Risk perception, choice of drinking water and water treatment: evidence from Kenyan towns

Joseph Onjala, Simon Wagura Ndiritu and Jesper Stage

ABSTRACT

This study used household survey data from four Kenyan towns to examine the effect of households' characteristics and risk perceptions on their decision to treat/filter water as well as on their choice of main drinking water source. Because the two decisions may be jointly made by the household, a seemingly unrelated bivariate probit model was estimated. It turned out that treating non-piped water and using piped water as a main drinking water source were substitutes. The evidence supports the finding that perceived risks significantly correlate with a household's decision to treat non-piped water before drinking it. The study also found that higher connection fees reduced the likelihood of households connecting to the piped network. Because the current connection fee acts as a cost hurdle which deters households from getting a connection, the study recommends a system where households pay the connection fee in instalments, through a prepaid water scheme or through a subsidy scheme.

Key words | drinking water, subjective risk perception, water quality, water treatment

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INTRODUCTION

This paper presents a study on decisions about drinking water sources and in-home water treatment behaviour, drawing on household data collected in Kenyan towns. Specifically, the aim was to understand how people think about and respond to the perceived riskiness of different water sources when they are choosing their drinking water, and what their risk-averting behaviour entails. For those who had potential access to piped water but chose not to use it, the choice of using risky non-piped water sources was studied. The study also investigated the role of the connection fee as a hurdle to connecting to the piped network. We follow previous literature (see Nauges & Whittington (2010) for a literature review) and use source attributes and household characteristics as explanatory variables. Unlike previous studies, the analysis here was predicated on the assumption that the two decisions on water source and water treatment are taken jointly; also, the effect of perceived risk and the substitution effects of the decisions were tested – which was not the case in earlier studies.

In Kenya, as in many developing countries, insufficient access to clean drinking water and the resulting health issues are serious problems (Kimani-Murage & Ngindu 2007; WHO 2013). Approximately 80% of hospital attendance in Kenya is due to preventable diseases and about 50% of these diseases relate to water, sanitation and hygiene (GoK 2011). Only 57% of households use water from sources considered safe (GoK 2008). In addition, access to safe water supply and sanitation varies greatly across regions and across income groups. Wealthy households buy bottled water for drinking, but for most households this option is unaffordable. The main way for non-wealthy households to

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improve water quality is by treating water domestically through boiling, filtering, or chlorination. Domestic water treatment has been shown to be one of the most effective means of reducing the risks and costs associated with preventing water-borne diseases, especially diarrhoea (see e.g., Tumwine *et al.* 2002; Clasen *et al.* 2007a, 2007b; Graf *et al.* 2008; Leiter *et al.* 2013). However, despite the importance of increasing water quality through domestic treatment, empirical research remains scarce on the relationship between water treatment and the factors – such as risk perception – that drive this decision.

Some researchers have studied the effects of informing households about the riskiness of their drinking water sources and subsequent averting behaviour. For instance, Madajewicz *et al.* (2007) provide information on unsafe wells to encourage Bangladeshi households to switch to safer wells. Jalan & Somanathan (2008) report that, through a randomised experiment, they provided information to households that their unpurified water was dirty, and, through this, increased domestic water treatment.

Although these studies find that informing households about the health effects of unsafe drinking water leads them to treat water or even change water sources, especially among those using unsafe non-tap water sources, there are potential methodological problems with the way these studies were conducted. Providing households with information and later revisiting the same households could lead to bias in the responses provided by the respondents, as they might wish to please the interviewers. For example, a respondent might not in fact have changed his/her behaviour, but might nonetheless feel pressure to state that s/he had if the person asking had educated him/her in the past about the benefits of changed behaviour. This potential interviewer bias (see e.g., Bradburn (1983) or Singer *et al.* (1983) for discussions of how interviewer expectations can affect survey responses) could affect both the magnitude and statistical significance of the estimates obtained through this approach.

In this study, no risk information was provided to the respondents. Instead, respondents were asked about their perception of certain risks, and the study assesses the implications such risk perceptions have on averting behaviour. In this case, therefore, the responses were not affected by risk information advanced to the respondent, but rather by the respondent's own experience accumulated through actual use of a given water source.

Different households have different risk perceptions for water from various sources. Therefore, each water source has an implicit health risk, which varies depending on the quality of the water as well as the technology required to access the water. Consumers make judgements about how risky different water sources are. In their choice of a main water source, they compare the expected health risk from consuming the specific water to the cost and time use linked to using the water source in question, where less risky water sources – such as piped water – generally come at a higher cost (at least when connection fees are considered) than more risky sources. At the same time that a main water source is chosen, a decision is made as to whether or not to undertake the perhaps costly treatment of the chosen water source. Consumers will treat water if the expected utility of health benefits of domestic treatment – measured as a change in expected water-related illness – exceeds the cost of such treatment (Redding *et al.* 2000).

Thus, when the members of a household choose their drinking water, they worry about access to and quality of the water. If they doubt the quality – a doubt that could be driven by many factors – they may decide to treat the water. The choice of a source of drinking water is likely to be made jointly with the decision as to whether or not to treat the water, which will create statistical problems if the source choice and treatment decision are modelled separately (Greene 2012). Hence, the study follows Nauges & Van den Berg (2006) to model, simultaneously, the choice of the drinking water source and the decision to treat water before drinking.

This paper contributes to the literature by answering the following questions:

- How does risk perception influence a household's choice of a source of drinking water and whether or not it gets treated?
- How do connection fees and perceived risk differences between piped and non-piped water affect whether or not households with potential access to safe piped water choose to be connected?

Because people will respond according to their own personal perceptions of risk and not to objective risk measures as calculated by, for example, water specialists (Slovic 1987), this study tested the effects of risk perception not only on the choice of source of drinking water, but also on averting behaviour.

MATERIALS AND METHODS

Study sites

Data for this study came from residential households in four Kenyan towns – Eldoret, Kericho, Kisii and Kisumu – surveyed during 2008. The four towns were purposefully selected to represent diverse physical, socio-economic and ethnic backgrounds. Thus, Eldoret is one of the few towns in the country with an adequate water supply; that is, there are rarely any occasions when the town suffers water shortages. Kericho draws its water from the local rivers. The water intake is located in the Mau Forest, one of Kenya's largest water catchment areas. From the intake, pumps drive water to a modern treatment facility. Kericho is one of the only towns of its size in Kenya to employ such a treatment works. In Kisii, on the other hand, the water and sanitation facilities are inadequate and poorly managed: less than 40% of residents are connected to piped water services. In Kisumu, acute water shortages, declining quality and poor sanitation have been recurrent problems, despite the town's proximity to the second largest freshwater lake in the world, Lake Victoria.

Study design

To achieve 911 interviews, 1,422 contacts were made during the survey, representing a 64% response rate. The survey was conducted by enumerators who had been recruited from the University of Nairobi. The interviews were in English or Swahili, depending on the language preferred by the individual respondent. A detailed description of the sampling and administering of the questionnaire is provided in the Appendix (please see the Supplemental Material available online at http://www.iwaponline.com/washdev/004/131.pdf).

Prior to the main survey, focus groups were consulted to assist in designing the survey instrument. To implement the final survey, a structured questionnaire was administered. Each town was stratified into three broad residential areas on the basis of income levels. A list of the residential areas and their associated income groupings was prepared. The initial sample was randomly recruited from each residential estate. Thus, the clustered, stratified, multi-stage, probability sample design had the goal of giving every urban household an equal and known probability of selection for interview. The process was vetted by teams of scholars at the Kenya Institute for Public Policy Research and Analysis and the Institute for Development Studies at the University of Nairobi, as well as by Ministry of Water officials. The final survey instrument was approved by the National Council for Science and Technology.

The survey covered water sourcing behaviour, water costs, household demographics and housing, and households' perception of water quality and safety, as well as major socio-economic characteristics that might influence a household's choice of water source. We did not include questions on quantities or per-unit costs (whether monetary costs, as for piped water, or value of time used in collection, as for non-piped water) in our survey because billing from the water utilities tends to be irregular, making collection of data on quantities and costs of piped water difficult. However, as discussed earlier, the main cost discouraging households from connecting to the piped water network is typically the connection fee itself, which we did collect data on; once a household is connected, the per-unit cost of water is lower for piped water than for non-piped water sources.

According to the World Health Organization–United Nations Children's Fund Joint Monitoring Program for Water Supply and Sanitation (available at http://www.wssinfo.org/definitions-methods/introduction/ (last accessed 14 January 2014)), improved drinking water sources include piped water into the dwelling, plot, or yard; public taps/standpipes; tube wells/boreholes; protected dug wells; protected springs; and rainwater collection. Unimproved drinking water sources include unprotected dug wells; unprotected springs; carts with small tanks/drums; tanker-trucks; and surface water (rivers, dams, lakes, ponds, streams, canals, or irrigation channels). 'Improved' encompasses three dimensions of water security: quality, proximity and quantity. Hence, water from vendors (cart with small tank/drum, or tanker-truck), although mostly originating from safe sources (piped or borehole), is categorised as 'Unimproved', as the quality of this water on delivery varies considerably in practice. Therefore, in our analysis of the water source subsamples, the following categories were identified:

- Piped water (piped water into dwelling, plot, or yard).
- Non-piped but improved water.
- Non-piped, unimproved water.

The United Nations Population Division (2000) has defined 'access to water' as 'an adequate amount of safe drinking water located within a convenient distance from the user's dwelling', but notes that for purposes of statistics compilation actual use has often been used as the indicator instead. In line with the theoretical definition, in this study, 'access' to a source by a household was defined to mean that the source was available in the area/estate where the household resided. Thus, for example, a household was defined as having access to piped water if it lived in a residential area/estate where connection to the piped water network was possible; nonetheless, the household in question could choose not to establish a connection and, thus, not actually use piped water. Households living in areas where access to piped water was not available might nonetheless have access to both improved and unimproved water sources; they could then choose whether or not to use improved water.

In our analysis of water treatment, households were defined as having 'treated' their water if they reported treating it with chemicals (which few did in practice), boiling it or filtering it.

Statistical specification

Following Hindman Persson (2002), the modelling of the choice of water source was based on the Random Utility Model. In this model, the household faces a discrete set of water source choices, choosing the water source that maximises its utility subject to budget and water availability constraints.

Given the assumed simultaneous nature of the decisions about water source and water treatment, seemingly unrelated bivariate probit models are estimated for the following three groups.

For the first group, the subsample of households living in a residential area/estate where access to piped water is possible, the choice of piped as opposed to non-piped water as the main source of drinking water is studied, adopting the following bivariate probit model:

$$l_1^* = X_1'\beta_1 + \varepsilon_1; \quad S_1 = 1 \text{ If } l_1^* \succ 0; \quad S_1 = 0 \text{ otherwise} \tag{1}$$

$$l_2^* = X_2'\beta_2 + \varepsilon_2; \quad T_1 = 1 \text{ If } l_2^* \succ 0; \quad T_1 = 0 \text{ otherwise} \tag{2}$$

$$\varepsilon_1, \varepsilon_2 \text{ and } \rho_1 \sim \text{Bivariate normal,}$$

where S_1 is the choice of using piped water; T_1 is the decision to treat water; l_1^* and l_2^* are the unobserved latent variables from which the two decisions are defined; X_1 and X_2 are the vectors of independent variables for both decisions; ε_1 and ε_2 are the error terms, which may be correlated (given by the correlation coefficient, ρ statistics); otherwise, a univariate binary probit model is appropriate (Greene 2012).

For the second group, those who do not have access to piped water, but who do have access to improved non-piped water sources, the study looked at the decision to use improved non-piped water sources for the main source of drinking water rather than an unimproved source. For this, the following bivariate probit model was adopted:

$$l_3^* = X_1'\beta_3 + \varepsilon_3; \quad S_2 = 1 \text{ If } l_3^* \succ 0; \quad S_2 = 0 \text{ otherwise} \tag{3}$$

$$l_4^* = X_2'\beta_4 + \varepsilon_4; \quad T_2 = 1 \text{ If } l_4^* \succ 0; \quad T_2 = 0 \text{ otherwise} \tag{4}$$

$$\varepsilon_3, \varepsilon_4 \text{ and } \rho_2 \sim \text{Bivariate normal,}$$

where S_2 is the choice of using a non-piped improved water source and T_2 is the decision to treat water. The other variables are as defined in Equations (1) and (2) above.

For the third group, people who have no access to improved water sources (piped water or improved non-piped water sources), the only decision is whether or not to treat the water. Hence, the probit model is estimated for the water treatment equation for the subsample of those with no access to improved water sources. The probit model is defined as follows:

$$l_5^* = X_2'\beta_5 + \varepsilon_5; \quad T_3 = 1 \text{ if } l_5^* \succ 0; \quad T_3 = 0 \text{ otherwise} \tag{5}$$

where T_3 is the water treatment for those who choose non-piped unimproved water sources as their main drinking water. All the other variables are as defined above.

The same explanatory variables are included for the socio-economic characteristics in the two (water source and water treatment) equations. Factors explaining a household's decision to obtain water from a certain source in developing countries are presented in a literature survey by Nauges & Whittington (2010). The factors they identify include source attributes (e.g., price, distance to the source, quality and reliability) and household characteristics (income, education, size and composition). Following existing literature on water sources (summarised in Nauges & Whittington 2010) and water treatment (e.g., Nauges & Van den Berg 2006), the variables included are as follows:

- Age, education and gender of the head of the household (also included in e.g., Madanat & Humplick 1993; Larson *et al.* 2006; Nauges & Strand 2007; Briand *et al.* 2009; Nauges & Van den Berg 2009).
- Number of children aged 0 to 5 years and ratio of females to males in the household (similar variables included in e.g., Mu *et al.* 1990; Rizaiza 1991; Rietveld *et al.* 2000; Strand & Walker 2005; Nauges & Strand 2007).
- Income category (similar variables included in e.g., Hindman Persson 2002; Larson *et al.* 2006; Nauges & Strand 2007; Basani *et al.* 2008; Nauges & Van den Berg 2009).
- The average perception of water safety in the town where the household lives (similar variables included in e.g., Briand *et al.* 2009; Nauges & Van den Berg 2009).

For the piped water equation, the effects of the connection fee and the average frequency of problems experienced with water pressure in the town where the household lives were also explored. High connection fees have been shown to deter households from connecting to piped water networks in other developing countries, and Devoto *et al.* (2012), for example, have argued for permitting households to pay the connection fee in instalments rather than all at once in order to encourage connections; it is reasonable to assume that connection fees may act as a deterrent in Kenya as well. Madanat & Humplick (1993) argue that households living in areas with higher pressure in their water pipes are expected to have a higher rate of connection to the piped network because low and irregular pressure in the network is frequently linked to delivery problems; subsequent studies (e.g., Adekalu *et al.* 2002; Rosenberg *et al.* 2007) have found this to be an important issue as well. Thus, this study controls for the problem of water pressure in the piped water model.

As pointed out by Whitehead (2006) and Nauges & Van den Berg (2006), it is likely that unobserved variables such as health history will affect both the household's perceived risk and its hygiene behaviour, causing potential endogeneity problems (see Greene 2012 for a discussion of the statistical issues that this can cause). In order to avoid this potential problem, the household's own risk perception is not considered; instead, the average perception of water safety in the town where the household lives was used. In the creation of the variable for risk perceptions of water safety in the towns, these perceptions were coded as 'No risk' (1), 'Little risk' (2), 'Some risk' (3) and 'Serious risk' (4). The 'Don't know' responses were deleted. The assumption is that the average opinion in the town is a good proxy of household opinion and will be exogenous in the estimated models.

RESULTS AND DISCUSSION

Descriptive statistics

A total of 911 households were interviewed. Table 1 reports descriptive statistics for the variables used in the study estimations. About 87% of the interviewed households earned a monthly income of less than KES 30,000 (approx. USD 360). Over 66% of the respondents had been educated to either the secondary or tertiary level. This high level of education is to be expected in Kenyan urban areas, where respondents usually engage in occupations which demand some basic skills and knowledge acquired at school.

For the households interviewed, piped water was most accessible in Eldoret, followed by Kericho and Kisii with respectively diminishing access. Kisumu had the least access (Table 2). On average, 70% of households indicated that they had access to piped water, while 92% had access to non-piped improved water sources. Non-piped water was more widely used than piped in Kericho, Kisii and Kisumu; a similar result was found for Kisumu by Wagah *et al.* (2010). All respondents from Kericho had access to non-piped improved water sources.

Table 1 | Descriptive statistics for variables used in the estimations

Variable	Variable description	Observations	Mean	Standard deviation	Min.	Max.
Water use						
Piped	Piped connection as main source of drinking water = 1, otherwise = 0	754	0.415			
Non-piped improved	Non-piped improved water as main source of drinking water = 1, otherwise = 0	754	0.406			
Non-piped unimproved	Non-piped unimproved water as main source of drinking water = 1, otherwise = 0	754	0.179			
Treat	Respondent treats water = 1, otherwise = 0	870	0.691			
Treatment expenditure	Purchase of treatment chemicals/month (KES)	170	51.900	47.058	5	300
Connection fee	Connection fee paid to the water utility as a deposit (KES)	909	1,642.684	577.529	1,000	2,500
Household characteristics						
Age	Respondent's age	891	34.163	9.000	18	70
Male	Male dummy = 1 if male	906	0.429			
Hhsize	Household size	909	5.084	2.704	1	16
Child	Children 0–5 years old	911	0.782	0.912	0	6
Ratiofem	Female to male ratio in the household	908	0.496	0.291	0	1
Education						
No schooling	Never been to school	880	0.043			
Primary	Grade 1–8 education attained	880	0.189			
Secondary	Form 1–4 education attained	880	0.323			
Tertiary	College diploma or university degree attained	880	0.445			
Income						
Income_1	Earns KES <1,000 a month	875	0.149			
Income_2	Earns KES 1,000–4,999 a month	875	0.110			
Income_3	Earns KES 5,000–9,999 a month	875	0.214			
Income_4	Earns KES 10,000–19,999 a month	875	0.248			
Income_5	Earns KES 20,000–29,999 a month	875	0.147			
Income_6	Earns KES >29,999 a month	875	0.133			
Town						
Eldoret	Respondent lives in Eldoret	909	0.295			
Kericho	Respondent lives in Kericho	909	0.260			
Kisii	Respondent lives in Kisii	909	0.221			
Kisumu	Respondent lives in Kisumu	909	0.224			

Note: Only 170 households used chemicals to treat water.

Table 2 | Share of households (%) with access to a water source and its use as a main source of drinking water (number of observations in parentheses)

Water source	Eldoret Access	Eldoret Use	Kericho Access	Kericho Use	Kisii Access	Kisii Use	Kisumu Access	Kisumu Use	Whole sample Access	Whole sample Use
Piped	92%; (247)	74%; (190)	91%; (215)	23%; (26)	53%; (107)	25%; (49)	32%; (65)	26%; (49)	70%; (636)	41%; (309)
Non-piped improved	94%; (252)	24%; (62)	100%; (236)	53%; (60)	97%; (195)	44%; (86)	77%; (157)	52%; (98)	92%; (836)	41%; (309)
Non-piped unimproved	70%; (188)	2%; (5)	89%; (210)	25%; (28)	97%; (195)	31%; (60)	55%; (112)	22%; (41)	77%; (700)	18%; (136)
Total number of responses	100%; (268)	100%; (257)	100%; (236)	100%; (114)	100%; (201)	100%; (195)	100%; (204)	100%; (188)	100%; (909)	100%; (754)

Using a risk ladder, the survey probed the respondents' risk perception by asking the following question: 'How would you judge the safety of the water from the following sources before the household does any treatment?' Table 3, which presents the results of this part of the survey, shows variation in the perception of risk relating to the named water sources. Overall, piped water (private and public tap water) was considered safe by most of the respondents. Non-tap sources were generally considered to have only some or little risk by most of the respondents; rainwater was considered to have no risk. Thus, many of the respondents did not perceive any large discrepancies in quality among the various water sources.

On average, 69% of the surveyed respondents treated their drinking water. Of those who used piped water, 67% treated it in some fashion; for users of non-piped improved water the corresponding share was 75%, while for users of non-piped unimproved water it was 77%. Thus, a relatively high number of households were found to be treating piped water, indicating that they did not perceive piped water as being of good quality for drinking purposes.

Probability of choosing piped water source and water treatment

Table 4 reports the estimated coefficients for the piped water and water treatment decisions in Equations (1) and (2), and the marginal effects of the joint probability that the household chooses piped water and treats its drinking water. A likelihood ratio test was carried out of the null hypothesis that the correlation coefficient between the two equations equals zero. It

Table 3 | Household's risk perception of water quality, by source (%)

Source of water	No risk	Little risk	Some risk	Serious risk	Don't know
Piped into dwelling	58	17	7	3	16
Piped to yard/plot	18	61	13	3	4
Public tap/ standpipe	15	57	21	6	1
Tube well/borehole	6	25	44	24	2
Unprotected spring	12	35	34	11	7
Rainwater	44	29	19	2	6
Cart with tank	5	24	40	23	8

Table 4 | Seemingly unrelated bivariate probit for treatment equation and piped connection (those with access to a piped connection)

Variables	Piped connection	Treatment equation	Marginal effects
Age	0.016*	– 0.005	0.003
	(–0.010)	(0.009)	(0.003)
Male	– 0.246*	– 0.225	– 0.123***
	(0.149)	(0.140)	(0.048)
Potential water carriers (age > 5)	– 0.017 (0.033)		– 0.005 (0.009)
Monthly income (base = KES 20,000 +)			
KES 0–4,999	– 0.429*	– 0.964***	– 0.334***
	(0.228)	(0.215)	(0.066)
KES 5,000–9,999	– 0.554**	– 0.548***	– 0.273***
	(0.223)	(0.214)	(0.060)
KES 10,000–19,999	– 0.125	– 0.244	– 0.094
	(0.192)	(0.195)	(0.064)
Education (base = No schooling)			
Primary	0.046	– 0.340	– 0.073
	(0.442)	(0.477)	(0.113)
Secondary	0.154	0.263	0.105
	(0.417)	(0.464)	(0.104)
Tertiary	0.483	– 0.121	0.109
	(0.417)	(0.459)	(0.103)
Log connection fee	– 1.998***		– 0.571***
	(0.499)		(0.146)
Problem with piped water pressure	– 4.336*** (1.041)		– 1.239*** (0.299)
Risk perception (non-piped water)	1.213*** (0.173)		0.347*** (0.050)
Risk perception		– 0.489***	– 0.116***
		(0.160)	(0.040)
Constant	17.696***	1.621**	
	(4.480)	(0.638)	
Correlation between residuals of the two estimated equations	– 0.263** (0.106)		
Fisher's Z transformation (arc-hyperbolic tangent) of this correlation	– 0.270**		
	(0.114)		
Observations	432		

Wald test of rho = 0: chi^2 (1) = 5.6348 Prob > chi^2 = 0.0176.
Robust standard errors in parentheses: *p < 0.1, **p < 0.05, ***p < 0.01.

turned out that, for the users of piped water, the correlation coefficient (–0.26) was statistically different from zero. This means that the decisions to use piped water and to treat water, given that a household has access to piped water, are joint decisions. There is a negative correlation between choice of piped water and water treatment, meaning that a household's treatment of non-piped water and its choice of piped water as a main source of drinking water may be seen as substitutes.

Low-income households are less likely to treat water or use piped water as their main source of drinking water. Being in the income group earning below KES 5,000 (USD 60) a month reduces the likelihood of having a piped connection and of treating water by 33% on average, relative to the higher-income groups.

Figures 1–4 show how the level of the connection fee and the perceived risk difference between piped and

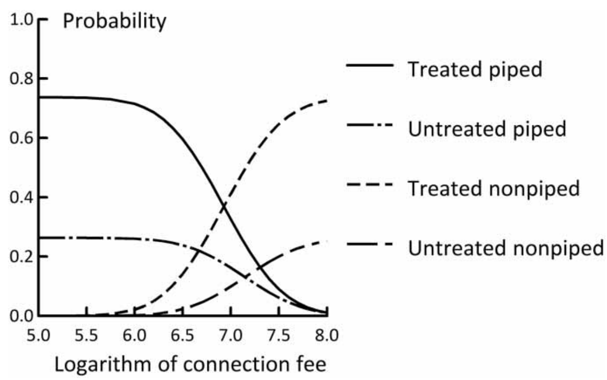

Figure 1 | Probabilities of selecting piped and non-piped water and of treating the water as a function of the connection fee to the piped water, evaluated at zero perceived risk difference between piped and non-piped water and at the sample means for all other variables.

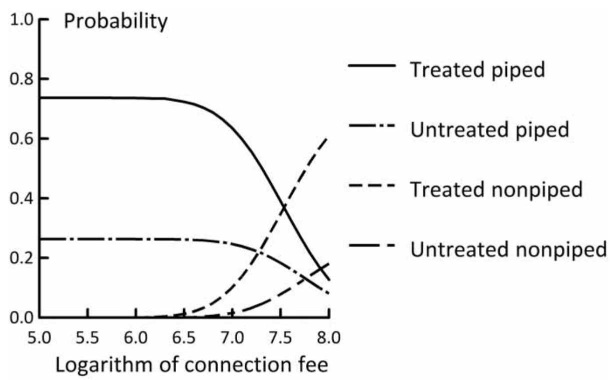

Figure 2 | Probabilities of selecting piped and non-piped water and of treating the water as a function of the connection fee to the piped water, evaluated at a perceived risk difference of one between piped and non-piped water along the risk perception scale and at the sample means for all other variables.

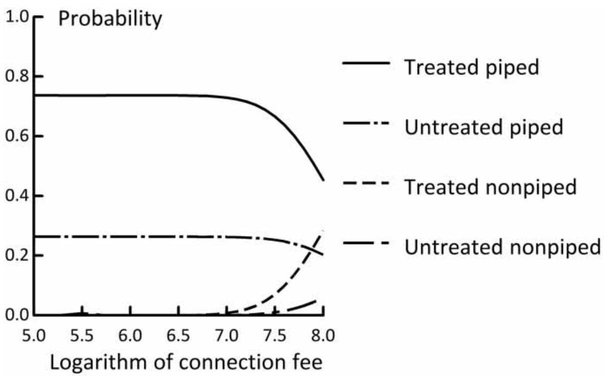

Figure 3 | Probabilities of selecting piped and non-piped water and of treating the water as a function of the connection fee to the piped water, evaluated at a perceived risk difference of two between piped and non-piped water along the risk perception scale and at the sample means for all other variables.

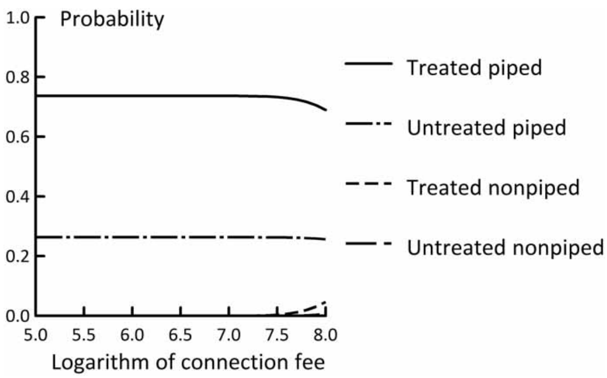

Figure 4 | Probabilities of selecting piped and non-piped water and of treating the water as a function of the connection fee to the piped water, evaluated at a maximum perceived risk difference of three between piped and non-piped water along the risk perception scale and at the sample means for all other variables.

non-piped water affect the decision to use piped water. Current connection fees range from KES 1,000 to 2,500, corresponding to log values of 6.9 to 7.8. We see that if the connection fee were low enough, everybody would use piped water, whether treated or (in fewer cases) untreated; however, depending on the perceived risk difference between piped and non-piped water, use of piped water would begin to drop off at rising fees. This would begin to happen at a connection fee of KES 400 for zero risk difference but not until the connection fees reach KES 2,500 or more for the maximum possible 3-unit difference on the risk perception scale. Thus, if the risk difference were perceived to be great enough, almost everyone would connect to the piped network even at the current levels of the connection fees, and almost all of the few households that did use nonpiped water would at least treat it.

Income matters a great deal both for the choice of water source and the decision on whether or not to treat the water (Figure 5). Over half of the households in the lowest income category use untreated water, and almost half use non-piped water; in the highest income category, over 80% treat their water, and almost all households that do not treat their water use piped water.

Problems with water pressure in the piped network play an important role (Figure 6). According to the coefficients estimated here, if there were no pressure problems in the piped network almost all households would choose

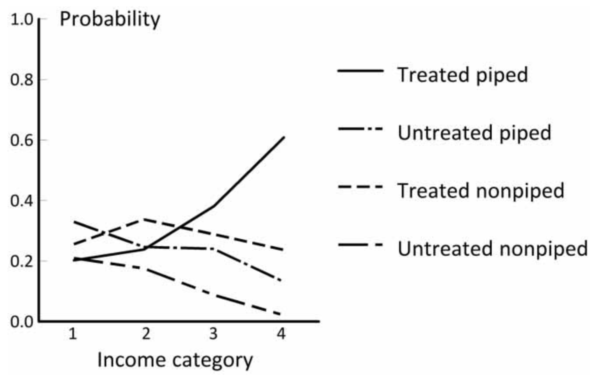

Figure 5 | Probabilities of selecting piped and non-piped water and of treating the water for households in the four different income categories, evaluated at the sample means for all other variables.

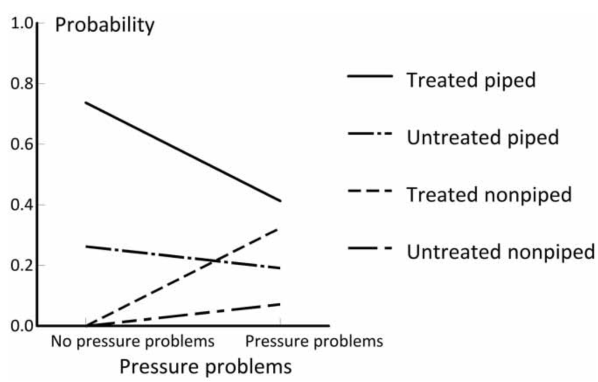

Figure 6 | Probabilities of selecting piped and non-piped water and of treating the water, evaluated with and without pressure problems in the piped system and at the sample means for all other variables.

piped connections, even at the current levels of the connection fees.

Probability of choosing non-piped improved water sources and water treatment

In this section, the bivariate probit model in Equations (3) and (4) is estimated for the choice of non-piped improved water sources and water treatment for those who have no access to piped water, but have access to non-piped improved water sources. The results are reported in Table 5.

The hypothesis of independence between non-piped improved water and water treatment, given that a household has no access to piped water but has access to non-piped improved water sources, is rejected. Because all the variables in the non-piped improved water source equation are insignificant (see Table 5), the probit model was not estimated for the choice of non-piped improved water, given that the household had no access to piped water. The results for the water treatment equation are consistent with the results for the model estimated above.

To treat or not to treat water before drinking it

For the subsample of households with no access to improved water sources, the only choice remaining was whether or not to treat unimproved water. Table 6 reports the results for the estimated water treatment model in Equation (5), given that the household's main source of drinking water was non-piped and unimproved. If the perceived risk of the water from the source they use is considered unacceptable by the households, then the probability of treating water increases. This result confirmed the important role perceived risk plays in changing health behaviour, as found in earlier studies that provided risk information (e.g., Madajewicz *et al.* 2007; Jalan & Somanathan 2008). These results also resonate with previous findings by Nauges & Van den Berg (2006), namely that households were aware that treating non-piped water lowered the risks related to the consumption of unimproved water.

The results of the current study further suggest that the probability of treating water decreases if the head of the household or the respondent is male. Males are 21% less likely than females to treat non-piped unimproved water. One possible explanation is that women, who are generally responsible for taking care of children in the study areas,

Table 5 | Seemingly unrelated bivariate probit model for treatment equation and non-piped improved water (those with access to non-piped improved water but not to a piped connection)

Variables	Non-piped improved water	Treatment equation
Age	– 0.00993	0.00214
	(0.0103)	(0.0108)
Male	0.0598	– 0.504**
	(0.212)	(0.247)
Child	0.0646	– 0.0183
	(0.122)	(0.134)
Female: male ratio		0.654
		(0.570)
Monthly income (base = KES 20,000 +)		
KES 0–4,999	0.346	– 0.847**
	(0.349)	(0.417)
KES 5,000–9,999	– 0.0631	– 0.849**
	(0.310)	(0.377)
KES 10,000–19,999	– 0.00575	– 0.107
	(0.303)	(0.405)
Education (base = No schooling)		
Primary	0.169	0.497
	(0.401)	(0.386)
Secondary	– 0.102	0.516
	(0.398)	(0.402)
Tertiary	– 0.148	0.707
	(0.408)	(0.444)
Risk perception (non-piped unimproved)	0.502 (0.405)	
Risk perception		0.284
		(0.275)
Constant	0.736	0.570
	(0.676)	(0.741)
Correlation between residuals of the two estimated equations	0.027 (0.148)	
Fisher's Z transformation (arc-hyperbolic tangent) of this correlation	0.0272 (0.148)	
Observations	219	
Wald chi^2 (21)	36.55	
Prob > chi^2		0.0189

Wald test of rho = 0: chi^2 (1) = 0.033546 Prob > chi^2 = 0.8547.
Robust standard errors in parentheses: $^{**}p < 0.05$.

Table 6 | Water treatment equation estimate (those with no access to improved water sources)

Variables	Coefficients	Marginal effects
Age	– 0.0392**	– 0.00904**
	(0.0169)	(0.00418)
Male	– 0.943*	– 0.219**
	(0.498)	(0.104)
Child	– 0.0366	– 0.00843
	(0.198)	(0.0459)
Female: male ratio	– 0.753	– 0.173
	(1.025)	(0.231)
Monthly income (base = KES 20,000 +)		
KES 0–4,999	– 1.247**	– 0.384**
	(0.528)	(0.185)
KES 5,000–9,999	– 0.755	– 0.201
	(0.491)	(0.149)
KES 10,000–19,999	0.0273	0.00623
	(0.567)	(0.128)
Education (base = No schooling)		
Primary	– 0.542	– 0.145
	(0.709)	(0.213)
Secondary	– 0.867	– 0.214
	(0.774)	(0.200)
Tertiary	– 0.119	– 0.0281
	(0.860)	(0.209)
Risk perception	1.817***	0.418***
	(0.595)	(0.146)
Constant	3.091***	
	(1.163)	
Wald chi^2 (11)	19.83**	
Observations	112	112

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

might find it more worthwhile to treat water to avoid water-borne diseases.

Notably, households with low incomes (less than KES 5,000) were less likely to treat non-piped unimproved water. On average, being a low-income earner reduced the likelihood of treating water by 38%, relative to the group with a higher income. This is disturbing because the same respondents who are more likely to be exposed to water-related health risks cannot afford medical care. Water treatment technologies, especially boiling, are becoming unattainable for the poor due to the high cost of fuel. For this reason, in order to increase the adoption of domestic water treatment, there is a concomitant need to increase the availability of relatively cheap water treatment technologies such as solar disinfection and chlorination (Clasen *et al.* 2007b).

CONCLUSIONS AND POLICY IMPLICATIONS

Using unique household data collected in four Kenyan towns, this paper has provided evidence on the drivers of household drinking water source choice and the decision on whether or not to treat water. In particular, the role of risk perceptions in household choice of drinking water source was investigated, along with domestic water treatment behaviour. The evidence showed that perceived risk drove a household's decision to treat non-piped unimproved water before drinking it. As the perceived risk of water increased, households were more likely to treat drinking water.

Unlike previous studies, this investigation took care of the possibility that choosing a piped water source and choosing to treat water were joint decisions. Our results showed that the decision to connect to a piped water network and the decision whether or not to treat water were indeed made jointly, while the choice to treat water and the choice of a piped water connection were substitutes.

The implications of these results are important to water sector regulators in Kenya. The water utilities charge connection fees, and our estimates suggest that this is an important factor when households decide not to connect to the piped network. We therefore propose policies where households pay the connection fee in instalments. This would enable households to overcome the connection fee hurdle and increase the number of households connected to the piped network.

However, our results also indicate that risk perceptions are crucial for household decisions about water. At present, our survey indicates that households see little difference in risk between the different water sources. However, if the perceived risk difference were greater, our simulations suggest that most households would either connect to the piped network (even at the current levels of the connection fees) or treat their non-piped water. Similarly, if there were problems with water pressure in the pipes (which is often linked to health problems associated with piped water), our results suggest that the willingness to connect to the piped network – even at current fee levels – would increase dramatically.

Thus, although connection fees clearly discourage households from connecting to the piped network, the perceived safety of the piped water, relative to other water sources, is a crucial factor as well. Letting households pay connection fees in instalments is called for, but so is better information on what the risk differences between different water sources actually are.

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