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Risk Perception, Choice of Drinking Water, and Water Treatment

Evidence from Kenyan Towns

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Abstract

This study uses 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 their choice of main drinking water source. Because the two decisions may be jointly made by the household, a seemingly unrelated bivariate probit model is estimated. It turns out that treating non-piped water and using piped water as a main drinking water source are substitutes. The evidence supports the finding that perceived risks significantly correlate with a household's decision to treat/filter unimproved non-pipe water before drinking it. The study also finds that higher connection fees reduce the likelihood of households connecting to the piped network. Because the current connection fee acts as a cost hurdle that 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: risk perception, water quality, drinking water, water treatment

JL Codes: Q53, Q56

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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 quest was to understand how people perceive the riskiness of different water sources when they are choosing their drinking water, and what their risk-averting behaviour entails. Because not all households have access to piped water, those who did not have access to improved water sources were asked whether they did anything to ensure that their water was safe and what factors determined what they did. For those who had potential access to piped water but chose not to use it, their 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. Unlike previous studies, the analysis here was estimated on the assumption that the two decisions on water source and water treatment are taken jointly, and the effect of perceived risk and the substitution effects of the decisions were tested.

This paper contributes to the literature on the economics of water quality by answering the following questions: (1) How does risk perception influence a household's choice of a source of drinking water and whether it gets treated/filtered? (2) Why do households with potential access to safe piped water choose not to be connected? To answer these questions,

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several models are investigated. First, to determine whether the decisions to choose a source of drinking water and to treat a source of water are jointly made, a seemingly unrelated bivariate probit model is estimated. For the subsample of those with potential access to a piped connection, the choice of piped water sources and treatment of non-pipe water turn out to be substitutes. This study finds that perceived risks significantly correlate with a household's decision to treat or filter unimproved non-pipe water before drinking it, and that higher connection fees reduce the likelihood of households connecting to the piped network. Because the current connection fee 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. These findings about households' drinking water choices are important for better planning by water service providers. In addition, understanding household behaviour toward treatment of unsafe non-pipe water is an important precaution against water-borne diseases.

Improved access to water supply and sanitation remains one of the primary ways of addressing poor health in developing countries. As stipulated by the United Nations Millennium Development Goal (MDG) 7, target C aims to "reduce by half the proportion of people without sustainable access to safe drinking water" by 2015. Since 1990, access to drinking water coverage has expanded in sub-Saharan Africa by about 22%, though it still remains low, with only 60% of the population served (UN 2010). The challenge for water improvements remains greater for most sub-Saharan African countries, where coverage is mostly below average.

In many developing countries, insufficient access to clean water and adequate sanitation and the resulting health issues are acute problems. Every year, the lack of safe water, sanitation, and hygiene causes about 88% of deaths from diarrhoeal diseases, accounting for 1.5 million such deaths – the majority of which occur among children under the age of 5 (UNICEF 2008). To win any health battles in developing countries, therefore, secure clean water and sanitation facilities for all should be a government priority. Health psychologists recognise the perceived risk of illness as one of the most important factors in a household's precautionary behaviours (Redding et al. 2000). The same argument can be applied to household decisions about treating drinking water seen to be of dubious quality in order to avoid illness.

In Kenya, as in many other developing countries, insufficient access to clean drinking water and the resulting health issues are serious problems that call for more research into increasing water quality. While significant gains in water infrastructure development have been realised since the turn of the 20th century, water supply in Kenya is still inadequate, with only 57% of households using water from sources considered safe (GoK 2008). In addition, access to safe water supply and sanitation varies greatly across regions. Approximately 80% of hospital attendance in Kenya is due to preventable diseases. About 50% of these diseases relate to water, sanitation and hygiene (GoK 2011). Wealthy households buy bottled water for drinking, but for most households this option is unaffordable. One way households 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., Clasen et al. 2007a, 2007b). However, despite the importance of increasing water quality through domestic treatment, empirical research remains scarce on the relationship between water treatment and factors such as risk perception that drive this decision.

There appear to be few studies focusing on the above issues. Notable exceptions are those by Cai et al. (2008), Jakus et al. (2009), and Nauges and Van den Berg (2006). Nauges and Van den Berg study the perception of health risk and averting behaviour for non-pipe water sources in Sri Lanka. Jakus et al. (2009) examine why people in the United States (US) buy bottled water, while Cai et al. (2008) explore altruistic averting behaviour of removing arsenic risk in drinking water in the US. The studies find that a household's averting behaviour increases with its perception of a health risk. While the latter two studies also find that education increases averting behaviour, Cai et al. (2008) do not find any evidence that education influences water treatment expenditure. Thus, the results of all these studies are mixed. For this reason, no general conclusions can be drawn from the limited existing literature on whether and how water treatment is affected by risk perception. In addition, there was no study that modelled the effect of risk perception on the choice of drinking water sources and water treatment in Africa, where poor water quality is an issue of immense concern.

Estimations regarding households' choice of water sources in developing countries also remain scarce, especially in African cities. Few studies focus on the household's choice of a water source; again, exceptions are Basani et al. (2008), Hindman Persson (2002), Madanat and Humplick (1993), Mu et al. (1990), and Totouom et al. (2012). Nonetheless, these studies do not investigate water quality concerns in the household's choice of water source – a gap the current study aims to fill.

Another consideration is that the water utility charges a connection fee that entails a security deposit plus the cost of piping, a water meter, labour and other connection expenses. This fee has been shown to affect a household's decision to connect to the piped network (Basani et al. 2008).

With the exception of Totouom et al. (2012), these other studies do not consider the likelihood of water source choice and water treatment to be joint decisions. To the authors' knowledge, there are no studies testing whether the domestic treatment of low-quality water serves as a substitute for a piped water connection.

Because people behave according to their personal perception of risk and not according to the objective risk measures as calculated by water engineers or scientists, this study tests the effect of risk perception on the choice of a source of drinking water and on averting behaviour. The findings suggest that perceived risk is significantly correlated with a household's decision to treat/filter non-piped unimproved water before drinking it and with the choice of piped water as the main drinking water source. This result confirms the important role perceived risk plays in changing health behaviour.

The structure of the paper is as follows. The next section discusses the economics of water quality in general, while the section that follows explains the extent of water quality problems and water pricing in Kenya**.** The survey data and descriptive statistics are discussed next, followed by a presentation of the theoretical framework and methodology. Next, the study results are presented, and the last section concludes the discussion.

The Economics of Water Quality

Water quality has been of interest to many disciplines, especially scholars studying water-related health issues. The consumption of safer drinking water is being championed by scholars and development workers as a panacea for a multitude of causes of ill health and death among the socio-economically marginalised in particular. Some 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 and 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 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 the previous studies were conducted. Providing households with information and later revisiting them could lead to bias in the responses provided by the respondents, as they may 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 he/she had, if asked by someone who had educated him/her in the past about the benefits of changed behaviour. This potential response bias could affect both the magnitude and statistical significance of the estimates obtained through the approach. In this study, however, no risk information is provided to the respondents. Instead, respondents were asked about their perception of certain risks, and the study assesses the implications such risk perceptions would have on averting behaviour. In this case, therefore, the responses are not biased by the risk information advanced to the respondent but rather by the respondent's own experience accumulated through actual use of a given water source.

Several approaches have been applied to study water quality issues, including randomised experiments (e.g., Kremer et al. 2011; Jalan and Somanathan 2008), while research on non-market valuations has been applied to study water quality perceptions (e.g., Poe and Bishop 1999; Whitehead 2006). All of these studies show that, in developing countries, the choice regarding a drinking water source has health implications: because most of the common diseases found in these countries are water-borne, their incidence can be drastically reduced by increasing the quality of water from the main sources that households use. In Brazil, the provision of piped water has significantly reduced infant mortality, especially in the most disadvantaged communities (Gamper-Rabindran et al. 2010). In a review paper, Olmstead (2010) observes that the treatment of drinking water provides the highest net benefit of any environmental policy intervention.

To better understand the role of improved water sources on child health, economists have begun to evaluate the impact of improved water source policies. Kremer et al. (2011), using a randomised evaluation to study the impact of improved water source quality achieved via spring protection in rural Kenya, found that the incidence of reported cases of diarrhoea among children fell by a marginally significant 20%. Although Jalan and Ravallion (2003) found overall health benefits related to access to piped water, they also found that health gains from piped water tended to be lower for children in households with less well-educated women. In addition, they found no significant health gains for 40% of those with the lowest incomes. This suggests that, even though there is a positive link between the provision of improved water sources, enhanced drinking water quality and a lower incidence of child diarrhoea, exactly how this positive link is established remains unclear.

Self-protection through averting behaviour is a critical factor in the analysis of public risk mitigation policy (Cai et al. 2008). It is likely that what affects households' averting behaviour is the risk they themselves perceive rather than some objective measure unknown to the household or the researcher. Therefore, once it is clear how risk perceptions influence water treatment behaviour, policymakers have an opportunity to influence household risk perceptions. In the context of drinking water, there have been many discussions of averting behaviours. These behaviours include treating water, purchasing bottled water, or boiling contaminated water.

With the exception of Cai et al. (2008), Nauges and Van den Berg (2006) and Jakus et al. (2009), most studies on drinking water (Abdalla et al. 1992; Collins and Steinbeck 1993; Laughland et al. 1993; Whitehead et al. 1998) do not specifically incorporate perceived risks. This study aims to fill this notable gap in the literature on the economics of water quality.

The Extent of Water Quality Problems in Kenya

About 80% of all communicable diseases in Kenya are water-related. Hence, households' access to safe water and sanitation is required to improve health standards in Kenya (GoK 2007). Increased commercial farming activities, coupled with rapid industrialisation and lax law enforcement, have led to increased effluent discharge into water bodies and disposal of farm chemicals and waste into rivers. All these factors have resulted in the degradation of Kenyan surface water resources (GoK 2007). The 2009 population census showed that a significant share of the Kenyan population depends on water from lakes, rivers, ponds and dams, all of which are regarded as unsafe sources. Thus, many people are exposed to serious health problems as a result of water-borne disease, among other things.

Compliance With Quality Standards

Kenya's Water Act of 2002 established the Water Services Regulatory Board (WASREB) to regulate water and sanitation services in the country. WASREB currently does not take samples to cross-check water quality results from water service providers (WSPs), but relies on certification and random tests by the Kenya Bureau of Standards. Moreover, the Act established the Water Resources Management Authority (WRMA). The WRMA is responsible for regulating water resource issues such as water allocation and water quality management. Thus, the WRMA requires any group or individual developing a well or sinking a borehole to file a complete analysis of the water quality in the course of test pumping.

The number of water quality tests carried out by WSPs improved from 79% in 2006/7 to 90% in 2008/9. A sector benchmark classification published by WASREB in 2010 categorised 27 WSPs (35%), i.e., mainly the large ones, as being of good quality (water quality>95%), while 2 were classified as being of acceptable quality (water quality 90–95%). The remaining 48 WSPs either fell within the unacceptable range or did not submit any information.

Even in urban areas where WSPs are quality-compliant, service provision for the urban poor is largely left to the informal sector/private water vendors, leading to insufficient control of water quality. Vendors exploit information asymmetries to sell low rather than high quality water. Poor people who cannot buy even low-quality water have only one alternative: to spend hours fetching water of poor quality.

Pricing of Water in Kenya

The regulator (WASREB) develops guidelines for the fixing of tariffs for water service provision. The tariffs set are, in theory, required to balance commercial, social and ecological interests by ensuring water access to all while allowing water service boards and WSPs to recover justified costs. Due to public and political pressure, however, the tariffs have remained static over the last few years and do not cover the costs of maintaining the water infrastructure, let alone expanding it.

All WSPs in Kenya have adopted varying increasing block tariffs (WASREB 2010). This means that, on the one hand, high-usage consumers pay marginally higher unit prices, which could discourage excessive consumption. On the other hand, the poor (low-usage consumers) have access to water through what are assumed to be affordable tariffs. It should be noted that the price for the first ten-unit block applies only to those users who use a total of less than 10 m^3 per month. If a consumer exceeds this level of use, the price of the second block would apply to the first 10 m^3 too. The tariff includes a water supply fee, sewage collection fee, and treatment fee.

WSPs vary widely in respect to their approved tariff levels, unit costs of production, and unit operation costs. Table 1 shows the average tariff, unit cost of production, and unit operating cost of water billed over the periods 2006/7 and 2008/9. Over these periods, the tariffs increased from KES 36 to KES 40 due to a rise in the cost of water provision, the inclusion of a higher number of small WSPs, high levels of water loss, and unbilled water use (WASREB 2010). Although popular for the poor, block tariffs can create structural disadvantages for the unconnected poor. This is because the water vendors that supply households that have no piped connections typically purchase water in bulk at the top price tiers. Thus, the poor end up buying water that the utilities have resold at the highest cost.

Table 1. Description of the Applicable Water Tariffs in Eldoret, Kericho, Kisii and Kisumu

Period	Average tariff (KES/m^3)	Unit cost of production (KES/m^3)	Unit operating cost of water billed (KES/m^3)
2006/7	36	18	26
2008/9	40	23	35

Source: WASREB (2010:58)

As in other developing countries, water vendors in Kenya often act as a link between unconnected households and the utility. In some cases, water is purchased from the utility and sold directly to households. In other cases, water is purchased from the utility and sold to intermediaries, who in turn sell to households. As water passes through the marketing chain, prices ratchet up. Water delivered through vendors and cartels is often 10–20 times more costly than water provided through a utility (UNDP 2006). For example, a survey by Gulyani et al. (2005) shows that vended water costs more than piped water in Nairobi city as well as in the towns of Kakamega and Nakuru. In these urban centres, the average cost of water from water kiosks is remarkably high: kiosk owners charge 18 times what they pay for the water from the utilities. The pricing also tends to vary according to the season, and increases in relation to distance from the source.

In order to be connected to the piped network, a consumer is required to sign a water agreement and to pay the connection fee and deposit. Currently, deposits required from new consumers range from KES 1,000 (approximately USD 12[1]) for general consumers, to KES 15,000 (approximately USD 181) for the largest consumers. These deposits provide security against any outstanding payments. The deposit requirement tends to block many consumers from applying for their own individual meters, however, so these households end up purchasing piped water from either a public stand/vendor or other alternative sources.

Data and Descriptive Statistics

Data for this study came from a survey of residential households conducted in 2008 in four Kenyan towns: Eldoret, Kericho, Kisii and Kisumu. To achieve 911 interviews, 1,422 contacts were made during the survey, representing a 64% response rate. The non-response

[1] 1 Kenyan Shilling (KES) = 0.01204 US Dollar (USD) (or 1 USD = 83.077 KES) as at December 2010.

contacts included subjects who were unavailable either because they were absent from home at the time or declined to be interviewed. The four towns were purposefully selected to represent diverse physical, socio-economic and ethnic backgrounds.

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, the water and sanitation facilities are inadequate and poorly managed. Very few residents are connected to water services and there is inadequate service coverage (less than 40%) due to low production and distribution capacity. In Kisumu, acute water shortage (absolute scarcity), declining quality and poor sanitation have been recurrent problems, despite its proximity to the second largest freshwater lake in the world, Lake Victoria.

Prior to the main survey, focus groups were consulted to assist in designing the survey instrument. Sixteen graduates at the University of Nairobi were recruited as research assistants and trained for the survey, ensuring there were four for each town. 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.

The survey data covered water sourcing behaviour, water costs, household demographics and housing, and households' perception of water quality and safety. The study also scrutinised major socio-economic characteristics that influenced a household's choice of water source. All sourcing options were considered, i.e., both piped and non-piped water sources. The sample includes respondents who got their water piped into their dwelling, plot or yard, as well as those who obtained water from non-piped sources, i.e., public taps, surface water (rivers, dams, lakes, ponds, streams, canals, or irrigation channels), boreholes, protected or unprotected wells, rainwater, and protected or unprotected springs.

Descriptive Statistics

In Kenyan towns, households very often have to choose one among a set of water sources for their main drinking water. These choices are generally grouped into two: improved and unimproved sources. According to the World Health Organisation (WHO, 2005), improved drinking water sources include: piped water into dwelling, plot or yard; public tap/standpipe; tube well/borehole; protected dug well; protected spring; and rainwater collection. Unimproved drinking water sources include: unprotected dug well; unprotected spring; cart with small tank/drum; tanker-truck; and surface water (river, dam, lake, pond, stream, canal, 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), though mostly from safe sources (piped or borehole), is categorised as unimproved; as mentioned earlier, the quality of this water varies considerably in practice. Therefore, in our analysis of the water source subsamples, the following categories were identified:

- Piped water
- Non-piped but improved water, and
- Non-piped and unimproved water.

In this study, *access* to a source means that households in that residential area/estate have the potential to get water from it. This definition implies that access to piped water does not necessarily mean having a piped water connection: it means being in a residential area/estate where connection to the piped water network is possible. For the households interviewed, piped water is most accessible in Eldoret, followed by Kericho and Kisii. Kisumu has the least access (Table 2).

Table 2. Share of Households (%) with Access to a Water Source and its Use as a Main Source of Drinking Water

Water source	Eldoret		Kericho		Kisii		Kisumu		Whole sample	
	Access	Use	Access	Use	Access	Use	Access	Use	Access	Use
Piped	92	74	91	23	53	25	32	26	70	41
Non-piped improved	94	24	100	53	97	44	77	52	92	41
Non-piped unimproved	70	2	89	25	97	31	55	22	77	18

On average, 70% of households indicated that they had access to piped water, while 92% had access to non-piped improved water sources. With the exception of Eldoret, the use of non-piped water as the main source of drinking water was higher than piped water use. Similar results are found for Kisumu by Wagah et al. (2010). All respondents from Kericho had access to non-piped improved water sources; thus, Kericho had conclusively achieved MDG7's "C" target. The high cost of being connected to a piped water supply could explain why some households who had access to the piped network did not utilise it, preferring non-piped water instead. Overall, therefore, the high access to improved water sources shows an impressive picture of these towns toward achieving MDG7 on access to safe water for all.

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?* The respective sources were then read out one by one. The response options given were as follows: 1 = *No risk*, 2 = *Little risk*, 3 = *Some risk*, 4 = *Serious risk*, 9 = *Don’t know*. 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, despite the differences in expected objective water quality, many of the respondents did not perceive any large discrepancies in quality among the various water sources.

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 reports the descriptive statistics of the variables used in the study estimations. More than 70% of the interviewed households earned a monthly income of less than KES 50,000 (approx. USD 600). Specifically, about 46% had incomes between KES 5,000 and KES 19,999 (approx. USD 60–240), while 28% earned between KES 20,000 and KES 50,000 (approx. USD 240–600). In the study sample, over 66% of the respondents had been educated to either the secondary or tertiary level. This high level of education is generally expected in Kenyan urban areas, where respondents usually engage in occupations which demand some basic skills and knowledge acquired at school. In addition, the average household consists of five members.

On average, 69% of the surveyed respondents treat their drinking water by either boiling or filtering it first. Households that used chemicals to treat their water reported spending an average of KES 52 (USD 0.63) a month, with a maximum of KES 300 (USD 3.61). The tabulation reveals that the majority of those who treated water use non-piped unimproved (77%), followed by non-piped improved (75%) and then piped (67%). Unexpectedly, a relatively high number of households were found to be treating presumably safe piped water. Hence, it can be concluded that households do not perceive piped water as being of good quality for drinking purposes. This is reasonable since Kenyans have no confidence in the water utility. This suggests, again, that the domestic treatment of water is not necessarily driven by the objective water quality but, rather, by households' risk perceptions.

Due to data limitations, it was not possible to compare the perceived risk related to water consumption from the various sources against an objective measure of risk as calculated by water engineers or other scientists. In addition, for each water source, there may be a significant amount of missing information since not all households were always able to give their opinion on each source.

Table 4. Descriptive Statistics on Variables Used in the Estimations

Variable	Description	Observations	Mean	Standard deviation	Min.	Max.
Piped	Piped connection as main source of drinking water = 1, otherwise = 0	754	0.415	0.493	0	1
Non-piped improved	Non-piped improved water as main source of drinking water = 1, otherwise = 0	754	0.406	0.491	0	1
Non-piped unimproved	Non-piped unimproved water as main source of drinking water = 1, otherwise = 0	754	0.179	0.384	0	1
Treat	Respondent treats water = 1, otherwise = 0	870	0.691	0.462	0	1
Age	Respondent's age	891	34.163	9.000	18	70
Male	Male dummy = 1 if male	906	0.429	0.495	0	1
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:Male ratio in the household	908	0.496	0.291	0	1
Education						
Primary	Grade 1–8 attained	880	0.189	0.391	0	1
Secondary	Form 1–4 attained	880	0.323	0.468	0	1
College	Diploma attained	880	0.369	0.483	0	1
University	Degree attained	880	0.076	0.265	0	1
No schooling	Never been to school	880	0.043	0.203	0	1
_ Income_1	KES <1,000 a month	875	0.149	0.356	0	1
_ Income_2	KES 1,000–4,999 a month	875	0.110	0.313	0	1
_ Income_3	KES 5,000–9,999 a month	875	0.214	0.410	0	1
_ Income_4	KES 10,000–19,999 a month	875	0.248	0.432	0	1
_ Income_5	KES 20,000–29,999 a month	875	0.147	0.355	0	1
_ Income_6	KES 30,000–49,999 a month	875	0.133	0.339	0	1
Eldoret	Respondent lives in Eldoret	909	0.295	0.456	0	1
Kericho	Respondent lives in Kericho	909	0.260	0.439	0	1
Kisii	Respondent lives in Kisii	909	0.221	0.415	0	1
Kisumu	Respondent lives in Kisumu	909	0.224	0.417	0	1
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	1642.684	577.529	1,000	2,500

Note: Only 170 households use chemicals to treat water.

Theory and Methodology

Households were assumed to have a reasonably accurate perception of the risk of the various water sources. It was assumed that this perception would determine which they chose as their main source. Underlying this is the assumption that the revealed preference is based on a household's expected utility from alternatives.[2] A household was expected to reveal its preference in line with the objective of maximising its welfare. This preference can be represented by a utility function and the decision problem can, therefore, be modelled as a standard expected utility maximisation problem. Following Hindman Persson (2002), the modelling of the choice of water source is based on the Random Utility Model (RUM). The household faces a discrete set of water source choices, where the household chooses the water source that maximises its utility subject to budget and water availability constraints. Different households have different risk perceptions for water from various sources. Therefore, each water source has a price which varies depending on the quality of the water, as well as the technology required to access the water.[3]

Risk Perception

In general, economic analyses of risk perception incorporate risk perceptions into the individual utility functions and then derive the associated demand functions (e.g., Lusk and Coble 2005; Viscusi 1990; Zepeda et al. 2003). Consuming contaminated water implies a health cost, and consumers make judgments about how contaminated different water sources are. In their choice of a main water source, they compare the expected health cost from consuming the specific water to the cost of using the water source in question, where less risky water sources – such as piped water – generally come at a higher cost than more risky sources. In the same way that a main water source is chosen, a decision is made whether 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 domestic treatment. Following the economic models that analyse risk perception, the following testable hypotheses are proposed:

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[2] In our study areas, not all households have access to all the water sources. This will be taken into account during the estimation procedures.

[3] See Hindman Persson (2002) for a detailed derivation of the RUM for water source choice that is consistent with utility maximisation.

(a) Individuals who perceive a greater risk from using a water source will be less likely to choose that water source than individuals who perceive a lower risk, and

(b) The more risky the individuals perceive the water source to be, the more likely they are to treat the water from that source.

Model Specification

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 not to be independent of the decision to treat or not treat water before drinking it. At the time the household decides on its water source, it is assumed it also decides whether to treat the water. Hence, the study follows Nauges and Van den Berg (2006) to simultaneously model the choice of the drinking water source and the decision to treat water before drinking. Given the assumed simultaneous nature of the decisions about water source and water treatment, several seemingly unrelated bivariate probit models are estimated for the following possible groups.

First, for the subsample of households living in a residential area/estate where potential 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:

$$l_1^* = X_1^{'}\beta_1 + \varepsilon_1;\ S_1 = 1 \text{if } l_1^* \succ 0;\ S_1 = 0, \text{ otherwise} \quad (1)$$

$$l_2^* = X_2^{'}\beta_2 + \varepsilon_2;\ T_1 = 1 \text{if } l_2^* \succ 0;\ T_1 = 0, \text{ otherwise} \quad (2)$$

ε_1 ε_2 and ρ_1 ~Bivariate normal (BVN)

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, and 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 2008).

Second, for 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:

$$l_3^* = X_1^{'}\beta_3 + \varepsilon_3;\ S_2 = 1 \text{ if } l_3^* \succ 0;\ S_2 = 0, \text{ otherwise} \qquad (3)$$

$$l_4^* = X_2^{'}\beta_4 + \varepsilon_4;\ T_2 = 1 \text{ if } l_4^* \succ 0;\ T_2 = 0, \text{ otherwise} \qquad (4)$$

$$\varepsilon_3, \varepsilon_4 \text{ and } \rho_2 \text{ ~Bivariate normal (BVN),}$$

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

Third, for people who have no access to improved water sources (piped water or improved non-piped water sources), the only remaining decision is to treat or not 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:

$$l_5^* = X_2^{'}\beta_5 + \varepsilon_5;\ T_3 = 1 \text{ if } l_5^* \succ 0;\ T_3 = 0, \text{ otherwise} \qquad (5)$$

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 (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 and 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 and water treatment, the variables included are as follows:

- Age, education and gender of the head of the household
- Number of children aged 0 to 5 years
- Ratio of females to males in the household
- Income category, and
- The average perception of water safety in the town where the household lives.

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. Madanat and 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. Thus, this study controls for the problem of water pressure in the piped water model.

As pointed out by Whitehead (2006) and Nauges and Van den Berg (2006), perceived risk is likely to be endogenous in the treatment of water behaviours. If some unobserved variables (such as health history) determine both perceived risk and a household's hygiene behaviour, then one could be facing an omitted variable problem (Nauges and Van den Berg 2006). This means that instruments are required that would drive risk perception but which would be uncorrelated with hygiene behaviour. We were not able to find suitable instruments for perceived risk in our data. Therefore, in order to avoid endogeneity problems, 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.[4] Following Nauges and Van den Berg (2006), an exogenous variable was constructed for the average risk perception[5] in the town where the household lives. In the creation of the variable, risk perceptions of water safety in the towns were coded as *No risk* (1), *Little risk* (2), *Some risk* (3), and *Serious risk* (4). The *Don't know* responses were deleted. Basically, 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.

Because there are multiple water sources, the average risk perception for the main drinking water source for each household was considered in the treatment equation. For the piped water source choice, the risk perception with respect to non-piped water was considered. The idea is that, when choosing a water source, one considers the risks of the potential alternatives; however, for the treatment decision, what matters is the perception of the chosen water source as risky or not. Generally, people in a town will talk about water-borne diseases;

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[4] If the individual household's risk perception is used instead of an average risk perception, many observations for individual water sources are lost. Thus, for most of the water sources, the results are no longer significant (or statistical significance is reduced). Nonetheless, for most of the regressions, the results are consistent with those from the village-level risk perception estimation. Results are not presented here due to space limitations, but can be provided upon request.

[5] Because there are 12 water sources, it was possible to have reasonable variation in the average risk perception variable. This is because only the average risk perception for the main water source that the household used for drinking was considered.

thus, the average risk perception is likely to be widespread in practice, even if individual households describe the same perception differently.

Ideally, one also needs to control for the cost of obtaining water from all the water sources (both the sources households use and those they do not use). In our data set, full information about the opportunity cost of water from all sources is not available. However, there are data on the connection cost to the piped network. It is expected that households which have experienced problems with water pressure are less likely to prefer piped water than households which have not experienced such problems (Madanat and Humplick 1993).

Econometric Results

Probability of Choosing Piped Water Source and Water Treatment

First, the bivariate probit model is estimated to check whether the choice of a piped water source and a decision to treat water are indeed jointly made. Table 5 reports the estimated coefficients for the piped water and water treatment decisions, plus the marginal effects of the joint probability that the household chooses piped water and treats its drinking water. A likelihood ratio test of the null hypothesis that the correlation coefficient (ρ statistics) equals zero against the alternative that ρ does not equal zero was also carried out. It turned out that, for the users of piped water, the correlation coefficient (-0.30) is statistically different from zero (see Table 5). This means that the decisions to use piped water and to treat water, given that a household had 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 34% on average, relative to the higher-income groups. A larger proportion of women in relation to men in the household increases the probability by 14% that the household treats its drinking water.

If non-piped water in the town is perceived as being risky, there is a higher probability that the household has a piped connection. However, risk perception turns up negative in the treatment equation, if the household has access to a piped connection. This could be explained by the outcome that piped water choice and water treatment are substitutes.

To capture the connection cost variable, the official connection fee to the piped network for each town is included. This fee does not include piping materials and labour, which are household-specific. The variable enters the access to water model in logarithmic form. The estimated marginal effect suggests that a 10% increase in the connection fee reduces the probability of a piped connection by about 6%. As expected, problems with water pressure reduce the likelihood of connecting to the piped network.

Table 5. 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	0.0141	-0.00804	0.00214
	(0.00924)	(0.00952)	(0.00305)
Male	-0.217	-0.120	-0.0909*
	(0.147)	(0.148)	(0.0503)
Child	0.0392	0.0652	0.0269
	(0.0774)	(0.0776)	(0.0271)
Female:Male ratio		0.595*	0.142*
		(0.352)	(0.0852)
Monthly income (base = KES 20,000+)			
KES 0–4999	-0.408*	-0.992***	-0.337***
	(0.227)	(0.216)	(0.0655)
KES 5,000–9,999	-0.525**	-0.547**	-0.268***
	(0.222)	(0.214)	(0.0599)
KES 10,000–19,999	-0.0937	-0.254	-0.0880
	(0.195)	(0.195)	(0.0655)
Education (base = No schooling)			
Primary	0.0636	-0.319	-0.0633
	(0.440)	(0.490)	(0.112)
Secondary	0.173	0.315	0.124
	(0.416)	(0.475)	(0.101)
Tertiary	0.510	-0.0733	0.129
	(0.416)	(0.472)	(0.100)
Log connection fee	-2.004***		-0.578***
	(0.496)		(0.148)
Problem with piped water pressure	-4.240***		-1.224***
	(1.020)		(0.298)
Risk perception (non-piped water)	1.192***		0.344***
	(0.170)		(0.0500)
Risk perception		-0.481***	

Variables	Piped connection	Treatment equation	Marginal effects*
		(0.167)	
Constant	17.58***	1.388**	
	(4.428)	(0.659)	
Athrho	-0.305***		
	(0.112)		
Rho	-0.296***		
	(0.102)		
Observations	432		

Notes: Wald test of rho = 0: chi^2 (1) = 7.38617 Prob > chi^2 = 0.0066
* Marginal effects after biprobit y = Pr(piped=1, treat=1) (predict) = 0.45155907
Robust standard errors in parentheses
* p < 0.1, ** p < 0.05, *** p < 0.01

Probability of Choosing Non-piped Improved Water Sources and Water Treatment

In this section, the bivariate probit model 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 6.

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 are insignificant (see Table 6), 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.

Table 6. 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-pipe unimproved)	0.502	
	(0.405)	
Risk perception		0.284
		(0.275)
Constant	0.736	0.570
	(0.676)	(0.741)
Athrho		0.0272
		(0.148)
Rho	0.027	
	(0.148)	
Observations		219
Wald chi^2 (21)		36.55
Prob > chi^2		0.0189

Notes: Wald test of rho = 0: chi^2 (1) = 0.033546 Prob > chi^2 = 0.8547
Robust standard errors in parentheses
* p < 0.1, ** p < 0.05, *** p < 0.01

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 is whether or not to treat unimproved water. Table 7 reports the results for the estimated water treatment model, given that the household's main source of drinking water is 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 confirms the important role perceived risk plays in changing health behaviour, as found in earlier studies that provided risk information (e.g., Jalan and Somanathan 2008; Madajewicz et al. 2007). These results also resonate with previous findings by Nauges and Van den Berg (2006), namely that households are aware that treating non-piped water lowers 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, might find it more worthwhile to treat water to avoid water-borne diseases, for example. These results are in line with experimental measures of risk aversion studies, where it is often found that women are more risk-averse than men (Eckel and Grossman 2008).

Notably, households with low incomes (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. 2007a).

Table 7. 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

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

Conclusions and Policy Implications

Using unique household data collected in four Kenyan towns, this paper provides evidence on the drivers of household drinking water source choice and the subsequent household behaviour of treating water. In particular, the role of risk perceptions in household choice of drinking water source is investigated, along with domestic water treatment behaviour. The evidence found shows that perceived risk drives a household's decision to treat non-piped unimproved water before drinking it. As the perceived risk of water increases, households are more likely to treat non-piped unimproved drinking water.

Unlike previous studies, this investigation takes care of the possibility that choosing a piped water source and choosing to treat water are joint decisions. The bivariate results for the estimated models show that the decision to connect to a piped water network and the decision whether or not to treat water are joint decisions. Thus, the choice to treat water and the choice of a piped water connection are substitutes.

The implications of these results are important to water sector regulators in Kenya. The water utility charges a connection fee. The estimated marginal effect suggests that a 10% increase in connection fee reduces the probability of a piped connection by about 6%. A policy is therefore proposed where households pay the connection fee in instalments or through prepaid or subsidised schemes. These options would enable households to overcome the connection fee hurdle and increase the number of households connected to the piped network.

Water service boards do not currently provide information on the quality of water at non-piped sources and rural water points. Through awareness campaigns, water service boards should strive to provide information on the quality of all sources used for drinking water.

The results also showed that treating non-piped water and having piped water were substitutes. Hence, there is a need for water service providers to put greater effort into providing affordable piped water sources in urban residential areas in particular, and to offer households information on the quality of their water both at the point of source and at the point of use.

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