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Demand for environmental quality: averting behaviors impacts and valuation in Southern Ghana

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Abstract

Using a cluster randomized evaluation in Southern Ghana, this paper estimates the impacts of water quality testing and information on averting behaviors, demand and expenditures on water, sanitation and hygiene (WASH). Households are randomly assigned into either child treatment or adult treatment or comparison group. The study also elicits households' valuation of water quality testing and information using a stated preference approach. The study finds that averting behaviors and expenses on WASH increased more in the treatment households than the comparison households. The results also show that the experiment does not lead to demand for WASH information and infrastructure, except for water treatment in the adult treatment group. Contingent valuation estimates of households' willingness to pay (WTP) for water quality testing and information are lower than the cost, and are consistent with previous studies which show low valuation of water quality technology in Ghana. The WTP in the treatment groups are lower than the comparison group. The study also finds differential impacts on some of the outcome measures based on the random assignment into the treatment groups. The results have research and policy implications on the demand for preventive health goods and environmental quality in developing countries.

Keywords: Averting behaviors; Environmental quality; Ghana; Information; Randomized evaluation; Valuation

Highlights

- This paper tests whether provision of home water testing kits and information induces averting behaviors and expenses.
- Households are randomly assigned into either child treatment or adult treatment or comparison group.
- Results show that the intervention leads to significant increases in WASH expenditures and averting behaviors.

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- The results have research and policy implications on the demand for preventive health goods.

Introduction

In many developing countries, millions of people still suffer from the use of unsafe water sources. *Escherichia coli* (*E. coli*) contamination of water sources, for example, presents public health challenges leading to several water, sanitation and hygiene (WASH)-related morbidities including diarrhea. It is estimated that about 25% of the population worldwide consumes water that is contaminated by fecal matter. Globally, about 1.1 billion people consume drinking water with its safety classified as moderate risk, i.e., those with >10 *E. coli* per 100 mL (Bain *et al*., 2014). In Ghana, fecal contamination (i.e., presence of *E. coli*) affects 43.5% of sampled water sources and 62.1% of household stored water. About 8.4% of all water sources and 17.6% of household stored water suffer from very high risk of *E. coli* contamination (i.e., *E. coli* >100 cfu/100 mL) (Ghana Statistical Service (GSS), 2014).

While a number of strategies exist (e.g., water purification including boiling, chlorine, etc.; water infrastructure such as borehole, piped water, and spring cleaning) in improving water quality at the household level, information is becoming increasingly available on intervention options with the potential of significant positive impact on averting behaviors[1] and WASH investment (Madajewicz *et al*., 2007; Jalan & Somanathan, 2008; Hamoudi *et al*., 2012; Brown *et al*., 2017; Trent *et al*., 2018). One example is the Aquagenx Compartment Bag Test (CBT) or hydrogen sulfide (H_2S) which is used to test for the level or presence of *E. coli* in a given water sample. Water quality self-testing, as the name indicates in this study context, involves households testing their own stored water using CBT and relying on the information in managing drinking and general purpose water (see also Okyere *et al*., 2017, 2019; Okyere, 2018).

This paper makes contributions to the literature of impacts of water quality informational interventions in two main ways. First, this paper tests whether provision of home water testing kits and information on safer water storage and purification practices induce households to change these practices, particularly those related to monetary expenses. Understanding the factors affecting demand for point of use water treatment technologies is an important policy question, particularly in developing countries context including Ghana, where it is difficult to implement broader infrastructure changes within a short period of time. Here, the study uses both real and hypothetical reported behaviors and investment decisions in the literature (Jenkins & Scott, 2007; Jalan & Somanathan, 2008). Second, the study is the first, based on our knowledge, to undertake valuation of water quality testing and information in the literature. The study elicited households' valuation of water quality testing and information and the associated factors that influence their willingness-to-pay (WTP) for it. Using the randomized experimental design, the study attempts to analyze the role of water quality information in influencing the household's WTP. Specifically, we study whether water quality information influences the discount or premium households are willing to pay in getting their water tested. This is relevant in terms of research and policy implications to understand households' expressed interest in future investments

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[1] Averting behavior is defined as engaging in actions or activities in risk reduction from environmental hazard (see also Jalan & Somanathan, 2008; Hamoudi *et al*., 2012).

on water quality interventions in resource-poor countries including Ghana. This study also fits into the broader literature on the demand for preventive health care goods and environmental quality including water purification in developing countries (see Cohen & Dupas, 2010; Fischer *et al*., 2019; Berry *et al*., 2020).

This study addresses a policy relevant question of the role of information in increasing households' investment and averting decisions on WASH in southern Ghana. 512 households in the Greater Accra region of Ghana in 16 clusters were randomly allocated to participate in water quality self-testing and also received information in the form of handouts on how to improve household water quality. One half of the treatment was assigned to schoolchildren while the other one half was assigned to adult household members in order to determine the effects of intra-household decision-making on information. The comparison group neither participated in the water quality self-testing nor received information on how to improve household water quality (see also Okyere & Asante, 2017; Okyere *et al*., 2017, 2019; Okyere, 2018).

After four surveys conducted in 2014 and 2015, we found several policy relevant results. The main finding from the study is that information matters and the one who receives the information is essential in inducing averting behaviors and expenditures, demand and valuations. The results show that the intervention leads to significant increases in overall WASH and water expenditures, purchase of soap and detergent, and covering of all storage containers in the child treatment group; purchase of chlorine and change in water treatment, storage, handling techniques in the adult treatment group; and discussions on water quality (see also Jalan & Somanathan, 2008). The study also estimated stated WTP for test kits and found that the intervention groups have lower WTP than the comparison group (i.e., those without the intervention). Households are willing to pay for water quality testing and information, although their valuations are far lower than the current market price of the water test kits used for the study. This result is consistent with Berry *et al*. (2020), who found low valuation for water purification technology relative to cost in Ghana. Nevertheless, there are a number of water test kits available on the market that households in our study setting could afford. On the contrary, the study finds that information has no effects on the demand for WASH information and infrastructures including installing water supply systems, except for water treatment in the adult treatment group. This may suggest potential financial constraints limiting the role of information in influencing the demand for environmental quality. The results are robust to alternative specifications including randomization inference test of 2,000 replications.

Materials and methods

Theory of change for the water quality testing experiment

Supplementary Material, Figure A1 shows the theory of change (ToC) linking the water quality testing experiment to averting behaviors, investment in WASH, and other outcome measures. The main purpose of this paper is to show the possible channels between the experiment and averting behaviors and WASH investments (see also Jalan & Somanathan, 2008; Hamoudi *et al*., 2012). The link between the experiment and the outcome measures depends on several assumptions, including household participating in the training workshop on water quality testing experiment, household being able to perform water quality testing, household understanding and applying the knowledge on water quality information in managing the WASH environment, the test kits being able to differentiate between the microbial quality of different water sources, household switching to improved WASH practices, among others. However, the failure of these assumptions would lead to the inability of the experiment to improve the outcome measures (see also Okyere *et al*. (2017, 2019) and Okyere (2018) for details on research design). This article focuses on outcome measures on averting behaviors and WASH investments that are achievable within the shortest possible time. Therefore, this article tests two main hypotheses. Relative to households in the comparison group, households in the intervention group have: (1) increased averting behaviors and (2) increased WASH investments.

Study settings

The study ran from July 2013 to June 2015 and it involved 512 randomly selected households in 16 communities in the Ga South municipality and Shai-Osudoku district in the Greater Accra region of Ghana. Greater Accra is Ghana's most densely populated region and was selected due to the presence of multiple use water systems (see also Okyere *et al*., 2017; Okyere, 2018). Water supply sources are diverse ranging from surface water to piped water into premises based on WHO's Joint Monitoring Program (JMP) classification. Fecal contamination of water sources is pervasive in the Greater Accra region as 33.2% of sampled water sources had *E. coli* risk level ranging from medium (i.e., 1–10 coliform forming units (CFU) per 100 mL (cfu/100 mL)) to very high (i.e., >100 cfu/100 mL) while 41.7% of stored household drinking water had *E. coli* risk level ranging from medium (i.e., 1–10 cfu/100 mL) to very high (i.e., >100 cfu/100 mL) (Ghana Statistical Service, 2014). The reasons for the fecal contamination are diverse, including use of unimproved/unsafe water sources, poor water handling and management, and poor sanitation.

Experimental design

A full description of the experimental design is found elsewhere (Okyere *et al*., 2017, 2019; Okyere, 2018). In summary, the study randomizes the intervention at the school level, with the treatment provided directly to a sample of 128 schoolchildren in four public basic schools, to 128 parents/guardians in four public basic schools, and no intervention (comparison group) of 256 households in the remaining eight public schools in Ga South municipality and Shai-Osudoku district in the Greater Accra region of Ghana. Public basic schools were selected from communities with multipurpose water systems and poor WASH environment. Therefore, the unit of randomization is the public basic school and the primary sampling unit is the schoolchildren who represented the households. Thus, in the adult household members' intervention group, instead of the randomly selected schoolchildren, we rather used their parents/guardians for the experiment. Selection of schoolchildren was stratified by grade and gender before sampling. In addition, the selected schools map to communities, which means that there is no potential overlap of communities each school serves, and therefore no potential spillovers.

The study had ethical clearance from the Center for Development Research (ZEF), University of Bonn, Germany and the Noguchi Memorial Institute for Medical Research (NMIMR), University of Ghana, Legon. Consent and assent forms were administered to the household heads/guardians and schoolchildren, respectively. The first phase of the intervention was administered from July to October 2014 where the selected treatment group received training on how to use water test kits to identify the level of *E. coli* using the Aquagenx CBT, two CBT kits and two handouts containing nine water quality improvement messages for free. The second phase of the intervention was completed in March 2015 where the information component based on two handouts was repeated for the treatment groups. The treatment households participated in each round of the interventions using the same procedures for both groups and were also told to discuss the intervention with their respective households (see Okyere *et al*., 2017, 2019; Okyere, 2018). Supplementary Material, Figure A2 presents the timeline for the data collection and introduction of the experiment.

Baseline summary statistics and mean F-*tests*

Supplementary Material, Table A1 presents baseline summary statistics (separately for each study arm) and mean *F*-tests between the treatment and comparison groups (see also Okyere *et al*., 2017, 2019; Okyere, 2018). At the end of the baseline survey, a total of 505 households out of the 512 sampled households was successfully interviewed with the breakdown as follows: 125 households in the child treatment group, 127 households in the adult treatment group, and 253 households in the comparison group. Overall, households in the study arms are quite similar. Six out of the 24 mean *F*-tests from the Bonferroni multiple comparison tests failed the test of the null hypothesis that there is no distinguishable difference across the study arms based on the traditional confidence levels. The cluster randomized design with only 16 clusters raises important issues including power and balance. This is important as 25% of the covariates are different across the study arms. The treatment effects' analyses address these potential biases by including these variables that were statistically significant as controls. Furthermore, the analyses include the baseline data in the regressions, and also use randomization inference test with 2,000 repetitions (refer to Rosenbaum, 2002; Duflo *et al*., 2007; Fujiwara & Wantchekon, 2013; McKenzie, 2017; Heß, 2017; Young, 2019; Okyere *et al*., 2019). Previous analyses (Okyere *et al*., 2019) show that attrition rate relative to baseline covariates does not differ by study arm and also the baseline characteristics are balanced across the attritors and non-attritors.

The outcome variables on expenditures and behaviors are self-reported and are similar to those in previous studies (Jenkins & Scott, 2007; Jalan & Somanathan, 2008; Kremer *et al*., 2011). Panel A, based on information on household expenses on WASH, shows that in our study sites households spent GHS 41.75 (approximately US$13) on purchasing various WASH-related items in the last 4 weeks preceding the survey, 41.1% report purchasing water and 9.1% purchasing chlorine/alum for treating water. Panel B reports socio-economic characteristics for households. Most of the respondents (69%) of the survey were household heads. About 8% of the household heads completed senior secondary school or tertiary education. About 75% of the households engage in agriculture and/or allied activities while 25.3% of the households undertake irrigated agriculture. On average, six persons live in the households.

Panel C shows the WASH behaviors and knowledge of the households. About 73.1% report using improved main drinking water sources based on JMP classification. About 58.6% of the households rely on improved main general purpose water sources; 12% of the households undertake some form of water treatment before consumption (see also Okyere *et al*., 2017, 2019; Okyere, 2018) and 22.6% of the households have considered treating water to make it safer for consumption. About 38.2% of the households have a latrine/toilet while 34.5% have considered installing their own latrine/toilet. About 22.1% of the households have considered installing their own water supply system. Finally, about 18.5% of households had ever received WASH information while 34.9% had considered receiving WASH information.

Estimation strategy

First, an intention-to-treat (ITT) (i.e., differences between treatment and comparison groups) is estimated using linear approximation of a reduced form equation based on similar notations as Kremer *et al.* (2011):

$$Y_{jt}^{WT} = \propto_t + \emptyset_1 CT_{jt} + \emptyset_2 AT_{jt} + X_j^{WT'} \emptyset_3 + (CT_{jt} * X_j^{WT})' \emptyset_4 + (AT_{jt} * X_j^{WT})' \emptyset_5 + \varepsilon_{jt}$$

where Y_{jt}^{WT} is the averting behaviors and expenses for household j at time $t(t \in \{0, 1, 2, 3\})$ for the four survey rounds (waves), AT_{jt} is an adult treatment assignment variable equal to 1 after household was assigned to adult treatment group, CT_{jt} is the child treatment assignment variable equal to 1 if household was assigned to the child treatment group, X_j^{WT} represents the baseline household characteristics, and ε_{jt} represent the error term which correlates across the survey rounds (waves). Random allocation of intervention ensures that $\emptyset_1$ and $\emptyset_2$ are unbiased estimate of the ITT for the household water quality testing and information (see Finkelstein *et al.*, 2012). The ITT analysis is applicable since some of the households assigned to the intervention did not participate in the water quality testing and information experiment.

Second, differential effects based on comparison between child and adult treatment groups are estimated and these results are also reported in Table 1. Survey round/wave fixed effects are introduced in the estimations to control for seasonal variations affecting household WASH. Clustered standard errors at the public basic school level are reported. The study relies on Stata's *ritest* command (Heß, 2017) to undertake randomization inference with 2,000 repetitions (see also Rosenbaum, 2002; Duflo *et al.*, 2007; Fujiwara & Wantchekon, 2013; McKenzie, 2017; Heß, 2017; Young, 2019).

As previously reported (Okyere, 2018; Okyere *et al.*, 2019), uptake rate is high. Unsurprisingly, schoolchildren are more likely to participate than adults (84% vs 54%) and this may be due to the differences in motivating and constraining factors which have been analyzed in detail elsewhere (Okyere & Asante, 2017). Training procedures including venues for the trainings (i.e., school compound), training manuals, and trainers were the same for both treatment groups, except that schoolchildren were trained during school hours while the parents/guardians were trained in the evening and/or during weekends to accommodate potential business activities.

Results and discussion

Impacts on water, sanitation and hygiene expenditures

In theory, household water quality testing and information could lead to direct impacts of safe water behaviors and microbial water quality, and also indirect impacts on WASH investments. Table 1, Panel A presents the impacts of household water quality testing and information on WASH expenditures in the 4 weeks preceding the surveys. The study is interested in outcomes that are water-related and those that are sanitation and hygiene-related. Expenses on water and chlorine were considered to be those that are directly linked to the experiment while expenses on sanitation and hygiene-related items (such as soap and detergent) were considered to be indirectly related to the experiment. Here, we expected that the experiment would have positive effects on both purchases and amount spent on the items (see also

Table 1. Impacts on averting behaviors, expenses, and demand for water, sanitation and hygiene.

Dependent variable	Mean (SD) of the comparison group (1)	Child treatment (2)	Adult treatment (3)	Randomization inference *p*-value (4)	Child treatment–adult treatment (5)	Randomization inference *p*-value (6)
Panel A: Water, sanitation and hygiene expenditures						
Total water and sanitation expenses (GHS)	49.94 (33.29)	8.67*** (2.11)	−5.19** (2.25)	0.08*	14.92*** (2.71)	0.08*
Water expenses (GHS)	10.73 (17.38)	7.12*** (1.24)	−2.03 (1.32)	0.12	9.97*** (1.72)	0.08*
Soap and detergent expenses (GHS)	19.75 (12.07)	1.25* (0.72)	0.12 (0.77)	0.43	1.20 (0.90)	0.44
Purchased chlorine/alum (self-report)	0.05 (0.22)	0.00 (0.01)	0.03* (0.02)	0.28	−0.03* (0.02)	0.15
Chlorine/alum expenses (GHS)	0.19 (1.25)	−0.05 (0.08)	0.12 (0.09)	0.03**	−0.21** (0.10)	0.02**
Panel B: Averting behaviors and group discussions on water quality						
Change in water treatment, storage and handling techniques	0.15 (0.36)	0.00 (0.03)	0.12*** (0.03)	0.02**	−0.12*** (0.04)	0.05*
All storage containers are covered	0.48 (0.50)	0.07* (0.04)	−0.03 (0.04)	0.14	0.13*** (0.04)	0.08*
Discussions on water quality	0.05 (0.22)	0.20*** (0.03)	0.27*** (0.03)	0.41	−0.07* (0.04)	0.53
Panel C: Households' demand for environmental quality						
Household has considered treating water	0.25 (0.44)	−0.08** (0.04)	0.09** (0.04)	0.01***	−0.134*** (0.05)	0.06*
Household has considered installing latrine	0.39 (0.49)	−0.06 (0.04)	0.03 (0.05)	0.24	−0.09 (0.05)	0.30
Household has considered installing water supply system	0.27 (0.45)	−0.03 (0.04)	−0.01 (0.04)	0.78	−0.00 (0.05)	1.00
Household has considered receiving WASH information	0.45 (0.50)	0.05 (0.04)	0.03 (0.05)	0.80	0.01 (0.05)	0.83

Notes: Clustered robust standard errors for randomization reference with 2,000 repetitions in parentheses.

Household and household head controls include: respondent is household head, head completed secondary education or beyond, age of household head (years), household engages in agriculture and/or allied activities, iron roof indicator, household resides in rural district (Shai-Osudoku district), household assets are high (i.e., 1 if percentile 50–100 of household assets), and household engages in irrigated agriculture. Missing data will affect the number of observations for the respective outcome measures.

Analyses in Panel A rely on four rounds of data, those in Panel B rely on the two follow-up surveys and the endline survey, and Panel C relies on only baseline and endline surveys.

***Significant at the 1% level, **significant at the 5% level, *significant at the 10% level.

Brown *et al*., 2017). Presentation and discussion of results follows closely previous studies (Fujiwara & Wantchekon, 2013; Okyere *et al*., 2019).

The experiment on household water quality testing and information generates considerable differential effects based on random assignment into the treatment arms. Total WASH expenses in the four weeks preceding the surveys increase by GHS 8.67 in the child treatment group while there is a decrease of GHS 5.19 in the households in the adult treatment (Panel A, columns (2) and (3)). The results are statistically significant in both the standard *t* test and the randomization inference test (column (4)). Water purchases increase by GHS 7.12 in the households in the child treatment group while there is a decrease of GHS 2.03 in the households in the adult treatment group which is not statistically significant at the traditional confidence interval (columns (2) and (3)). The results are statistically significant in the standard *t* test but not statistically significant in the randomization inference test (column (4)). The results on households in the adult treatment group were unexpected, since parents are in charge of household expenditures and it would have been expected that the effect should be stronger when adults receive information. The results show that there are other mechanisms, including financial constraints, in place affecting household investment decisions. However, taken together with previous studies (Okyere *et al*., 2017; Okyere, 2018), which showed limited use of improved water sources in the adult treatment group, could also explain the lower expenses on water as shown in this study. Increase in water expenses in the child treatment group was expected as households switched to expensive but safer sources such as sachet water and piped water instead of free but contaminated sources including canals or river or streams (see Okyere *et al*., 2017; Okyere, 2018).

In addition, soap and detergent expenses increase by GHS 1.25 in the households in the child treatment group. No similar positive effects are found in households in the adult treatment group. Chlorine/alum purchases increase by 3 percentage points in the adult treatment group. There is no additional effect for households in the child treatment group. Results are significant in the standard *t* test but not statistically significant in the randomization inference test (column (4)). We do not find a statistically significant effect for chlorine expenses in any of the treatment groups. The results are not statistically significant in the standard *t* test but statistically significant in the randomization inference test (column (4)). The results for the adult treatment group are not surprising as it may show, as previous analyses (Okyere *et al*., 2017, 2019; Okyere, 2018) found, less hand-washing with soap and high likelihood of water treatment for this group.

Results in columns (5) and (6) show the differences in WASH expenditures for child treatment and adult treatment groups. The results confirmed the preceding ones showing that child treatment group households have larger effect size than those in the adult treatment group for WASH and water expenses. The results are statistically significant in both the standard *t* test and the randomization inference test. The results for the child treatment group are in consonance with previous studies (Onyango-Ouma *et al*., 2005) that found the potential of using children as 'agents of change' in health interventions in Kenya. However, the households in adult treatment groups have larger effect sizes when it comes to purchase of chlorine for water treatment. The results are statistically significant in both the standard *t* test and the randomization inference test or are closer to *p*-value of 10%.

Treatment effects on averting behaviors and group discussions on water quality

We use the same questions as in Jalan & Somanathan (2008) to study the treatment effects on averting behaviors and group discussions on water quality, and the results are presented in Table 1, Panel B. This section addresses a policy relevant question of whether information could lead to changes in averting behaviors. In columns (2) and (3), we find that households in the adult treatment group are 12 percentage points more likely to change averting behaviors. There is no statistically significant effect for households in the child treatment group. The results are statistically significant in both the standard *t* test and the randomization inference test (column (4)). This is an important positive indicator on households switching from unimproved or unsafe methods to improved or safe methods (see also Trent *et al.*, 2018). For instance, water handling changes included use of long handles in fetching water instead of short handles that can easily contaminate the water sources. Similarly, we find that group discussions on water quality is 20 percentage points higher in the child treatment and 27 percentage points higher in the adult treatment group compared with households in the comparison group. The results are statistically significant in the standard *t* test but not statistically significant in the randomization inference test (column (4)). We do find additional effects of 7 percentage points on covering of all water storage containers for the child treatment group (column (2)). No similar positive effects are found in households in the adult treatment group but rather we see a negative effect which is not statistically significant at the traditional confidence interval (column (3)).

Results in columns (5) and (6) show that the effects on averting behaviors seem larger for households in the adult treatment group than those in the child treatment group, except covering of all water storage containers. Most of the results are statistically significant in both the standard *t* test and the randomization inference test (column (6)). This is an important intermediate outcome which shows that household access to information on water quality did change due to the intervention. Descriptive analyses on the use of the test kits by the treatment groups also indicate usage after participation in the intervention and subsequent provision of the test kits (results available upon request). However, the study could not address whether the results are driven by the test kits or informational training and handouts as both are analysed simultaneously. That could be an avenue for future studies.

Estimating changes in households' demand for water, sanitation and hygiene

In this section, we analyzed the effects of water quality testing and information on household's demand for WASH (refer to Table 1, Panel C). We are motivated to study whether providing information could lead to households making future investments in WASH. Demand is defined loosely in terms of households considering to receive WASH information or install WASH facilities. If households are constrained by present circumstances in terms of resource availability, then asking questions about future investment decisions in WASH could generate additional insights on the role of information. Here, we adapted the demand questionnaire from Jenkins & Scott (2007). Their study was limited to only sanitation (i.e., demand for latrines/toilets). We expand their questions to other WASH hardware such as water supply systems. Another addition from this study is the inclusion of WASH software strategies (e.g., WASH education) aside the usual issues involving WASH hardware strategies (e.g., building of toilets/latrines and water supply systems). The questions were asked in the baseline survey (i.e., April/May 2014) and the endline survey (i.e., May/June 2015). We use the same estimation strategy as those in analyzing the impacts on averting behaviors and expenses.

In Table 1, Panel C, we find that households in the child treatment group are 8 percentage points less likely to consider to treat water (column (2)) while that of households in the adult treatment group increase by 9 percentage points (column (3)). The results are statistically significant in both the standard *t* test and the randomization inference test (column (4)). This result is confirmed by the results in columns (5) and (6) that show that households in the children treatment group are worse off (i.e., less likely) compared to their counterparts in the adult treatment group in undertaking water purification in this study context. The result is statistically significant in both the standard *t* test and the randomization inference test (column (6)). This is not surprising as results in previous studies (Okyere *et al.*, 2017; Okyere, 2018) showed households in the child treatment group switching to improved water sources instead of engaging in costly activities of water treatment or purification. In addition, the results in Table 1, Panel A indicate that households in the child treatment group increase their expenses on water and this may influence their inability to engage in water treatment.

The major result emanating from the study is the lack of 'systematic positive effect' of the experiment on the demand for improved WASH, except for consideration for water treatment in the adult treatment group. The lack of impacts on most of the indicators on demand for WASH hardware may probably be due to limited access to finance/capital or credit which has to be spent on other household expenses such as food, clothing, health, education, among others. Nevertheless, the positive effects on water treatment is indicative of households' willingness to invest in, presumably, less costly or expensive preventive health goods and services. The fact that the study finds no effect on demand for WASH hardware suggests that perceived high investment costs play a big role in households' future investment decisions, at least in this study context, and that information alone may not be enough in improving households' demand for improved WASH environment. Lastly, the results in Table 1, Panel C showing a lack of effects on interest in making future investments may be consistent with the relatively low WTP for test kits (i.e., the intervention did not shift priorities; the results are reported in Tables 2 and 3).

Valuing household water quality testing and information

This section relies on a stated preference approach such as contingent valuation (CV) technique in analyzing WTP for household water quality testing and information. Measuring WTP based on the Becker–DeGroot–Marschak (BDM) mechanism, stated and revealed preference methods has been applied in many studies on valuation of environmental quality, and health and nutrition behaviors (see Asenso-Okyere *et al.*, 1997; Oster & Thornton, 2009; Kremer *et al.*, 2011; Chowdhury *et al.*, 2011; Berry *et al.*, 2020). In addition, this section explores the linkages between WTP for household water quality testing and information, and baseline covariates. We use data from the three follow-up surveys conducted in 2014 and 2015, which asked respondents how much they would be willing to pay per quarter (i.e., every three months) for two water test kits, training on how to conduct the water quality testing and receipt of handouts containing water quality improvement messages. These components consist of the entirety of the water quality self-testing experiment undertaken in Southern Ghana.

Estimating willingness to pay for household water quality testing and information

We used CV questions in the three follow-up surveys which asked about respondents WTP to get water tested for *E. coli*. Here, WTP is defined based on a set of questions in which respondents were asked 'if household is offered two water testing kits and/or training exercise on its use and/or water quality message per quarter (i.e. every three months) at GHS 5, would household take it and so on up to GHS 30'. The World Health Organization (WHO) indicates that water from sources have to be tested for *E. coli* at least twice per annum. Due to the potential of water recontamination between

Table 2. Contingent valuation of quarterly water quality testing and information (2014 and 2015 surveys).

Panel A: Full sample (i.e., three follow-up surveys)		
Proportion willing to pay this amount for water quality testing and information	Percent	Observations (Household-wave)
GHS 5 (US$ 1.41)	0.807	1,383
GHS 10 (US$ 2.82)	0.454	1,085
GHS 15 (US$ 4.23)	0.515	476
GHS 20 (US$ 5.63)	0.637	234
GHS 25 (US$ 7.04)	0.590	139
GHS 30 (US$ 8.45)	0.855	83
Average maximum bid	**Mean**	**s.d.**
Ghana cedi (GHS)	8.51	7.84
US dollars (US$)	2.43	2.26
Panel B: Child treatment		
Proportion willing to pay this amount for water quality testing and information	Percent	Observations (Household-wave)
GHS 5 (US$ 1.41)	0.809	340
GHS 10 (US$ 2.82)	0.392	265
GHS 15 (US$ 4.23)	0.450	100
GHS 20 (US$ 5.63)	0.643	42
GHS 25 (US$ 7.04)	0.462	26
GHS 30 (US$ 8.45)	0.750	12
Average maximum bid	**Mean**	**s.d.**
Ghana cedi (GHS)	7.65	6.48
US dollars (US$)	2.18	1.85
Panel C: Adult treatment		
Proportion willing to pay this amount for water quality testing and information	Percent	Observations (Household-wave)
GHS 5 (US$ 1.41)	0.777	341
GHS 10 (US$ 2.82)	0.442	260
GHS 15 (US$ 4.23)	0.549	113
GHS 20 (US$ 5.63)	0.586	58
GHS 25 (US$ 7.04)	0.613	31
GHS 30 (US$ 8.45)	0.900	20
Average maximum bid	**Mean**	**s.d.**
Ghana cedi (GHS)	7.90	6.65
US dollars (US$)	2.26	1.88
Panel D: Comparison group (hypothetical scenario)		
Proportion willing to pay this amount for water quality testing and information	Percent	Observations (Household-wave)
GHS 5 (US$ 1.41)	0.821	702
GHS 10 (US$ 2.82)	0.489	560
GHS 15 (US$ 4.23)	0.525	263
GHS 20 (US$ 5.63)	0.657	134
GHS 25 (US$ 7.04)	0.622	82
GHS 30 (US$ 8.45)	0.863	51
Average maximum bid	**Mean**	**s.d.**
Ghana cedi (GHS)	9.20	8.84
US dollars (US$)	2.63	2.57

Notes: s.d. represents standard deviation.
Exchange rate at first follow-up survey was: GHS 3.21288 = US$1.00; second follow-up survey was: GHS 3.33130 = US$1.00; and third follow-up (endline) survey was: GHS 4.10475 = US$1.00 (Source: OANDA Corporation; www.oanda.com). The exchange rate used is the average between the buying and selling rate (i.e., mid-rate). The average exchange rate across the three follow-up surveys was GHS 3.54964 = US$1.00.

Table 3. Correlates of willingness to pay for household water quality testing and information.

	(1)	(2)	(3)	(4)
Variables	Dependent variable: Maximum bid (in GHS)			
Child treatment	−1.336**	−1.108	−1.435***	−1.092
	(0.602)	(1.131)	(0.553)	(1.029)
Adult treatment	−1.072	−1.290	−1.096*	−1.277
	(0.660)	(1.061)	(0.591)	(1.000)
Household had ever received WASH information	0.822	0.832	0.779	0.801
	(0.985)	(0.990)	(0.886)	(0.895)
Child treatment* Household had ever received WASH information	−0.755	−1.010	−0.705	−0.964
	(1.673)	(1.748)	(1.429)	(1.491)
Adult treatment* Household had ever received WASH information	−1.734	−1.477	−1.894	−1.645
	(1.466)	(1.464)	(1.265)	(1.259)
Child treatment* Baseline asset is high		−1.548		−1.599
		(1.112)		(1.015)
Adult treatment* Baseline asset is high		−2.659**		−2.773**
		(1.158)		(1.142)
Child treatment* Baseline WASH expenses		0.014		0.012
		(0.015)		(0.014)
Adult treatment* Baseline WASH expenses		0.040*		0.040
		(0.023)		(0.029)
Head had SSCE or above qualification	1.648	1.728	1.634	1.718*
	(1.126)	(1.105)	(1.007)	(1.000)
Age of household head (years)	−0.016	−0.016	−0.026	−0.025
	(0.112)	(0.110)	(0.107)	(0.105)
Squared of household head's age	−0.000	−0.000	0.000	0.000
	(0.001)	(0.001)	(0.001)	(0.001)
Household head is a male	1.786***	1.827***	1.810***	1.854***
	(0.560)	(0.577)	(0.508)	(0.522)
Household size	−0.451*	−0.442	−0.439*	−0.426
	(0.273)	(0.272)	(0.264)	(0.265)
Squared of household size	0.026*	0.025*	0.025*	0.024*
	(0.014)	(0.014)	(0.014)	(0.014)
Improved sanitation	−0.216	−0.212	−0.192	−0.189
	(0.506)	(0.504)	(0.452)	(0.454)
Improved drinking water	−0.627	−0.588	−0.689	−0.656
	(0.568)	(0.574)	(0.505)	(0.506)
Household engages in agriculture and/or allied activities	0.581	0.470	0.543	0.420
	(0.615)	(0.611)	(0.555)	(0.550)
Iron roof indicator	0.439	0.387	0.503	0.456
	(0.523)	(0.517)	(0.468)	(0.470)
Household engages in irrigated agriculture	−0.038	−0.020	−0.000	0.029
	(0.615)	(0.609)	(0.544)	(0.543)
Household asset is high	0.722	1.709**	0.740	1.759***
	(0.528)	(0.757)	(0.470)	(0.679)
Household WASH expenses at baseline	0.008	−0.004	0.009	−0.003
	(0.009)	(0.013)	(0.009)	(0.012)
Household resides in rural district (Shai-Osudoku district)	1.002*	1.072**	1.017**	1.104**
	(0.514)	(0.514)	(0.470)	(0.463)

(*Continued.*)

Table 3. (*Continued.*)

Variables	(1)	(2)	(3)	(4)
	Dependent variable: Maximum bid (in GHS)			
Constant	9.132***	9.032***	9.322***	9.149***
	(3.294)	(3.255)	(3.119)	(3.059)
Wave fixed effects	Yes	Yes	Yes	Yes
Observations (household-wave)	1,278	1,278	1,278	1,278
R-squared	0.041	0.048	0.041	0.048
Number of households	481	481	–	–
Prob > chi^2	9.53×10^{-5}	0.000	1.02×10^{-6}	1.74×10^{-6}

Notes: Robust standard errors in parentheses.
***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

point of source (POS) and point of use (POU), we think it will be more appropriate to undertake quarterly water quality testing at the POU. We focus on households who participated in the experiment and estimate whether those who have first-hand experience in water quality testing and information will have greater WTP. This is compared with the comparison group whose valuation is based on expected utility instead of the treatment group's actual/real utility. In addition, our data collected over time (three wave panel data), allow us to estimate WTP over time across the treatment and comparison groups. Since we use panel data instead of cross-sectional data, we are confident of the results as they represent medium- to long-term effects. Finally, we analyze the reasons why some of the households were not willing to pay any amount of money to get water tested.

Table 2 presents the contingent valuation of quarterly water quality testing and information. The WTP for GHS 5 was high (82.1%) among the comparison group, followed by 80.9% in the child treatment group, with the least being households in the adult treatment group (77.7%) for quarterly water quality testing. In the case of the WTP for GHS 10 (US$2.82) across the treatment arms, 48.9% of the households in the comparison group accepted this bidding price category, followed by households in the adult treatment group (44.2%), while about 39.2% of the households in the child treatment group accepted the offer at this bidding price category. In the highest bidding price category of GHS 30 (US$ 8.45), households in the adult treatment group were the highest (about 90%) who accepted this offer, followed by those in the comparison group (86.3%) with the least being households in the child treatment group (about 75%). The number of households in the bidding game for water quality testing and information decreases sharply with higher bidding price categories – indicating limited purchasing power of households in the study setting.

Across the treatment arms, households in the comparison group had the highest mean maximum bid of GHS 9.20 (US$2.63), followed by households in the adult treatment group of GHS 7.90 (US$2.26), with the least being households in the child treatment group of GHS 7.65 (US$2.18). The amount is sizeable and it represents, based on some assumptions and requirements about CV questions, the value or premium respondents placed on water quality testing and information. The mean maximum bid is less than US$7, which is the price of one CBT test kit (depending on the quantity purchased) used in the study. In the bidding game, we proposed two test kits which will cost about US$14 and also factoring in the cost of printing and disseminating the handouts containing the water quality improvement messages, then the mean maximum bid of US$2.43 is on the lower side. Nevertheless, given the limited purchasing power of the households in the study setting and less familiarity with water quality testing, the premiums for water quality testing and information are relatively high. In addition, there are several test kits which cost far less, for instance H_2S test kits from HiMedia cost around US$0.50 per kit (Hamoudi *et al.*, 2012), which could be utilized. Bain *et al*. (2012) also provides a summary of water test kits and their respective costs which will be suitable for resource-poor settings including Aquatest™, Petrifilm, and Coliplate™. In the near future, competition and technology advancement could also drive the price of the CBT test kit downwards, making it more affordable to households in resource-poor settings.

Among households/respondents who decided not to pay to get water tested, the most commonly cited reasons were as follows, using question formats previously used by Jenkins & Scott (2007): perceived high costs of the test kits (13 cases); savings and credit issues as some of the respondents were retired workers and others had no work (9 cases); other reasons (9 cases in total), including it should be given for free (4 cases) and no relevance for water test kits as it does not improve water quality (5 cases); satisfied with existing quality of water supply (4 cases); government's responsibility to provide water quality information for free (3 cases); poor options for the test kits mainly due to technical complexity (3 cases); competing priorities linked to other needs (1 case); and lacking decision-making as the respondent was not the household head or spouse (1 case).

Relationship between willingness to pay for household water quality testing and information, and baseline covariates

We estimate the correlates of WTP for water quality testing and information in Table 3. We show the results from regressions estimated for the full sample in a panel data structure (using data from the three follow-up surveys). The dependent variable is the maximum bid the respondent offered to get their water tested and this is regressed on a vector of baseline covariates. Four regressions are estimated for the determinants of WTP for water quality testing and information. In column (1), we estimate the regression for the effect of the treatment assignment (i.e., child treatment, adult treatment group, and comparison), WASH information, and their interaction on the premium associated with water quality testing and information. In column (2), we include other interaction terms of the treatment assignment and WASH expenses and assets for heterogeneity in treatment effects. In columns (3) and (4), we analyze pooled regressions without the panel attributes/structure of the data. Robust standard errors are reported. The F-tests for the regressions pass the goodness of fit measure with p-values less than 5%. This indicates that the independent variables jointly and statistically significantly explain variations in the maximum bid for water quality testing and information.

Interestingly, we find that the premium for households in the child treatment group was GHS 1.34 lower than that of the comparison group and it is statistically significant at 5% level (column (1)). The premium for households in the adult treatment group was GHS 1.07 lower than those in the comparison group which was not statistically significant. The results are largely robust to alternative specifications (columns (2)–(4)). These results indicate that provision of water quality information (i.e., participation in the experiment) do not translate to higher premiums associated with water quality testing and information (see also Fischer *et al.*, 2019; Berry *et al.*, 2020). The result shows that the dissemination of information by different actors (i.e., intra-household allocation) affects the premium associated with water quality testing and information. In addition, enthusiasm (based on expected benefits) could lead to higher premiums among households in the comparison group than those who actually benefit from a given intervention. Over time, the effects in the treatment groups wane leading to lower premiums associated with water quality testing and information compared with the comparison households.

However, since no water test kits were actually purchased by any of the groups, the WTP represents a hypothetical scenario for all groups and, therefore, measures of WTP in all groups may suffer from hypothetical bias (i.e., difference between stated and actual WTP). The difference between the treatment and comparison groups as already indicated is that the former group has an exogenously induced higher probability of having used the product. Given that the treated households have already received the intervention, while the comparison group have not, the product might be considered to be different across the treatment and comparison groups (i.e., 'known' information for the treatment and 'new' information for the comparison group). However, this was necessary to prevent potential contamination of the randomized evaluation. Nevertheless, taking the WTP as shown, the study suggests that: (1) average demand for water testing kits is likely to be low at current market prices (see also Berry *et al*. (2020) for valuation of water purification technology in Ghana), and (2) free provision and information does not seem to increase WTP for subsequent testing. These results fit into the broader literature on the demand for preventive health care goods and environmental quality in developing countries (Cohen & Dupas, 2010; Fischer *et al*., 2019; Berry *et al*., 2020).

Other factors influencing WTP include household head being a male, household size and its squared, residence in rural district, and household asset. The positive effect of male-headed households is expected, as in many developing countries due to cultural and traditional reasons, males have more economic and social opportunities leading to higher purchasing power than females. Number of people in the household is negatively associated with WTP for water quality testing and information. Rather the squared of household size has a positive effect. Larger households have more people to feed and also have other competing priorities, therefore, with limited resources it becomes difficult for them to invest in not too familiar technology like water quality testing and information. Household asset leads to higher WTP for water quality testing and information. This is expected as these are households who could afford the test kits and information. Households in the rural district compared with their counterparts in the urban district have higher WTP for water quality testing and information. This is an interesting result as higher WTP could lead to demand and/or adoption of technologies in rural settings in Southern Ghana and elsewhere. There is heterogeneity in the treatment effects as interaction between adult treatment group and baseline assets shows a negative relationship with WTP while interaction between adult treatment group and baseline WASH expenses has a positive relationship with the WTP.

Conclusions

In this study, we estimated the impacts of household water quality testing and information on averting behaviors and expenses on WASH using an experimental research design in Southern Ghana. The study focused on easily measurable indicators used in previous studies (Jenkins & Scott, 2007; Jalan & Somanathan, 2008). We also expanded the analyses to cover expenses on WASH in the 4 weeks preceding the surveys. The results are robust to alternative specifications including randomization inference test of 2,000 replications.

The principal finding is that there are changes in WASH investment decisions to relaxing information constraint. More importantly, household water quality testing and information induces averting behaviors and expenditures. We also found differential impacts based on the random assignment into either child treatment or adult treatment. The policy implication is that providing information can be effective in achieving risk mitigating behaviors. However, the effects differ based on the treatment assignments indicating that intra-household allocation matters when it comes to information dissemination to improve WASH investment decisions (see also Okyere *et al*., 2017; Okyere, 2018). Given that the children and adults were trained separately, could the results indicate differences to how the message about the experiment is conveyed? The results point to the possibility of the two groups conveying different sets of information from the experiment. Furthermore, the results suggest that households relying on unimproved water sources could be reducing consumption of water from contaminated sources, and with the reverse happening for those consuming water from improved/safe sources. Similarly, households consuming water from unimproved/unsafe water sources could be intensifying water treatment/purification based on the information from the experiment while those consuming safe/improved sources continuously use those sources. These results and their variations have been documented in the literature (see Madajewicz *et al*., 2007; Jalan & Somanathan, 2008; Hamoudi *et al*., 2012; Luoto *et al*., 2014; Brown *et al*., 2017; Okyere *et al*., 2017, 2019; Okyere, 2018).

To what extent does information affect households' demand for WASH? The study finds that household water quality testing and information increase demand for water treatment only when adults are treated, but not that of WASH information and infrastructures. The results from the experimental design suggest that household water quality testing and information could lead to demand for water purification interventions in resource-poor settings. Ultimately, imperfect information affects demand for water purification interventions in developing countries. The main policy implication is that information could be used as a social marketing tool in ensuring demand of water purification interventions in Southern Ghana and elsewhere. However, the fact that the study finds no effect on demand for WASH hardware suggests that resource constraints play a big role in households' future investment decisions, at least in this study context, and that information alone may not be enough in improving households' demand for improved WASH environment.

We also addressed an essential policy question of the role of information in influencing premium households WTP for water quality testing and information. The study shows that households in Southern Ghana are willing to pay for water quality testing and information, although the mean maximum bid is far lower than the costs of the test kits used for the study (see also Berry *et al*., 2020). Nevertheless, there are several water test kits available on the market (for instance, H_2S test kit) that the majority of the households could afford. The stated preference estimates of WTP for water quality testing and information for households in the treatment groups are lower than that of the comparison households and this is consistent with previous studies where intervention groups have lower valuation than those in the comparison group.

Finally, the results also show that household socio-economic status matters in determining the WTP for water quality testing and information. Specifically, baseline factors affecting positively a household's WTP include household head being male, household assets, and household residence in rural district. Household size negatively affects premiums associated with water quality testing and information. These are the factors that have to be taken into consideration when determining premiums for water quality testing and information in developing countries. Therefore, policymakers and researchers should consider these factors in developing low cost water quality testing kits in developing countries. However, these factors may be unique to this current study in terms of context and product (i.e., use of CBT) and may not be generalized for other products or studies. Thus, these results suggest further research on how socio-economic and demographic characteristics affect valuation of water quality technologies in developing countries.

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Data availability statement

Data cannot be made publicly available readers should contact the corresponding author for details.

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