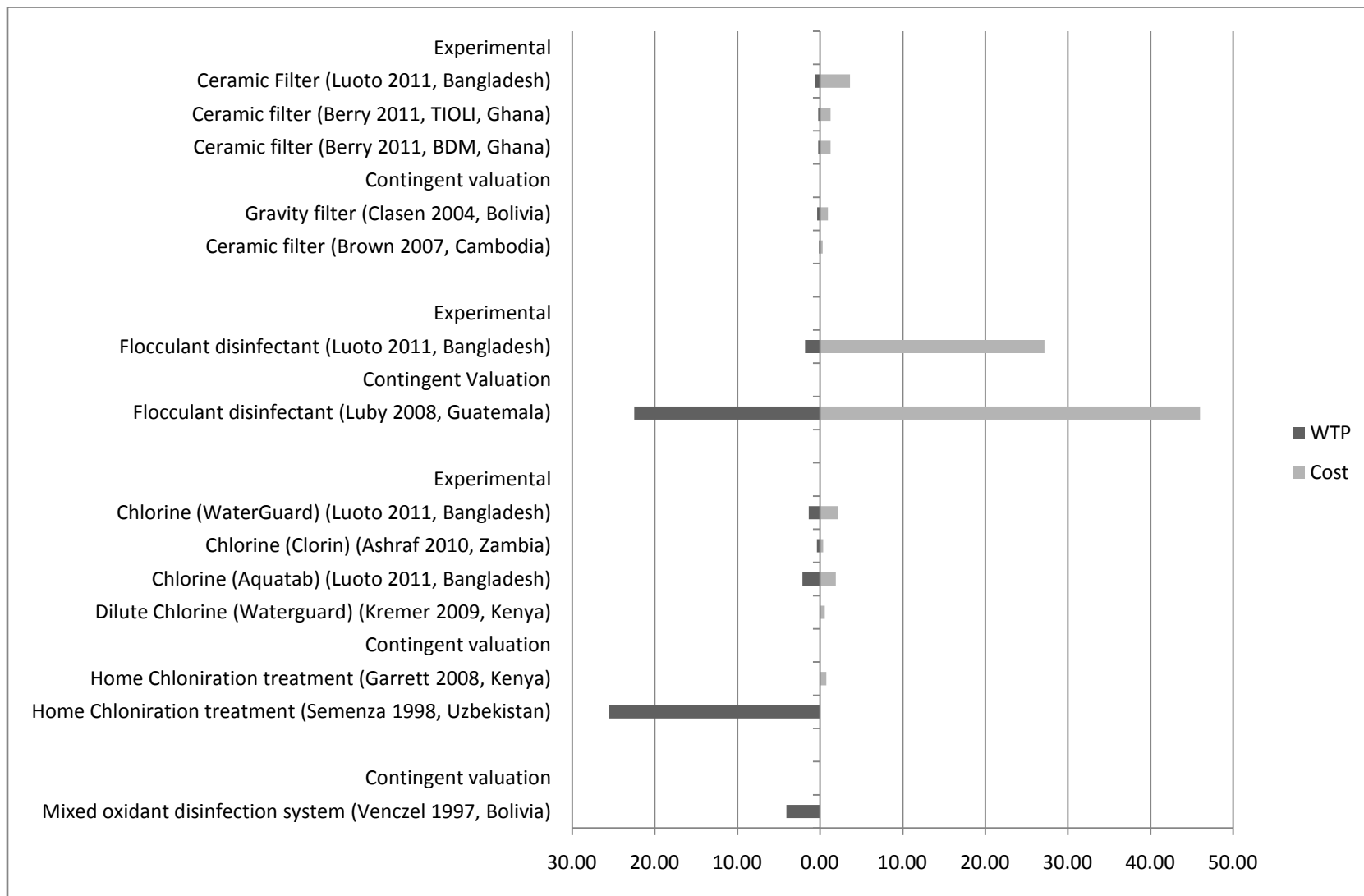
³⁴ Costs include only the bottle of Chlorine but not the safe storage containers.

³⁵ To estimate WTP per household per year I assumed water consumption per household per year is 25 l per day (Clasen *et al.* 2004, pp 656). Finally WTP and costs are converted into ppp \$ of year 2009.

³⁶ To estimate WTP per household per year I assumed water consumption per household per year is 25 l per day (Clasen *et al.* 2004, pp 656). Finally WTP and costs are converted into ppp \$ of year 2009.

³⁷ To estimate WTP per household per year I assumed water consumption per household per year is 25 l per day (Clasen *et al.* 2004, pp 656). Finally WTP and costs are converted into ppp \$ of year 2009.

Figure 3 Willingness to pay and cost for cleaner water (1000 liters) in ppp \$2009: evidence from experimental and contingent valuation studies³⁸.



Notes:

* Note that both WTP and Costs are converted from the local currencies to \$ with the exchange rates reported in each of the studies. Nonetheless, studies and interventions differ in time and therefore, comparisons of WTP and Costs across studies need to acknowledge the latter source of variation.

³⁸ Kremer et al. 2011 is excluded from the Figure since the study reports only the annual WTP and costs for spring protection unrelated to the quantity of water consumed by the household.

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