Heterogeneous Preferences for Water Service Improvements: Evidence from Anuradhapura District of Sri Lanka

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ABSTRACT

This study employed a choice based stated preference approach to examine the public preference and preference heterogeneity for water service improvements in rural Sri Lanka. The empirical research was carried out in Anuradhapura District of Sri Lanka, and included a survey of 160 households with piped-borne water supply served by both National Water Supply and Drainage Board and Community Based Organizations. The results found that there is strong public preference for water service improvements and households are willing to pay substantially for water service improvements, particularly for the water quality improvements. Latent Class and Random Parameter Logit model results reveal that there is significant preference heterogeneity regarding water service improvements which would not be captured by the standard Multinomial Logit model. Therefore, values generated in this study may be most helpful for decision-makers providing policy guidance in a cost benefit analysis of water supply policy options. However, water as a basic requirement for sustaining human life, any policy decisions on service improvements should be evaluated in both economic and social equity context.

KEYWORDS: *Water quality, Choice Experiment, Multinomial Logit model, Latent Class model, Random Parameter Logit model*

Introduction

Ensuring access to safe and adequate water supply is considered a key strategy for livelihood improvements in the developing World. The benefits of improvement of water supply include improved health status of the poor, avoidance of costs associated with adverse health impacts related to water, improved labour productivity and reduced avoidance costs. However, despite the obvious benefits of improvements in water supply, investment and financing of these improvements are generally below the socially optimal level in the developing world. There are several reasons for this including poverty, lack of understanding of socio-economic benefits of such improvements, non-existence or poor functioning of markets, and the lack of information about the short and long term health benefits.

In developing countries water supply projects have traditionally been designed from a supply-side point of view which often neglects the consumers' needs, demographic conditions and financial realities (Whittington *et al*., 1993). In the last three decades, researchers and policy makers have started focusing much more on demand driven approaches for water supply and sanitation which need to be based on an understanding of the behaviour of water consumers and their ability and willingness to pay for improved services (Whittington *et al.,* 1990). Therefore, it is important to demonstrate and value the demand for water service improvements in order inform policy decisions on financing, allocation and efficient management of scare water resources.

As in most developing countries, urban and rural water demand in Sri Lanka has grown significantly over the last decades as a result of population growth, urbanisation, industrialization and economic growth. However, it is challenging for the policy makers in the developing world to improve water supply without having adequate information to evaluate how such improvements will benefit different groups of consumers. With this background, this study employ a Choice Experiment (CE) approach to measure the economic benefits of water service improvements because it enables quantification of the monetary value of changes in water service attributes by estimating the marginal rate of substitution between the non-monetary attributes and with respect to monetary one.

Although there are a number of studies which have applied CE for evaluating the welfare effects of environmental amenities in developed and developing countries, there are only a handful of studies that have valued drinking water quality and service improvements with the application of CE method. In light of the existing literature, there are several research gaps in valuing the benefits of improvements to water supply in developing countries in general and in relation to use of CE in particular. Many studies only cover few improvement attributes and most do not consider preference heterogeneity because they use simplified choice models. This study helps to fill this gap by including a range of attributes for alternative water service improvement schemes. Furthermore, it will investigate preference heterogeneity by using more extended choice models in addition to the Conditional Logit (CL) i.e. Latent Class (LC) and the Random Parameter Logit (RPL) models.

Methodology

Theoretical Framework

As one of the Stated Preference methods, CE has its roots in the conjoint analysis, which was extensively used in market research (Blamey *et al.,* 1999). Currently the method is used across many policy and management areas, including valuation of ecosystem services and environmental quality changes, marketing, food and agriculture, transportation and health economics. The CE approach is based on the combination of Lancaster's theory of value and random utility model of choice behavior developed by McFadden (McFadden, 1974; Ben-Akiva and Lerman, 1985). The Lancaster theory of value assumes that the utility or value of goods and services is derived from their characteristics or attributes.

With reference to this study, if we assume that each household (*h*) selects a water supply policy alternative (*j*) from among all of the possible policy options in the choice set *C* the utility function choice set *C* the utility function for each household U_{hj} can be expressed as follows:

$$U_{hj} = V(X_{hj}) + \varepsilon(X_{hj}) \tag{1}$$

Where V (X_{hj}) denotes the deterministic component of utility, described as a function of the attributes (*X*) of the policy alternatives, ε (X_{hj}) describes the error term which represents the unobservable factors affecting individuals' choices. Random component in the utility function permits the researcher to create probabilistic specification over the consumer choice behaviors (Adamowicz *et al.*, 1998).

The probability of a household (h) selecting alternative (j) over the other alternatives (*k*) can be expressed as follows:

$$\text{Prob}_e\,(j/C) = \text{prob}\left\{V_{hj}+\varepsilon_{hj}>V_{hk}+\varepsilon_{hk};\forall j \ni C\right\} \quad = \text{prob}\left\{V_{hj}-V_{hk}>\varepsilon_{hk}-\varepsilon_{hj}\right\} \tag{2}$$

Assuming that the relationship between given utility and the attributes is linear in parameters and that the error terms are identically and independently distributed with a type 1 extreme value (Gumbel) distribution then the above equation (2) can be specified and estimated with CL model specification and the probability of selecting alternative (*j*) can be expressed as follows,

$$\text{Prob}_h\,(j/C) = \frac{\exp(V(X_{hj}))}{\sum \exp(V(X_{hk}))} \tag{3}$$

Where the conditional indirect utility function estimated using the following functional form,

$$V_{hj} = \beta + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_n X_n \tag{4}$$

Where β denotes the Alternative Specific Constant (ASC) and captures the effects on utility of signing up to a policy, other than the utility captured by the water service attributes included in the model. The number of attributes *n* relates to the particular water service improvement alternative j and the vector of β_1-β_n are the coefficients of the attributes of X_1-X_n.

In addition to the CL model, this study also applied LC and RPL models in order to capture the preference heterogeneity in water service improvements. LC model capture the heterogeneity in preferences at different class/segments among the respondents while RPL capture the preference variation at individual level. For more comparisons between the different specifications see (Revelt and Train, 1998; McFadden and Train, 2000; Boxall and Adamowicz, 2002; Greene and Hensher, 2003).

Data Collection and Analysis

The study was conducted in the Anuradhapura District North Central Province (NCP) of Sri Lanka, where most piped borne water supply schemes are not up to an acceptable standard in terms of water quality and other service characteristics, and water related health impacts are quite common. Existing water supply schemes in the area manage by both National Water Supply and Drainage Board (NWSDB) which is governmental organization and Community Based Organizations (CBO's). Ground water in the province has high levels of Fluoride (F), Electrical Conductivity (EC), Hardness (H) and Total Dissolved Solids (TDS) (Dissanayake, 1991,1996; Padmasiri 2004,2005; Tennakoon, 2004). In many parts of the area, fluoride levels exceed the World Health Organization (WHO) recommended upper limit (ranging between 0.5-1 mg/l) and in some areas reach 8-10 mg/l. This high fluoride levels cause dental fluorosis among children in the area, and skeletal fluorosis cases have also been recorded. Excessive concentrations of heavy metals from excessive use of agro-chemicals have become another major contributor to the water related health impacts (particularly renal failure) prevailing in the area.

In this study the water service options are explained by the characteristics of water quality, reliability (available service hours per day), pressure level and management organization. Monthly payment for water supply was used as the monetary attribute to measure implicit prices related to improvements. The final selection of the attributes and their levels were based on 2 focus groups discussions, expert interviews and a number of key informant discussions.

The Experimental Design technique (Louviere *et al*., 2000; Hensher *et al*., 2005) is an integral part of the CE. Its main objective is to create a set of choices in a most efficient way by means of combining levels of the attributes into profile of alternatives and subsequently into choice. The choice design of this study generated 64 (2^4*4^1) combinations of choices (full factorial). This study employed Fractional Factorial Orthogonal design was used to reduce the design to a manageable size.

The constructed choice design includes 8 choice cards and each choice set included two generic or unlabelled water supply policy alternatives A and B, and the Status-Quo (SQ) option. Data were collected surveying total of randomly selected 160 households with piped borne water supply in selected two Divisional Secretariat (DS) areas in Anuradhapura District, namely Medawachchiya and Padaviya.

Table 1: Attributes and the levels of the choice design

Attributes	No of Levels	Description
Water Quality	2	Low High
Reliability (hrs/day)	2	12 24
Pressure Level	2	Low High
Supply and Management	2	NWSDB Community Based Organization
Price (Rs/Month)	4	300, 500, 700,900

Results and Discussion

MNL and MNL with Interaction Models Results

We first specified the standard MNL with only attributes and the ASC as explanatory variable. The second model incorporated socio-economic variables as interaction terms with the ASC (Table 2). As socio-economic characteristics of all respondents in each choice set are identical**,** they are included as an interaction term with the ASC in order to analyse whether they help to explain the preferences for participating in improved water supply schemes.

Table 2: MNL and MNL with interactions

Attributes and Variables	MNL Model	WTP (Rs/Month)	MNL with Interactions
	Coefficients (S.E)		**Coefficients (S.E)**
ASC	0.523 (0.172)***		1.000 (0.440)**
Quality	1.731 (0.100)***	873	1.738 (0.1000)***
Reliability	0.420 (0.093)***	212	0.426 (0.093)***
Pressure Level	0.388 (0.098)***	196	0.391 (0.098)***
Management Org:	0.239 (0.097)***	121	0.248 (0.097)***
Price	-0.00198 (0.000239)***		-0.00200 (0.00024)***
Gender	-		-0.857 (0.159)***
Age	-		0.001 (0.0046)
Education	-		0.091 (0.081)
Income	-		0.000 (0.000)***
Log-Likelihood Ratio(LLR)	-904		-880
Pseudo R^2 (ρ^2)	0.26		0.29

*, **, *** refer to 10%, 5% and 1% significance level with two-tailed tests

Both the standard MNL model and the interaction model show statistically better estimation in terms of the McFadden's Pseudo R^2 ($\rho 2$) which are 0.26 and 0.29, respectively. The interaction model provides a slightly better estimation in terms of higher ρ^2 and lower LLR compared to the standard MNL model without interaction terms. All parameters of the attributes emerged with the expected signs and significant in both models, meaning that all attributes influence the trade-offs between the proposed policy options compared to the SQ option. Interaction model found that the coefficient of gender variable has a negative sign and significant, meaning that women tend to prefer improved water supply more than men. Higher income households are likely to be willing to pay higher price in order to obtain improved water supply.

Latent Class Model Results

There are a number of standard criteria to select the number of segments that should be included in the LC model. In order to find out the best LC model, 1, 2 and 3 segment models were estimated. Two standard criteria were used to guide the selection of the LC model; the minimum Akaike Information Criteria (AIC) and the minimum Bayesian Information Criteria (BIC) along with ρ^2 and LLR. We found that the three-segment LC model gave the most useful representation of preference heterogeneity for improvements in water supply (Table 3).

Table 3: LC model

Attributes/ Variables	Segment 1		Segment 2		Segment 3	
	Coefficients (S.E)	**WTP**	**Coefficients (S.E)**	**WTP**	**Coefficients (S.E)**	**WTP**
ASC	-1.660 (0.307)***		3.256 (0.471)***		1.215 (0.326)***	
Quality	1.807 (0.098)***	2502	0.534 (0.318)*	201	2.245 (0.208)***	333
Reliability	0.307 (0.102)***	425	0.245 (0.266)	-	1.025 (0.192)***	152
Pressure Level	0.148 (0.112)	-	2.223 (0.390)***	837	0.542 (0.228)***	80
Management	-0.077 (0.120)	-	0.954 (0.358)***	360	0.975 (0.200)***	145
Price	-0.000722 (0.0002)***		0.0026 (0.0008)***		-0.00674 (0.0005)***	
Class Prob:	0.57		0.14		0.29	
LLR		-735				
Pseudo R^2		0.40				

*, **, *** refer to 10%, 5% and 1% significance level with two-tailed tests

According to the predicted population probabilities found in the LC model, 57% of the sample respondents were assigned to segment 1 which consists of people expressing the highest value for quality improvements (WTP Rs. 2502 for improved quality) compared to the segment 2 and 3, which representing the remaining 14% and 29% respectively. Furthermore, negative and significant ASC parameter of segment 1 imply that majority (57%) of the respondents prefer to join with improved piped water supply rather continue with the existing supply. It has found that all parameters of the attributes in the LC model are significant in only in segment 3. Water pressure level and the type of management organization were not significant determinants of preferences for the respondents belongs to segment 1 while pressure level and management are not significant in segment 1 and reliability is not significant factor for the respondents belongs to segment 2.

RPL Model Results

RPL model captured the individual random heterogeneity in systematic way in relation to the water sector improvement.

Table 4: RPL Model

Attributes	Coefficients (S.E)	Mean WTP(CI)	SD of Random Parameters
ASC	0.704(0.224)***		
Quality	2.922 (0.345)***	709 (1081-664)	3.449 (0.407)***
Reliability	0.844 (0.184)***	205 (325-98)	1.280 (0.217)***
Pressure Level	0.644 (0.188)***	156 (310-82)	1.282 (0.201)***
Management Org:	0.529 (0.146)***	128 (225-16)	0.0361 (0.319)
Price	-0.00412 (0.000)***		
LLR	-712		
Pseudo R^2	0.42		

*, **, *** refer to 10%, 5% and 1% significance level with two-tailed tests
Confident Intervals (CI) for WTP was calculated using the delta method

All the parameters of the attributes in the model are consistent with the expected behaviour and also significant (Table 4). The estimated standard deviations for randomly distributed parameters were also significant (except management) which give evidence of the presence of random taste variation across the respondents.

Table 5: Model selection criteria for MNL, MNL with interaction terms, LC and RPL models

Model	Number of Parameters (P)	Pseudo R^2	Log Likelihood at Convergence (LLC)	Log Likelihood Evaluated at 0 (LL0)	AIC	BIC
MNL	6	0.26	- 904	-1230	1892	889
MNL Interact:	10	0.29	-880	-1230	1784	850
LCM	18	0.40	-735	-1230	1506	689
RPL	10	0.42	-712	-`1230	1444	687

Pseudo R^2 is calculated as 1 - (LLC/LL0), AIC is calculated as {-2*(LL-P)} and
BIC is calculated as {-LLC + [(P/2)*ln(N)]}

The results of the study clearly show that the introduction of the random taste variation into the model provides much better estimation compared to the MNL models. The RPL model shows slightly better estimation compare to the LC model in terms of higher ρ^2 and lower LLR, AIC and BIC (Table 5). Further, consistent with economic theory, negative sign and significance of the price coefficient in all tested models confirmed that a higher utility can be obtained by choosing offered alternatives at a lower price. The analysis also consistently confirms positive and highly significant impact of changes in the water quality parameter in all the tested models.

According to the results of the MNL model, which does not account for the unobserved heterogeneity among respondents, suggests that the people are willing to pay Rs. 873 per month for water quality improvements. The LC model in turn suggested that there is a significant variation between three population segments in terms of their preference for the improvement of water quality. People are willing to pay Rs. 2502, Rs. 201 and Rs 333 per month in segment 1, 2 and 3 respectively for improved water quality.

Using the RPL model, which is superior in terms of a statistical fit and provide more reliable welfare estimations, people are WTP Rs.709 per month for water quality improvements. This is substantially higher than current average monthly household payments for water supply which is around Rs. 300-400 per month. Further, the calculated mean WTP is high enough to cover the average cost of water supply estimated by the NWSDB which is currently around Rs 30-35 for the supply of one unit (1000 L) of water to the residential sector and the average household per capita water consumption in the area around 15-20 units.

Study also found that the majority of respondents preferred NWSDB operated systems over the ones operated by the CBO’s. This stressed the need of enhancing the technical and financial capacity of the CBO’s to operate the water supply projects.

Conclusion and Policy Implications

Although it is not straightforward to elicit public preference for the improvements of public utility like water, it is an important area of work in developing countries where the current piped water service is not up to the acceptable standard and water related health impacts are quite common. In this context, this paper contributes to the limited literature on valuing water service improvements applying CE method in a developing country’s context following a comprehensive framework using array of choice models, from the standard MNL model to a more advance LC and RPL models.

Results of the models tested in the current study found that the public expressed high positive preference for water service improvement in general and water quality improvements in particular. LC and RPL models provide good specifications of the observed data and these specifications imply the significance of accounting for preference heterogeneity among the different segments of society as well as at the individual level in relation to the water service improvements, hence such heterogeneity should be considered in policy evaluation.

At the policy level, this study provides useful information and important signals for the water supply authorities and policy makers for prioritising public funds giving much more attention to water service improvements. This includes rationalization of new investment for the water sector enhancements and for formulation of cost recovery pricing policies which ultimately supports sustainable management of the scare water resources. However, as water is a basic necessity for human life and water service improvements is more capital incentive, the role of the government should not underestimate and the decisions in water service improvements should be evaluated in terms of both economic efficiency as well as social equity context.

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