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How much are households willing to contribute to the cost recovery of drinking water supply? Results from a household survey

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Abstract

Improving existing drinking water supply services in developing countries depends crucially on available financial resources. Cost recovery rates of these services are typically low, while demand for more reliable services is high and rapidly growing. Most stated preference based demand studies in the developing world apply the contingent valuation method and focus on rural areas. This study examines the willingness of households to pay for improved water supply services employing a choice model (CM) in an urban area in Ethiopia, a country with the lowest water supply coverage in Sub-Saharan Africa. The design of the choice model allows the estimation of the values of both drinking water reliability and safety. The estimated economic values can be used in policy appraisals of investment decisions. Despite significant income constraints, households are willing to pay up to 60 % extra for improved levels of water supply over and above their current water bill, especially households living in the poorest part of the city with the lowest service levels. Women value the improvement of water quality most, while a significant effect is found for averting behavior and expenditures.

1 Introduction

Urban drinking water is generally supplied publicly or under regulation. In the world, of every 10 people, 2 lack accesses to safe water supply, 5 have inadequate sanitation, and 9 do not have their wastewater treated to any degree. Due to low public investment and insufficient tariffs in urban water systems in Ethiopia, there exists a low level of service, rationing and unscheduled disruptions, a long wait of months or even years for customers who want new connections due to lack of pipes and meters among other facilities (World Bank, 2004).

Financing domestic water supply is important to ensure water access for the urban poor and to broaden livelihood options. For instance, it is expected that 44 % of the financial requirement of the entire water supply programme could be provided by government and the consumers, and the rest by external support agencies. This reflected the huge gap between the finance needed to maintain and operate the existing water supply system in Ethiopia. It represents a financial burden for the local and central governments which are already under considerable pressure from other investment activities and the fast growing urban population (Rahamato, 1999). The main objective of this study is to investigate urban households demand for improved water supply and to identify their willingness to pay in developing country's context, including Ethiopia.

Among stated preference (SP) methods, the contingent valuation of public programs is the most frequently employed valuation tool in environmental economics (Bateman et al., 2003). A limited number of studies have been conducted to investigate the demand for a domestic water supply service in rural and urban Ethiopia using contingent valuation (see Fissiha, 1997; Dhunfa, 1998; Alebel, 2004; Kinfe and Berhanu, 2007). However, the contingent valuation method is inadequate to value a single attribute of a multi-attribute good, such as a domestic water supply service. An appropriate alternative tool is Choice Modeling (Louviere et al., 2000), as it allows the investigation of an attribute of a good with many attributes and also attempts to model the decision process of an individual or a household in a particular context and is able to predict with great accuracy how individuals would react in a particular hypothetical situation.

The contributions of this study are that it adds to the limited study in this area as this choice modeling is the first study applied to the topic of urban domestic water services in Ethiopia and to inform policy makers on the provision of reasonable urban domestic water supply. In this study, a more advanced stated preference Choice Modeling (e.g. Blamey et al., 1999; Scarpa et al., 2007), is applied where households are asked to choose between different policy scenarios of improved water supply services at different water price levels. In the design of the Choice Modeling, a distinction is made between improved supply reliability and water quality. The limited number of Choice Modeling conducted in this area in the developed world focused on WTP to avoid water restrictions, for instance due to droughts (Hensher et al., 2006).

2 Methodology

2.1 Choice modeling

Choice Models rely on the theory of consumer demand, and are based specifically on Lancaster's characteristics theory of value, which assumes that consumers derive satisfaction not consuming the good per se but from the characteristics composing the good (Hanley et al., 2001). Employed in this analysis is the Random Parameter Logit (RPL) model which does not require the assumption of independence from irrelevant alternatives (IIA) and which can also account for unobserved, unconditional heterogeneity in preferences across respondents, unlike the Multinomial Logit model (MNL) that suffers from the IIA assumption and which treats preferences across respondents as being constant (Hausman and McFadden, 1984).

The random utility function in the random parameter logit (RPL) model is given by:

$$U_{ijt} = V_{ijt} + \varepsilon_{ijt} = Z_{ijt}(\beta + \eta_i) + \varepsilon_{ijt} \tag{1}$$

where respondent i receives utility U by choosing alternative j from a choice situation t. The utility is decomposed into a deterministic component V_{ijt} and a stochastic term ε_{ijt}. Indirect utility is assumed to be a linear function of the choice attributes z_{ijt} (as well as the social, economic and demographic characteristic, if included in the model) and parameter, β, which due to preference heterogeneity may vary between respondents by a random component, η_i. Assuming the error term follow an IID extreme value distribution of type I, the probability of choosing j in each of the choice sets can be derived (Revelt and Train, 1998).

Recent applications of the RPL model have shown that this model is superior to the MNL model in terms of overall fit and welfare estimates (Breffle and Morey, 2000). Even if unobserved heterogeneity can be accounted for in the RPL model, the model fails to explain the sources of heterogeneity (Boxall et al., 1996). One solution to detecting the sources of heterogeneity while accounting for unobserved heterogeneity could be to include interactions of household characteristics with choice specific attributes in the utility function. When the interaction terms are included, the indirect linear utility function (V_{ijt}) that is estimated becomes:

$$V_{ijt} = \beta_0 + \beta_1 Z_1 + \beta_2 Z_2 + \beta_n Z_n + \delta_1 S_1 + \delta_2 S_2 + \delta_m S_m \quad (2)$$

where n is the number of urban drinking water attributes considered and the vector of utility parameters β_1 to β_n are attached to the vector of attributes, Z_n. In this specification, m is the number of respondent specific household characteristics that explain the choice of the improved drinking water, and the vector of coefficients δ_1 to δ_m correspond to the vector of interaction terms s that influence utility.

2.2 Economic welfare measurement

In this section, the compensating surplus (CS) is calculated following Rolfe et al. (2000) and Bateman et al. (2003). This is a measure of the change in utility arising from a change in a good or service, and in this particular case a change in a domestic water supply service. It measures the change in income that would make an individual indifferent between the initial (status quo) and a subsequent situation (improved water supply) assuming the individual has the right to the status quo. This change in income reflects the individual's willingness to pay (WTP) to obtain an improved water supply. Assessment of economic welfare involves an investigation of the difference between the well-being (or utility) achieved by the individual under the status quo (or constant base) alternative and some other alternatives. It is therefore, a matter of considering the marginal value of a change away from the status quo. First, the values of the attributes that are associated with the status quo are substituted into the equation that estimates the indirect utility associated with that option. If socio-economic variables are included in that equation, the values to be substituted are the sample mean (or the individual specific welfare measures can be computed). Note that the monetary attribute is assigned a value of zero for this stage. Next, the values of the attributes that are associated with an alternative allocation of resources are substituted into the equation that relates to the relevant change attribute. The value of the relevant alternative specific constant (ASC) should be included in this calculation. Socio-economic variables are treated the same as for the status quo option and again the monetary attribute is set at zero. The utility associated with the change alternative (V_1) is then subtracted from the utility associated with the status quo option (V_0). If the model is linear (in the monetary attribute) this "indirect utility difference" is then divided by the negative of the coefficient associated with the monetary attribute (β):

$$\text{Compensating Surplus} = \frac{-(V_0 - V_1)}{\beta_{\text{Monetary attribute}}} \tag{3}$$

A negative value for this surplus estimate would indicate that the respondents are willing to pay the amount of the surplus in order to experience an improvement in their well-being caused by the reallocation of resources from the status quo to the change alternative. By setting up multiple scenarios of alternative resource allocation (by varying the values the levels of attributes can take) and repeating this arithmetic exercise, an array of values associated with the scenarios can be estimated. Note that these results apply only when all attributes enter in a linear fashion (Bennett and Blamey, 2001).

2.3 The experimental design

The set of attributes and levels used in this study are: (1) water supply (1, 2, 3 extra day per week), (2) water quality (dummy: no boiling at all), and (3) an increase in the households monthly water bill in Birr[1] (3, 5, 10, 15 and 20) (see Table 2). Paired choice sets were created using the fractional factorial orthogonal design procedure in SPSS, enabling the capture of main effects plus two-way interactions which produced 12 paired choice sets. A status quo alternative was added in all sets whose inclusion is instrumental to achieving welfare measures that are consistent with demand theory

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[1] Birr is Ethiopia's national currency. At the time of the study, 1 Birr was equal to approximately 0.06 USD.

(Louviere et al., 2000; Bateman et al., 2003). Each choice task asked the respondent to hypothetically choose one of the two available options, in addition to the status quo option. If neither of the two options was found satisfactory, the respondent could choose the "opt-out option". After collecting socio-economic data, each respondent was introduced to the type of choice task required. The results of 16 respondents were discarded because of inconsistencies. Thus, a total of 1740 (12 × 145) observations were obtained.

In June of 2010, a household survey was carried out with about 170 households in Hawassa city, about 300 km south of the capital city of Ethiopia, Addis Ababa, with a total population of about 160 000 (CSA, 2007). Because no recent statistical information about household characteristics was available, the survey was conducted in three zones identified by Hawassa Water Supply and Sewerage Service (HWSSS) namely, Misrak Wukro, Manaharia and Mahal Piasa. Misrak Wukro is generally considered the poorest part of the city, whereas households in Manaharia and Mahal Piasa are better off. In selecting respondents from each zone, first households with private compounds were identified, and secondly from these a household was chosen at random. The third criterion was that respondents were split as evenly as possible between male and female in order to allow for testing of gender related differences. Trained enumerators were used in the interview.

3 Results

3.1 Sample characteristics

The average monthly household income is USD 145. Given the average household size of 5, this gives a monthly per capita net income of USD 26. A larger proportion of the respondents (63 %) were female and respondents are, on average, 34 yr old. Consumption varies between 10 and 800 l per day per household. On average, a household has access of 4 days per week to drinking water supply and pays USD 2.2 per month for their water bill. Most households (58 %) also spend a considerable amount of money every month on substitutes such as bottled water. The result also shows that a household, on average, consumes about 3000 l (3 m^3) per month per household, which is about 100 l per day per household, according to this study. Given the average family size, per capita water consumption per day is 25 l, which is far below the world standard WHO (2004) of 45 l per capita per day.

3.2 The random parameter logit model

The result of the RPL model is presented in Table 3. All the attribute parameters are highly significant and have the expected signs. The positive sign of the values for all non-monetary parameters suggests that improvements in all the non-monetary attributes are more likely to bring about a positive utility among individuals. The result also shows that the coefficient for the monetary attribute is negative, as expected, implying that the utility of the households decrease as the monthly water bill increases. The estimated standard deviations are also significant and sizeable, indicating that we have captured unobserved heterogeneity with the random parameter specification Eq. (1). The alternative specific constant (combined into one as the experiment was generic) is also positive and statistically significant at 95 %, indicating that respondents receive more utility from the improvement than from the current water supply, ceteris paribus. Also, since the experiment was generic, this indicates that factors other than attribute levels affect behavior.

Results of the random parameter logit model with interaction given in Table 4 also show that out of the five socio-demographic variables, four of them were significant. These are: sex of the household head, income, the zone in which the respondents live and households aversion behavior. The sex of household head being positive and significant implies that women prefer improvement in the domestic water supply compared to male household heads. The positive sign of income indicates that the higher the income of a household the more the household head is willing to pay for the proposed change. Households in the study area, especially those living in the poorest part of the city with the lowest service levels, are willing to pay up to 60 % extra for improved levels of water supply over and above their current water bill. A significant effect is found for averting behavior and expenditures. The explanatory power of the model is increased by about 28 % as a result of including the socio-demographic characteristics. The models are estimated with a simulated maximum likelihood using Halton draws of 500 replications. From the results of the model, it can be concluded that households in Hawassa city support an improvement in domestic water service in terms of supply and water safety.

3.3 Welfare analysis

As indicated Eq. (3), the compensating surplus for the change from the status quo to the new scenario is estimated by calculating the difference between the values of the two scenarios and multiplying by the negative inverse of the coefficient for the monetary attribute (that is the water bill). Assuming that the status quo is water supply per week is 4 days, on average, and boiling for infants only is needed, the mean WTP for three scenarios are presented in Table 5. These three scenarios are: (1) availability of water per week is 5 days and boiling for infants only is needed; (2) availability of water per week is 4 days and boiling is not needed; (3) availability of water per week is 5 days and boiling is not needed.

It can be seen from the results that as the supply of water increases, the WTP also increases while the quality of the water is kept constant. When boiling for infants only is needed, WTP increases from 0 to USD 0.66 per month as the availability of water increases per week by one day. If the quality of water improves to the point where no boiling at all is needed, households are willing to pay USD 1.36. If it is supposed that, at least all of the households with private connection in the city, roughly 12 500, would be willing to pay this amount, then a total of USD 17 000 per month could be generated. The present value of these total benefits could then be compared with the present value of capital costs of this “ideal” option in order to calculate the net benefits. This implies that households prefer an improvement in the urban water service in terms of both the attributes of quality and supply of water. Thus, there is room for policy intervention to improve urban drinking water supply in the study area.

4 Conclusions

Choice Modeling can be used to investigate urban households demand for improved drinking water supply in terms of their willingness to pay in developing countries such as Ethiopia. It can be concluded that households in Hawassa city support improvement plan in the drinking water service in terms of quality and supply. Therefore, to minimize the operating and maintenance cost burden of expanding domestic water service to households in Hawassa city and similar cities in the country, these attributes can be targeted to design appropriate strategies to improve the current domestic water service and generate additional revenue as the households show a positive willingness to pay for the improvement plan. Moreover, the present value of the total benefits could then be compared with the present value of capital costs of this “ideal” option in order to calculate its net benefits. This economic value can be used in policy and project appraisals of improved drinking water investment decisions.

Supplementary material related to this article is available online at: http://www.drink-water-eng-sci-discuss.net/5/225/2012/dwesd-5-225-2012-supplement.zip.

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Table 1. An example of choice task.

	Policy Option 1	Policy Option 2	Status Quo
Water Supply (Extra days per week)	2	1	0
Water Quality (dummy: no boiling at all)	N0	For infants	For infants
Increase in monthly water bill	Birr 10	Birr 3	0
I prefer	☐	☐	☐

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Table 2. Sample characteristics.

Variable	Mean	Std	Min	Max
Monthly household income (in Birr)	2388.42	1665	50	8000
Proportion of female respondents	0.633	0.48	0	1
Age	33.917	6	16	80
Family size	5.617	3.25	1	21
Monthly water bill	36.199	31.22	2.0	210.0
Amount of water consumed per household/month	99.158	87.3	10	800
Aversion cost	32.092	57.2	0	252
Water supply per week per household	4.095	1.68	1	7

Table 3. Random parameter logit model.

Variable	Coefficient	Standard error
ASC	1.162***	0.168
Water Bill	−0.196***	0.012
Water Quality	2.933***	0.302
Water Supply	0.765***	0.091
Derived standard deviations		
Water quality	2.933***	0.303
Water Supply	0.765***	0.091
Log likelihood function	−1198.995	
McFadden Pseudo R^2	0.390	
Number of respondents	145	

*** denotes significance at 1 %

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Table 4. Results of random parameter logit model with interactions.

Mean Parameters	Coefficient	Standard Error
ASC	1.136^{***}	0.185
Water Bill	-0.136^{***}	0.013
Water Quality	1.826^{***}	0.937
Water Supply	0.763^{***}	0.495
Water Quality X Female respondents	0.889^{**}	0.281
ASC X Income	0.0001^{*}	0.0001
Water supply X living in Misrak Wukro	0.296^{**}	0.145
Water quality X aversion costs(Birr/month)	0.011^{***}	0.005
Derived Standard deviation		
Water Quality	2.867^{***}	0.310
Water Supply	0.715^{***}	0.079
Log likelihood function	−1176.864	
McFadden Pseudo R^2	0.381	
Number of respondents	145	

***, **, and * denote significance at 1 %, 5 %, and 10 %, respectively

Table 5. Mean WTP per month per household in USD.

	With Boiling		Without Boiling	
Water supply per week (in days)	4	5	4	5
WTP	0	0.66	1.12	1.36