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Estimation of the public benefits of urban water supply improvements in Ethiopia: a choice experiment

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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 household willingness to pay for improved water supply services in a choice experiment in an urban area in Ethiopia, a country with the lowest water supply coverage in Sub-Saharan Africa. The design of the choice experiment allows estimation of the value of both drinking water supply reliability and safety. The estimated economic values can be used in policy appraisals of improved supply investment decisions. Despite significant income constraints, households are willing to pay up to 80 percent extra for improved levels of water supply over and above their current water bill. Women and households living in the poorest part of the city with the lowest service levels value the improvement of water quality most. As expected, also averting behavior and expenditures play an important role.

Key Words: Water supply, Choice experiment, Domestic water demand, Ethiopia, Market segmentation, Willingness to pay

1. Introduction

Safe domestic water supply is an essential component of primary health care and plays a vital role in poverty alleviation. Inadequate water supply and sanitation services impact upon the lives of billions of poor people in the developing world (World Bank, 2004). Two in every ten persons lack access to safe water supply, five have inadequate sanitation, and nine do not have their wastewater treated. Yet, these estimates are believed to underestimate the extent of the drinking water supply problem. In many countries where water supply systems have been installed, the quality of the services provided is poor. Many consumers who are connected face unreliable water supply and when available, it is often not safe to drink (World Bank, 2004).

Water supply services in Ethiopia are among the lowest in Africa, with an average consumption of only 15 liter per capita per day in urban areas, which is far below the World Health Organization (WHO) standard of 45 liters per person per day. Safe domestic water supply is estimated to be available to 36 percent of the population in rural areas and 80 percent in urban areas (EWSRFA, 2004). According to the WHO, Ethiopia had the lowest level of water supply coverage in Sub-Saharan Africa in 2000 (39% compared to an average of 56% in Sub-Saharan Africa) and the second-lowest level of sanitation coverage (EPER, 2004). Unprotected water supply sources are one of the most important problems related to water supply quality. Consequently, a majority of the Ethiopians use unsafe and polluted water and are, as a result, exposed to a large variety of water-borne diseases. This is especially the case for the rapidly growing urban population.

Besides limited protection of water supply sources, financial constraints also play an important role in the current state of water supply in Ethiopia. Investment and operation costs of domestic water supply facilities are only partly covered by the consumers (15%). The central government contributes more or less the same as the consumers, but the majority of the costs (70%) are funded

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3 by financial sources from outside Ethiopia, primarily through international aid (Teshome, 2007).
4
5 There exists a huge gap between the finance required to maintain and operate the existing water
6 supply system and the revenues generated through the existing water tariff system and other
7 sources to match the growing demand for more reliable and safe water supply. Hence, additional
8 funding is needed.
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17 The main objective of this study is to assess household willingness to pay extra for improved water
18 supply services in an urban centre in Ethiopia. Hawassa is the 8th largest city of Ethiopia with a
19 population of almost 160 thousand people (CSA, 2007) and located almost 300 km south of the
20 capital Addis Ababa. Little to no empirical evidence is available in Ethiopia on how much urban
21 households would be willing to pay extra to improve water supply services for use in water supply
22 investment decision-making or tariff setting. The only published stated preference study by Kifle
23 and Berhanu (2007) asked 240 randomly selected households in Addis Ababa in a contingent
24 valuation survey for their willingness to pay (WTP) for a bucket of extra water. They found
25 positive WTP values ranging between 15 and 20 US dollar (USD) cents per bucket (i.e.
26 approximately 1.5-2.0 USD cents per liter) depending on the estimated statistical model. Probably
27 best known in the area of contingent valuation of drinking water supply in developing countries is
28 the work by Whittington (e.g. Whittington et al., 1990; Whittington, 1998). However, most of
29 these studies were conducted in rural areas. Very few applied contingent valuation studies exist for
30 urban areas in the developing world, exceptions being Soto Montes de Oca and Bateman (2006)
31 and Vásquez et al. (2009) in Mexico.
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55 In the study presented here, we apply a more advanced stated preference choice experiment (e.g.
56 Blamey et al., 1999; Scarpa et al., 2007), where households are asked to choose between different
57 policy scenarios of improved water supply services at different water price levels. In the design of
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3 the choice experiment, a distinction is made between improved supply reliability and water quality.
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5 The limited number of choice experiments conducted in this area in the developed world focused
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7 on WTP to avoid water restrictions, for instance due to droughts (Hensher et al., 2006). In the
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9 analysis of the results, special attention is paid to the stability of the respondents' choice behavior
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11 as they go through the sequence of choice tasks and their socio-demographic characteristics.
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17 The paper is organized as follows. Section 2 presents the theoretical choice model and Section 3
18
19 the design of the choice experiment and its implementation through the household survey. Section
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21 4 presents the results while Section 5 concludes and discusses the study's main policy
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23 implications.
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27 28 29 **2. The choice model**

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31 Preferences are modeled in terms of McFadden's (1974) Random Utility Model (RUM), allowing
32
33 for a separation of utility (U_{ijt}^c) into a deterministic part (V_{ijt}^c) and a stochastic part (ε_{ijt}^c). Choice
34
35 experiments fall in the class of attribute-based methods in which the deterministic part of utility for
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37 individual i for good j in choice task t is described in (1) as a linear function of its attributes X_{ijt}
38
39 and other explanatory variables Z_{ijt} (Train, 2003):
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$$48 \quad U_{ijt} = V_{ijt} + \varepsilon_{ijt} = \beta X_{ijt} + \alpha Z_{ijt} + \varepsilon_{ijt} \quad \forall j \in D_{it} \quad (1)$$

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53 In each choice task the respondent is presented with a limited set of policy proposals D_{it} , each
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55 proposing an improvement in domestic water supply and water quality. The stochastic term is
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57 assumed to follow an IID extreme value distribution of type 1.
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To account for preference heterogeneity, the preference parameters for the non-price attributes are allowed to vary across respondents, applying different mixing distributions. Equation (2) describes the mixed logit (ML) probability of individual i selecting alternative j in choice task t over other choice alternatives k . The utility coefficients β vary according to individual (hence β_i) with density $\Delta(\beta_i | b)$ for the non-price attributes. This density can be a function of any set of parameters and represents in this case the mean and covariance of β in the sample population.

$$P_{ijt} = \int \left(\frac{\exp[(\beta_i X_{ijt} + \alpha Z_{ijt})]}{\sum_{j \in D} \exp[(\beta_i X_{ikt} + \alpha Z_{ikt})]} \right) \Delta(\beta_i | b) d\beta_i \quad \forall j \in D_{it} \quad (2)$$

ML-models assume heterogeneity to be continuous over the interval spanned by the assumed distribution for the preference parameters (Scarpa et al., 2005). Treating preference parameters as random variables requires estimation through simulated maximum likelihood. Procedurally, the maximum likelihood algorithm searches for a solution by simulating draws from distributions with given means and standard deviations. Probabilities are calculated by integrating the joint simulated distribution. Recent applications of ML-models have shown that this model is superior to the standard multinomial logit model in terms of overall fit and accuracy of welfare estimates (e.g., Breffle and Morey, 2000; Layton and Brown, 2000; Morey and Rossmann, 2003; Provencher and Bishop, 2004; Brouwer et al., 2010a).

Mixed logit models account for respondent differences (preference heterogeneity) and repeated choices (Train, 2003). Even if unobserved heterogeneity is accounted for in a ML-model, the model may fail to explain the sources of heterogeneity (Hynes et al., 2008). To this end, interactions of respondent specific household characteristics can be included with choice specific

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3 attributes in the utility function to improve the model fit (Revelt and Train, 1998). We test to what
4 extent data from repeated individual choices can be combined into an aggregate choice model
5 using the Swait and Louviere (1993) test procedure. As part of this procedure, equality of scale
6 parameters is tested. Scale parameters, and as a result choice variance, may differ across repeated
7 choice sequences, for instance due to preference learning (Brouwer et al., 2010b).

8
9
10 Error component (EC) models furthermore accommodate correlation between the utilities of
11 alternatives (Brownstone and Train, 1999). Correlation between alternatives is accounted for by
12 including an error component with zero mean in the utility function specification to allow for
13 heteroscedasticity between those alternatives that are likely to be correlated. Scarpa et al. (2005)
14 recommend applying EC models when comparing less familiar (hypothetical) alternatives with
15 better known (existing) ones (the opt-out in this case).

16
17
18 Finally, if a price attribute is included in the choice experiment, welfare estimates can be derived
19 (e.g., Hensher et al., 2005). The welfare measure represents the monetary value arising from a
20 change in the bundle of water supply services, also referred to as the consumer surplus (CS). In the
21 study presented here, the economic welfare implications are estimated of different water supply
22 improvement policy scenarios. We now turn to the design of the choice experiment.

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3. The experiment

The choice experiment was designed in collaboration with the Hawassa Water Supply and
Sewerage Office (HWSSO), who is responsible for maintaining and operating the water system in
the city and collecting water fees from connected domestic households. Most consumers have a
private connection (73% of all water consumption), followed by public fountains (20% of the total
water consumption) and yard connections where one or more taps are installed in a household's

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3 backyard with a water meter (7% of the total consumption). In this study only those customers
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5 were interviewed who have a private connection.
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10 The HWSSO employs a progressive monthly water tariff system that is based on the amount of
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12 water consumed by the customer. For customers consuming less than 5 m³ per month the tariff is 1
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14 Birr¹, for those consuming between 5 and 10 m³ the tariff is 3.4 Birr. Consumption levels
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16 between 10 and 20 m³ have a tariff of 4.4 Birr and for amounts greater than 20 m³ the tariff is 5.5
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19
20 Birr.
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24 In the choice experiment, respondents were presented a series of possible water supply
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26 improvement scenarios, differing in the level of water supply reliability and water quality, at
27
28 different increases in their water fee. Respondents were asked to choose their most preferred policy
29
30 alternative. Based on expert interviews and focus group discussions, two relevant attributes for the
31
32 water supply services were selected together with their levels. Domestic water supply was
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34 extended with 1, 2 or 3 days per week and water quality was qualified as either needing boiling for
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36 infants only or no boiling at all. In addition, five price levels were identified: an increase in the
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38 household's monthly water bill of 3, 5, 10, 15 or 20 Birr.
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46 Alternative policy scenarios are created by combining these three variables based on their different
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48 attribute levels. Because respondents cannot be shown all different choice options, the number of
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50 possible combinations was reduced to 24 choice sets of 12 choice tasks each based on an
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52 orthogonal fractional factorial design generated in the statistical software SPSS, enabling the
53
54 estimation of main effects and two-way interactions. Each respondent was randomly shown one of
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56 these 24 choice sets of 12 choice cards. Each choice card shows two hypothetical choice
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¹Birr is Ethiopia's national currency. At the time of the study, 1 Birr was equal to approximately 0.06 USD.

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3 alternatives describing a future policy scenario along with the option to choose none of the two.
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5 Inclusion of this latter ‘status quo’ alternative is instrumental to be able to estimate welfare
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7 measures that are consistent with demand theory (Bateman et al., 2003). It was emphasized that
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9 respondents would not have to pay anything extra if they choose the opt-out. An example of a
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11 choice card is presented in Table 1.
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17 INSERT TABLE 1 HERE
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22 The design of the choice experiment was first pretested and subsequently implemented in June
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24 2010 through 170 in-person interviews in three zones in Hawassa city distinguished by the
25
26 HWSSO: Misrak Wukro, Manaharia and Mahal Piasa. The response rate was 100 percent, which is
27
28 not unusual for this kind of stated preference research in a developing country (Whittington, 1998).
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30 Although up-to-date statistical information about household characteristics is not available for the
31
32 different zones, the zones differ considerably in terms of their socio-economic status. Misrak
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34 Wukro is generally considered the poorest part of the city, whereas households in Manaharia and
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36 Mahal Piasa are better off. In each zone, first households with a private compound were identified
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38 and secondly from this a random selection chosen. A third sample selection criterion was that a
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40 more or less equal share of men and women in the households was to be interviewed to test for
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42 possible gender effects in domestic water supply valuation. Trained local enumerators were used
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44 for the interviews. After data screening, 145 of the 170 interviews could be used in the analysis (50
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46 from Misrak Wukro, 52 from Manaharia and 43 from Mahal Piasa). The results are presented in
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48 the next section.
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4. Results

4.1. Sample characteristics

Table 2 reports the socio-economic characteristics of the interviewed households. A majority of the respondents (63%) is female and respondents are, on average, 34 years old. Respondents were between 18 and 80 years of age. Average monthly household income is USD 145. Given the average household size, this equals a monthly per capita net income of USD 26. This is lower than the World Bank's international (PPP-adjusted) poverty line of USD 1.25 per day.

INSERT TABLE 2 HERE

Turning to the household's domestic water supply characteristics, consumption varies between 10 and 800 liters per day. On average, a household has 4 days per week access to drinking water supply and they pay USD 2.2 per month for their water bill. This is 1.5 percent of their monthly household income. Most households (58%) also spend every month a considerable amount of money on substitutes such as bottled water.

4.2. Aggregate choice model

All 145 respondents are interested in and willing to pay extra for improved water supply services and completed all 12 choice tasks. No protest voters were encountered in the data, i.e. respondents who consistently chose the opt-out alternative on all choice occasions. Across all 1740 choice occasions, the opt-out was chosen in 12 percent of the cases. As expected in unlabelled choice experiments, an equal distribution of choices is found between the two hypothetical alternatives. Choice behaviour was modelled using a combination of random parameter and error component models, accounting for the panel data structure of the choice model. For efficiency purposes, the

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3 models were estimated using a Halton sequence of 100 replications in a quasi-Monte Carlo
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5 maximum likelihood simulation (Bhat, 2001) in NLOGIT version 4.0.
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10 Two models are presented in Table 3. The first model only includes the attributes, whereas the
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12 second model includes additional socio-demographic respondent characteristics. Several possible
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14 interactions between the attributes and socio-demographic respondent characteristics were tested
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16 for their statistical significance. The model that came out best from a statistical point of view after
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18 systematic testing of all possible interactions, i.e. including statistically significant variables only
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20 at the 10 percent level, is presented in Table 2.
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32 The models are highly significant. The outcome of the χ^2 is 1302.473 with 7 degrees of freedom
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34 and 1506.455 with 11 degrees of freedom for the first and second model respectively. The
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36 estimated error component is significant in both models at the one percent level, indicating that
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38 respondents perceived the two hypothetical alternatives distinctly from the existing situation. The
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40 significant positive outcome of the alternative specific constant (ASC) in both models implies that
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42 respondents prefer a change instead of no change from the current situation.
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48 The attribute parameters are highly significant and have the expected signs. Households value the
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50 availability of additional drinking water supply and improved quality. An increase in the water bill
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52 is, as expected, valued negatively, implying that the utility of the households decreases as the
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54 monthly water bill increases. Water supply is included as a continuous variable and water quality
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56 as a dummy variable with the value one if the water needs no boiling. The attributes are
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58 characterized by significant preference heterogeneity. The standard deviations of the water supply
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3 service attributes are also significant and sizeable, indicating that we captured unobserved
4 heterogeneity in the random parameter specification. The standard deviation for water supply was
5 best captured by a Normal distribution and the standard deviation for water quality by a Uniform
6 distribution (e.g., Hensher et al., 2005). Based on these coefficient estimates marginal WTP and
7 standard deviations were calculated using the Krinsky and Robb (1986) procedure. Marginal WTP
8 for one extra day of domestic water supply is USD 0.3 per month, while marginal WTP for water
9 that requires no boiling is USD 1.2 per month. This is an increase in the average current water bill
10 of 14 and 53 percent respectively.
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24 The second model shows that including additional explanatory variables significantly improves the
25 model fit. The value of the log likelihood function is reduced further compared to the first model,
26 while the pseudo R-squared increases to almost 40 percent, which is high for this type of models
27 based on cross-section data. The size of the impact of all the attributes (and the ASC) is reduced
28 through the inclusion of the theoretically expected variable household income (richer households
29 are more likely to be willing to pay extra for improved water supply services than poorer
30 households), but also variables such as the zone in which the respondent lives (respondents living
31 in the poorest zone Misrak Wukro attach significantly more value to the improvement of water
32 supply) and current spending on bottled water as an alternative to water supplied by the HWSSO
33 (respondents who spend on average more money on bottled water value a water quality
34 improvement significantly more than respondents who spend less money on bottled water). As
35 expected, women who usually cook and take care of the children in the household value water
36 quality improvements more than men to a level where it does not have to be boiled anymore for
37 infants. No significant effect could be detected for any of the other socio-demographic respondent
38 characteristics (e.g., age, education or household composition).
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4.3. Tests of preference stability

One of the main assumptions underlying stated preferences is that respondents know their preferences and that these preferences are stable and coherent (e.g. Brown et al. 2008). This implies that individuals consistently know their preference ordering for a set of goods or services and the rate at which they are willing to trade off good characteristics, such as price and quality. Hence, from a set of alternatives the individual is assumed to be capable of selecting the most preferred one based on its characteristics. Choice behavior at the start of the experiment is expected to be consistent with choice behavior at the end of the experiment (Brouwer et al., 2010b). However, lack of familiarity and experience with the good or service involved and the hypothetical choice setting may undermine these a priori assumptions (Shaikh et al. 2007).

We examine possible learning and preference refinement effects by comparing the scale parameter over the choice sequence using the Swait and Louviere (1993) procedure. The scale parameter is inversely related to the variance of the error term (Louviere et al., 2000). If the scale increases, variance decreases, that is, people are making a more accurate choice between the presented alternatives. Obtaining estimates for the scale parameter therefore provides insight into preference refinement during a choice sequence (Holmes and Boyle 2005). Through repetition respondents are expected to be capable of making more precise and consistent decisions, because they learn about the survey format, the associated hypothetical market and their own preferences (List 2003).

We test whether the utility parameters β and the confounded scale parameters μ in the estimated choice model presented in Table 2 remain the same across the 12 choice tasks. To this end, a pairwise comparison is performed between the choice tasks. We split the 12 choice tasks in four sets of three tasks. In a first step, the estimated ML-model from Table 2 provides efficient estimates for $\mu^1\beta^1$, $\mu^2\beta^2$, $\mu^3\beta^3$ and $\mu^4\beta^4$ and a likelihood function for each set of three choice tasks. Then the scale

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3 parameter of, for example, the first set of three choice tasks is normalized to $\mu^1=1$ for identification
4 purposes. In a second step, a pooled model including the first and second set of choice tasks is
5 estimated, which has the effect of imposing equality on the preference parameters ($\beta^1=\beta^2$). In this
6 model the relative scale parameter μ^2/μ^1 is, however, not set equal to 1. A search procedure over a
7 range of relative scale parameters is applied to estimate the combination of scale and pooled
8 preference parameters providing the best model fit. At each possible relative scale parameter the
9 data for the second set of choice tasks are rescaled such that a ML-model can be estimated. After
10 the best fit model has been identified, a standard chi-square (Likelihood Ratio) test using the log
11 likelihoods of the models from step 1 and the best fit model of step 2 can be used to test the
12 difference between the preference parameters in the two choice sets under the null hypothesis that
13 they are the same.
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32 The third step tests for differences in scale across choice tasks. In principle this step is conditional
33 on accepting the mentioned chi-square test. It requires the estimation of a ML-model for the same
34 pooled model as in step 2, but with equality imposed on both preference and scale parameters this
35 time ($\beta^1=\beta^2$ and $\mu^1=\mu^2$). Again a chi-square test can be applied to compare the log likelihood of the
36 estimated model to the log likelihood of the pooled model with varying scale parameters. The
37 results of this test procedure are presented in Table 4.
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53 When comparing the estimated choice models between the four sets of choice tasks, both the null
54 hypothesis of equality of preference parameters and scale parameters are rejected at the 10 percent
55 significance level, except the scale parameter between the first and second choice set (last column
56 in Table 3). Hence, choice behavior at the start of the choice experiment is different compared to
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3 choice behavior at the end of the experiment. Remarkable is especially the increase in variance in
4 the third set of choice tasks (7-9) when examining the relative variance in rows 2 and 4 of Table 4.
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8 The variance between the first two sets of choice tasks is not significantly different, the variance
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10 then makes a significant jump in the third set and decreases significantly again in the last set of
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12 choice tasks compared to the first set.
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17 Comparing the estimated choice models across the four choice sets, the model based on the third
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19 choice set is the only model where one of the attributes (extra days of water supply) is not
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21 statistically significant at the 10 percent level. The attributes are statistically significant in all other
22
23 choice sets, including the increase in the water bill. Variation across the choice models is primarily
24
25 found in the interaction terms between the attribute water supply and aversion cost and the
26
27 attribute water quality and female respondents. These results suggest that overall the attributes
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29 remain fairly stable, but not the influence of the socio-demographic characteristics on choice
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31 behavior.
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39 **4.4. Economic welfare measures for water supply improvement policy scenarios**

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41 The welfare implications of different water supply improvement policy scenarios were calculated
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43 based on the estimated model in Table 2 including household characteristics. Currently, consumers
44
45 receive, on average, drinking water four days per week. In most cases, they have to boil the water
46
47 before they can drink it. Table 5 presents the estimated mean WTP values associated with
48
49 improvements in urban water supply services for the average respondent. Standard errors are
50
51 presented in brackets and are based on the Krinsky-Robb (1986) procedure. WTP for the water
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53 supply improvement policy scenarios are presented both in local currency (Birr) and US dollars.
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3 In case only water supply improves, not water quality, urban households are willing to pay, on
4 average, between 25 and 50 percent extra over and above their current monthly water bill of 36.2
5 Birr (USD 2.2). If water quality improves at the same time, the increase in the water bill
6 households would be willing to pay varies between 60 and 80 percent depending on the extra days
7 of domestic water supply.
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17 If the sample is representative, these values can be aggregated across the population from which it
18 was drawn in order to calculate a total economic value for the policy scenarios. This total
19 economic value can subsequently be compared with the necessary investment and maintenance
20 costs for the improvement of current water supply services in the city of Hawassa. Based on the
21 factors that turned out to be statistically significant in the second choice model presented in Table
22 2, women are expected to benefit most from improvement scenarios which include water quality.
23 Given the fact that we also found a significant spatial effect for one of the zones, investments in
24 water supply improvement will be most beneficial to households living in the poorest zone Misrak
25 Wukro.
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41 **5. Conclusions**

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44 Reliable water supply services are of paramount importance to the expanding urban populations in
45 the developing world. Improving existing water supply services depends crucially on available
46 financial resources. Cost recovery rates of water supply services provided by public utilities in
47 developing countries are typically low, while demand for more reliable services is high and rapidly
48 growing. In this study we examined public preferences for improved water services in an urban
49 area in a country with the lowest water supply coverage in Sub-Saharan Africa with the aim to
50 estimate the non-market value of water supply service improvements. This economic value can be
51 used in policy and project appraisals of improved supply investment decisions.
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3 The study adds to the limited stock of water supply reliability valuation studies. A number of
4 contingent valuation studies exist focusing on willingness to pay for improved water supply
5 services in developing countries, in particular in rural areas and few in urban zones. Almost no
6 studies exist that apply choice experiments. Those that do focus on WTP to avoid domestic water
7 restrictions or improve environmental river quality in developed countries. In the choice
8 experiment in this study we estimated compensating surplus welfare measures by asking a random
9 sample of households in Hawassa, Ethiopia for their willingness to pay for improved water supply
10 services, both in terms of quantity and quality. Currently, households have, on average, 4 days per
11 week access to drinking water, and consume almost 100 liters per day for which they pay USD 2.2
12 per month. Based on the average household size, daily per capita consumption is only 18 liters.
13 This is very low compared to the estimated average per capita consumption levels in the rest of the
14 developing world (UNESCO, 2003). Almost 60 percent of the interviewed households pay every
15 month an equal amount of money for alternative drinking water sources such as bottled water. All
16 households boil their water before they drink it. Water quality is not constant and often unsafe to
17 drink.

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41 Despite significant income constraints, all households appeared to be willing to pay substantially
42 extra for improved levels of water supply, especially those households living in the poorest part of
43 the city with the lowest service levels and who pay more for alternative water sources such as
44 bottled water. Although estimated preference parameters vary throughout the choice sequence in
45 the choice experiment, choice variability decreases significantly towards the end of the choice
46 experiment. This suggests the presence of learning effects whilst going through the choice tasks.
47 Mean WTP for more reliable water supply varies between 25 and 50 percent over and above the
48 current household water bill. If water quality is improved at the same time, this results in an almost
49 twice as high additional WTP depending on the extra days of water supply. Women who take care
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3 of infants in the household value the improvement of water quality to a level where boiling for
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5 infants is not necessary anymore most.
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10 Aggregating the estimated individual household WTP values across the total number of
11 households in Hawassa (approximately 12,500) under the assumption that the survey sample is
12 representative yields a rough indicator of the total benefits of future investment plans in improved
13 water supply services. The value of these benefits vary from USD 90,000 per year if water supply
14 services are improved by one day only to USD 165,000 per year if water supply is improved by
15 three days to, on average, seven days per week. If water quality is improved in the latter case at the
16 same time, the value of the total benefits equals USD 270,000. Discounted over a 25-year time
17 period at a discount rate of 10 percent this amounts to a present value of approximately USD 2.5
18 million. This discounted value can be compared to the capital costs of any future investment
19 decision in improved water supply services in the city.
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Table 1: Example choice card

	Option 1	Option 2	Current situation
Extra days per week	2	1	0
Boiling	No	For infants	For infants
Increase in monthly water bill	Birr 10	Birr 3	Birr 0
I prefer	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

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Table 2: Key demographic and water supply characteristics of the sample population

Characteristic	Mean	St. dev.	Min.	Max.
Share female respondents	0.63	0.48	0	1
Average age	33.9	6.0	18	80
Average household size	5.6	3.3	1	21
Household income (Ethiopian Birr/month ¹)	2388	1665	50	8000
Average daily water consumption (liters)	99.2	87.3	10	800
Average number of days water supply	4.1	1.7	1	7
Average monthly water bill (Birr ¹)	36.2	31.2	2.0	210.0
Average monthly aversion costs (Birr ¹)	32.1	57.2	0	252

¹ One Birr equaled approximately USD 0.06 at the time of the study.

Table 3: Estimated choice models

Variable	Model including water supply characteristics		Model including household characteristics	
	Coefficient	Standard	Coefficient	Standard
	estimate	error	estimate	error
ASC	2.611***	0.425	1.516***	0.464
Water supply (1,2,3 extra days/week)	1.309***	0.134	0.826***	0.099
<i>Standard deviation (Normal distributed)</i>	0.792***	0.218	0.417***	0.089
Water quality (dummy: no boiling)	4.805***	0.588	1.954***	0.289
<i>Standard deviation (Uniform distributed)</i>	7.900***	1.105	2.758***	0.272
Water bill (3, 5, 10, 15, 20 Birr/month))	-0.251***	0.017	-0.195***	0.008
ASC x household income (Birr/month)	-		0.0004***	0.0001
Water supply x living in Misrak Wukro	-		0.296**	0.145
Water quality x female respondents	-		0.822**	0.345
Water quality x aversion costs (Birr/month)	-		0.011***	0.005
Sigma error component	3.191***	0.523	3.240***	0.409
Log likelihood function	-1260.349		-1158.358	
McFadden pseudo R-squared	0.341		0.394	
N	1740		1740	

Significance levels: * 10% ** 5% *** 1%.

Table 4: Test results equality of preference (β) and scale (μ) parameters between choice tasks

Comparison		LL _{ti+j}		LR-test	Reject	Relative scale	Relative var.	LL _{ti+j}	LR-test	Reject
choice tasks (t)	LL _{ti}	LL _{tj}	($\mu_{ti} \neq \mu_{tj}$) ^a	(10 d.f.)	H ₀ : $\beta_{ti} = \beta_{tj}$?	(μ_{tj}/μ_{ti})	($\sigma^2_{tj}/\sigma^2_{ti}$)	($\mu_{ti} = \mu_{tj}$) ^b	(1 d.f.)	H ₀ : $\mu_{ti} = \mu_{tj}$?
1 1-3 & 4-6	-270.001	-313.504	-605.149	43.29	Yes	1.40	0.51	-605.484	0.67	No
2 1-3 & 7-9	-270.001	-329.888	-623.483	47.19	Yes	0.41	5.95	-628.437	9.91	Yes
3 1-3 & 10-12	-270.001	-239.144	-564.342	110.40	Yes	4.01	0.06	-569.474	10.26	Yes
4 4-6 & 7-9	-313.504	-329.888	-652.259	17.73	Yes	0.42	5.67	-660.236	15.96	Yes
5 4-6 & 10-12	-313.504	-239.144	-586.327	67.36	Yes	1.83	0.30	-590.800	8.95	Yes
6 7-9 & 10-12	-329.888	-239.144	-610.236	82.41	Yes	2.65	0.14	-619.113	17.75	Yes

LL: log likelihood; Likelihood Ratio (LR) tests performed at 10% significance level.

^a pooled mixed logit model with scale normalization; ^b pooled mixed logit model without scale normalization.

Table 5: Estimated WTP for water supply improvements per household per month

Policy scenario	Without water quality improvement ¹		With water quality improvement ²	
	<i>Birr</i>	<i>USD</i>	<i>Birr</i>	<i>USD</i>
	1 extra day per week water	9.8 (1.7)	0.6 (1.0)	21.3 (1.8)
2 extra days per week water	13.8 (2.7)	0.8 (0.2)	25.3 (2.5)	1.5 (0.1)
3 extra days per week water	17.9 (1.8)	1.1 (0.1)	29.4 (7.1)	1.8 (0.4)

¹ Water needs boiling for infants. ² Water needs no boiling.