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ORIGINAL ARTICLE

Household's willingness to pay for heterogeneous attributes of drinking water quality and services improvement: an application of choice experiment

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Abstract The service of providing good quality of drinking water can greatly improve the lives of the community and maintain a normal health standard. For a large number of population in the world, specifically in the developing countries, the availability of safe water for daily sustenance is none. Damaturu is the capital of Yobe State, Nigeria. It hosts a population of more than two hundred thousand, yet only 45 % of the households are connected to the network of Yobe State Water Corporation's pipe borne water services; this has led people to source for water from any available source and thus, exposed them to the danger of contracting waterborne diseases. In order to address the problem, Yobe State Government has embarked on the construction of a water treatment plant with a capacity and facility to improve the water quality and connect the town with water services network. The objectives of this study are to assess the households' demand preferences of the heterogeneous water attributes in Damaturu, and to estimate their marginal willingness to pay, using mixed logit model in comparison with conditional logit model. A survey of 300 households randomly sampled indicated that higher education greatly influenced the households' WTP decisions. The most significant variable from both of the models is TWQ, which is MRS that rates the water quality from the level of satisfactory to very good. 219 % in simple model is CLM, while 126 % is for the interaction model. As for MLM, 685 % is for the simple model and 572 % is for the interaction model. Estimate of MLM has more explanatory powers than CLM. Essentially, this finding can help the government in designing cost-effective management and efficient tariff structure.

Keywords Choice experiment · Water quality · Household preference · Choice modelling · Willingness to pay · Conditional logit model · Heterogeneous attributes

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Introduction

The World Health Organization (2004) estimated that 1.8 million people in developing countries die every year from diarrhea and cholera, mostly children, and related the causes of such death to unsafe water supply and inadequate sanitation and hygiene. Tap water in most developing countries is mostly unsafe for direct drinking and the supply services are commonly unreliable (Vasquez et al. 2009). While the world is surrounded by water, yet there is inadequacy of safe drinking water, which results in the prevalence of various waterborne diseases. According to the Nigerian Standard of Drinking Water Quality (2007), drinking water can be all water either in its original state or after treatment, intended for drinking, cooking or other domestic purposes, regardless of its origin or whether it is supplied from a drinking water system or a tanker or taken from a private well, and likewise all water used in any food production undertaken for the manufacture, processing, preservation, or marketing of products or substances intended for human consumption. Damaturu is battling with perennial problems of poor drinking or tap water quality, irregular and inadequate supply, inefficient water-related services, and lack of coverage of tap water connectivity. Most households source drinking water from private wells, dug or shallow wells, purchase of bottled or sachet water, purchase from water vendors, and this increases their rate of exposure to waterborne diseases. In this process a lot of valuable time and resources are misallocated. Evidence of some microbial in Damaturu municipal water has been established (Emeka and Weltime 2008; Oruonye and Medjor 2010) and high concentration of fluoride (Waziri et al. 2012). Improvement of drinking water quality and services to Damaturu would result in higher cost, which would have to be borne by users; hence acceptability of additional charges should be investigated (Genius et al. 2008). Thus the objective of this study is to assess and estimate a household's willingness to pay for heterogeneous attributes of drinking water quality and supply services.

Study area

Damaturu is the capital of Yobe State located in the north-eastern part of Nigeria. The main township covers an area of 20 km^2 (Babalola et al. 2010). The town has only few industrial establishments and it is largely characterized by agrarian economy, producing mainly millets, beans, groundnuts and gum Arabic. Damaturu had witnessed an unprecedented growth in human and high influx of population coupled with increases in commercial activities and construction of infrastructures since 1991 when it was declared the capital city of Yobe State. The population rose from <10,000 before 1991, to about 225,895 in 2011 (Babalola and Busu 2011). A household survey was conducted with 300 samples were chosen an interviewed from the study area. The main source of water to the town is from groundwater usually accessed from drilled boreholes, artesian wells, and private, dug wells (Emeka and Weltime 2008). Dawoud et al. (2008) posit that water supply to Damaturu was about 10,000 m^2/day in 2008 but the projected demand was 89,120 m^2/day; water supply to Damaturu town has been grossly inadequate because of the expanding population and increase in commercial activities. Yobe State Government in an effort to address the problem of water quality and supply system, has embarked on construction of municipal water plant "Damaturu Region Water Supply Project" which upon completion would supply potable water to Damaturu and some neighboring settlements.

Methodology

Survey design

Choice experiment (CE) method is consistent with random utility model (RUM). For the fact that individuals are assumed to choose the alternatives which maximize their utility, we can apply probabilistic models to choose between the different alternatives available in each choice set, therefore a good is valued in terms of its attributes (Table 1). In each choice set, an attribute representing three alternative management options including a status quo option is presented. A status quo was often included to account for 'forced choice' (Hensher et al. 2005). Likewise in all the choice sets, prices were introduced and thus, willingness to pay estimates for changes in attributes levels can be derived from marginal utility estimates (Poirier and Fleuret 2010).

Table 1 Classification of attributes used in the study

Attributes	Levels	Descriptions
Tap water quality (TWQ)		
TWQ1	*Nonsatisfactory*	1. Poor quality tap water that needs treatment before consumption
TWQ2	Satisfactory	2. fairly good tap water, but treatment is highly recommended to make it safer for consumption
TWQ3	Very good	3. poor quality drinking water which cannot be consumed without treatment
Total supply of water (TSW)		
TWS 1	*Very irregular*	1. Daily interruption of water supply
TWS 2	Irregular	2. Interruption of water supply at least once weekly
TWS 3	Regular	3. Regular water supply everyday
Tap water pressure (TWP)		
TWP 1	*Low*	1. Low tap water pressure, cannot reach those in upstairs, wastes time in water collection
TWP 2	Medium	2. Moderate pressure seldom reach those in upstairs
TWP 3	High	3. high water pressure can reach upstairs and minimizes wasting time
Water bill price (P)		
	N200	Water bill refers to household monthly water bills charged by Yobe state Water corporation, presented as amount (percentage) increase over the current bill
	N250	
	N300	
	N400	

Italics present the status quo attribute levels. N200# is equivalent to USD1.30 Approximately

Model specification

Mixed logit model is considered to be the most promising state-of-art discrete model currently available (Hensher and Greene 2003). Its derivation is straightforward, and simulation of its choice probabilities is computationally simple, it is highly flexible and can approximate any random utility model. It was able to overcome the three shortcomings of the standard logit: (1) it allows for random taste variation, (2) unrestricted substitution pattern and (3) correlation in unobserved factors over time (McFadden and Train 2000). It is also not restricted to be independent of irrelevant alternative (IIA) assumptions Kaffashi et al. (2012). Train (2003) stated that the MLM is the best method to solve this limitation of CLM compared to other logit and probit models. MLM was developed to relax the assumptions of IIA pertinent to CLM, and to account for the heterogeneous preferences of the respondents for their demand of tap water attributes, unlike CLM which claimed respondents have fixed or homogeneous preferences of tap water attributes. In MLM the distributions of the density functions were chosen by the analyst; distribution can be normal, log normal, uniform or triangular. This particular function makes it different from other discrete choice models; in this study normal distribution was adopted, because other distributions have been tried but did not produce any policy relevant results.

Let us assume that a sampled individual ($n = 1,\ldots.., n$) faces a choice among i alternatives in each of t choice situations of which he is expected to choose the alternative with the highest utility, this situation is represented in general form of discrete model as:

$$U_{\text{int}} = \beta_n' X_{\text{int}} + \varepsilon_{\text{int}} \tag{1}$$

X_{int} = a vector of explanatory variable

β_n' = a corresponding vector of taste parameters

ε_{int} = independent and identically distributed (IID) extreme value type 1, and independent of β_n' and X_{int}.

The coefficient taste parameter vector for each respondent β_n' can be decomposed as the sum of population mean b and a stochastic deviation η_n representing the respondent tastes in the population of the households. That is, each household has its own vector η_n of taste parameters, which deviates from the population mean b by vector η_n, so we can estimate b but not observe η_n. Thus the utility can be rewritten as:

$$U_{\text{int}} = (b + \eta_n) X_{\text{int}} + \varepsilon_{\text{int}} \tag{2}$$

Generally the unobserved portions of utility $(\eta_n X_{\text{int}} + \varepsilon_{\text{int}})$ are correlated between alternatives and choice set faced by each respondent, because of the common influence of η_n: hence mixed logit does not exhibit the IIA property of the conditional logit model (Train 2003). The mixed logit class of models assumes a general distribution over individuals and alternatives for η_n and an IID extreme value type 1 distribution for ε_{int} that is, η_n can take on a number of distributional forms such as normal, lognormal and triangular. Denotes the density of $\eta_n f(\eta_n|\Omega)$ where Ω are the fixed parameters of the distribution. For a given value of η_n, the conditional probability for choice i is logit, since the remaining error term is IDD extreme value:

$$L_i(\eta) = \frac{\exp(\beta' X_{\text{i}} + \eta_{\text{i}})}{\sum_j \exp(\beta' X_j + \eta_j)} \tag{3}$$

Since η is not given the unconditional choice, the probability in this formula is integrated to all of the values of η is weight by the density of η_i is as showed in equation L.

$$P_j = \int L_i \eta (f(\eta_n|\Omega) \mathrm{d}\eta \tag{4}$$

Models of this form are called mixed logit, because the choice probability $L_i(\eta)$ is a mixture of logit with f as the mixing distribution. The probability does not exhibit the well-known independence from irrelevant alternatives property IIA (Hensher and Greene 2003). By specifying random parameter of each β associated with the attributes of an alternative as having both a mean and a standard deviation, it is treated as random parameter, and also error components approach is also specified, since the standard deviation of a random parameter is an additional error component. The presence of a standard deviation of a β parameter indicates the presence of preference heterogeneity in the sampled population.

Since the analyst does not know the location of each individual's preference on the distribution, this can be accommodated by retrieving individual-specific preferences, by deriving the individual's conditional distribution based (within sample) on their choices (that is prior knowledge). Using Bayes' rule we can define the conditional distribution as equation.

$$H_n(\beta|\theta) = L_n(\beta) g(\beta|\theta) / P_n(\theta) \tag{5}$$

$L_n(\beta)$ is the likelihood of an individual's choice if they had this specific β; $g(\beta|\theta)$ is the distribution in the population of βs being in the population), and $P_n(\theta)$ is the choice probability function defined in open-form as:

$$P_n(\theta) = \int L_n(\beta) g(\beta|\theta) \mathrm{d}\beta \tag{6}$$

The ability of mixed logit to re-parameterize the mean estimates of random parameters, to establish heterogeneity associated with observable influence makes it even more attractive. The integral of the choice probability is approximated through simulation. For a given value of the parameters, a value of η is drawn from its distribution. Using this draw, the logit formula $3L$ is calculated. This process is repeated for many draws, and the mean of resulting $L_i(\eta)$'s is taken as the approximate choice probability given the equation (below), R is the number of replications (that is draws of η), η_{ir} is the draw, and SP_i is the simulated probability that an individual chooses alternative i (Hensher and Greene 2003).

Table 2 Respondents perception on how improved water quality and supply services can solve the problem of waterborne diseases

	Characteristics	Agreed strongly freq (%)	Agree freq (%)	Neither agree nor disagree freq (%)	Disagree freq (%)	Disagree strongly freq (%)
a	Improve education and awareness on the effect of consuming unsafe water	56 (18.7)	205 (68.3)	33 (11)	6 (2)	0 (0)
b	Reduces the prevalent of waterborne diseases	118 (22.5)	174 (33.1)	5 (1.7)	3 (1)	0 (0)
c	Improve the living standard of Damaturu inhabitants	90 (30)	181 (34)	10 (3.3)	19 (6.3)	0 (0)
d	Reduces household's cost of water treatment	95 (31.7)	195 (37.1)	5 (1.7)	5 (1.7)	0 (0)
e	Reduces households medical bills on treatment of water	105 (35)	186 (62)	6 (2)	3 (1)	0 (0)

Results and discussion

Descriptive statistics based on Likert scale was analyzed to investigate the perception of respondents on how improved tap water quality and supply services improvement would alleviate the problem of waterborne diseases in Damaturu. Households' perceptions on how the improved water quality and services improvement, would alleviate the problems of waterborne diseases when Damaturu region water supply project (DRWSP) is completed. 18.7 and 68.3 % represents the percentage of those who agree strongly and those who agree, that completion of DRWSP would improve education and awareness on the effect of consuming unsafe water, While 2 % disagree and 0 % strongly disagree. Waterborne diseases which can happen as a result of consuming unsafe water has been indicated by the respondents' that its prevalent would be reduced if quality of the drinking water improves, the percentage of those who agree was 39.3 % while those who agree represents was 58, 1 % disagree and 0 % disagree strongly. Improvement in the living standard has been strongly linked to consumption of safe water, respondents indicates that the completion of DRWSP would improve the standard of living of Damaturu inhabitants, those who agree strongly are 30 % and those who agree are 65 % while 0 % disagree strongly and 6.3 % disagree.

In order to consume safe water and avoid the problems of waterborne diseases, households in Damaturu often resort to some averting behavior like boiling of water, chlorination, filtration, purchase of bottled or sachet water. This often brings some additional cost to the households, however, with the completion of Damaturu region water supply project households' averting expenditure would reduce. Respondents' perception on this statement indicated that 31.7 % of the respondents agree strongly 65 % agree, similarly 0 % disagree strongly and 1.7 % disagree.

When any of the households member fall sick as a result of waterborne disease such households' income would be used to offset his/her medical bills and this have a negative effect on the gross household disposable income. 35 % of the respondents agree strongly and 62 % agree with the statement, that completion of Damaturu region water supply project would reduce the household medical bills on the treatment of waterborne diseases.

Table 2 shows that respondents understood the statements and supports the completion of YRWSP, and their perception is that the improvement in water quality and services attributes would have a positive effect of improving their overall standard of living. Hence, there is justification for government to embark on the project and subsequently to review its tariff structure for sustainability and cost recovery.

Table 3 Example of water management options

Q1. If option 4 and 7 are the only management option that are alternative to the current management option, which of the management option is your choice (please select one and indicate in the box)

	Management option 4	Management option 7	Continue current management practice
Tap water quality	Satisfactory	Satisfactory	Non satisfactory
Tap water supply	Irregular	Regular	Very irregular
Tap water pressure	Low	High	Low
% Increase on your monthly water bill	25 %	100 %	Your current bill
Options	X		

Experimental design

Table 3 shows the example of water management options presented to respondents. The tap water quality refers to the supply of drinking water by Yobe State Water Corporation (YSWC) with high quality for human consumption, the water should be free from pollutants, and it should be odorless, tasteless, colorless, and directly drinkable from the tap without any need for further treatment. Tap water

Table 4 Results for choice experiment models

Variables	Conditional logit		Mixed logit	
	Simple model	Interaction model	Simple model	Interaction model
TWQ2	1.5831 (0.1387)***	0.9689 (0.2414)***	1.9426 (0.699)**	3.5059 (1.2039)*
TWQ3	1.8832 (0.1683)***	1.1125 (0.2690)***	3.4558 (1.301)**	0.9730 (0551)**
TWS2	0.2521 (0.1154)***	0.2627 (0.1158)**	1.0327 (0.462)*	2.0070 (1.4400)
TWS3	1.4654 (0.1527)***	1.4826 (0.1532)***	1.0271 (0.489)*	0.9917 (0.4278)*
TWP2	0.7334 (0.2744)	2.2845 (0.8639)***	4.3778 (1.822)*	4.3138 (1.1375)***
TWP3	1.1732 (0.3154)***	2.5235 (0.7366)***	2.3025 (1.172)	0.5538 (0.9115)*
ASC	–	–	2.4809 (0.653)***	2.7420 (0.4447)***
PRICE	−0.8574 (0.1849)***	−0.8799 (0.1855)***	−0.5607 (0.216)***	−0.6124 (0.1520)***
TWQ2_EDU	–	0.3594 (0.1156)***	–	0.7685 (0.2323)***
TWQ3_EDU	–	0.4509 (0.1241)***	–	0.5060 (0.1604)***
TWP2_GEN	–	−2.3390 (0.8811)***	–	–
TWP3_GEN	–	−1.4494 (0.7321)***	–	−1.2970 (0.7251)*
			Derived standard deviation	
TWQ2	–	–	0.6506 (0.510)*	0.5709 (0.7183)*
TWQ3	–	–	1.4864 (0.852)	1.5560 (1.1739)
TWS2	–	–	7.9762 (4.344)*	62.7126 (32.6248)*
TWS3	–	–	0.4549 (0.410)	0.2654 (0.3499)
TWP2	–	–	1.0155 (1.019)	0.9099 (0.3774)*
TWP3	–	–	0.1485 (0.363)	0.5805 (1.5740)*
Summary statistics				
N (observations)	1,500	1,500	1,500	1,500
Log likelihood	−1424.751	−1412.831	−1391.358	−1370.363
R^2	0.135	0.142	0.155	0.168
Adjusted R^2	0.133	0.139	0.151	0.136

Standard errors in parentheses

* Significance at 10 % level, ** significance at 5 % level and *** significance at 1 % level

supply: refers to the total supply of water to the households' from the YSWC, it is measured in terms regular water supply without interruption. Tap water pressure refers to the pressure with which the water gushes out of the tap, this is important as high pressured tap water can reach households' overhead reservoirs and showers, and can also reach those residing upstairs, thus minimizing wasting time in waiting or fetching water. And water bill refers to household monthly water tariff, the revenue collection is not enough to cover the operation, managerial and maintenance cost.

Mixed logit model results

Table 4 shows the empirical results of both simple MLM and CLM. The result of simple MLM indicates that, two variables TWQ3 and TWQ2 are significant at 5 % level and TWS2, TWS3, TWP2 and TWP3 are significant at 10 % level and all having appropriate signs in their coefficient. Compared to R^2 in the simple model of the CLM, R^2 of the MLM has improved from 0.135 in CLM to 0.155 in MLM; this implies there is improvement in the explanatory power of the simple MLM.

Interaction model of MLM was analyzed using six main attributes coded as TWQ2, TWQ3, TWS2, TWS3, TWP2 and TWP3 they are all having significant *P* value signs. Likewise, all the parameters have appropriate a priori signs. TWQ2, TWS2, TWP3 are significant at 10 % while TWQ3 and TWP2 are significant at 5 and 1 %, respectively. Alternative specific constant (ASC) and price coefficient have appropriate a priori sign and at 1 % level of significant, interacted variables are significant at 1 % level TWQ3_EDU, TWQ2_EDU at 5 % level and TW3_GEN at 10 % level, this implies that those with higher level of education exhibits higher willingness to pay for very good water quality, similar to finding by Casey et al. (2005) interaction of income with primary variables proved insignificant. Hensher et al. (2005) indicates that respondents are willing to pay more when tap water supply increases. Standard deviation distribution in TWQ3,

Table 5 Marginal rate of substitution (%) estimated from CLM and MLM

Variables	Simple CLM (%)[a]	Interaction CLM (%)	Simple MLM (%)	Interaction MLM (%)
TWQ2	184.63	110.11	383.85	158.89
TWQ3	219.63	126.43	685.26	572.50
TWS2	29.40	29.86	204.06	327.75
TWS3	170.91	168.49	202.06	161.94
TWP2	8.55	259.61	865.05	704.43
TWP3	136.83	286.77	45.49	254.06

[a] The respondent is required to trade off how much (in %) he or she is willing to pay as an increase in the water billing over N200 approximately USD1.30 to enjoy a varying mix of drinking water quality and services improvement

TWQ2, TWP2, and TWP3 are significant at 10 and 5 %, respectively. The interaction model in MLM presents some improvements in that R^2 have improved from 0.142 to 0.168 in MLM, compared to CLM. That means interaction MLM has better explanatory power than the interaction CLM model. Likelihood ratio test between the simple model of MLM and interaction model MLM is 20.99 at 3 degree of freedom which is above 5 % Chi Square value, this mean that simple model is not better than the model with interaction. Because model with interaction have better statistical indicator power compared to the other models.

The payment vehicle for drinking water quality service improvement simply uses an increase in water billing price, measured as a percentage. The household is required to trade off how many percent (%) they would be willing to pay as an increase over the water price they pay to obtain and enjoy a varying mix of water service attributes. The attributes for the water billing price (PRICE). Thus, the marginal values can be calculated from the marginal rate of substitution between an attribute coefficient and the coefficient for the price parameter. MRS are estimated and reported in Table 5.

The marginal rates of substitution of the tap water attributes for each level, in the simple models of CLM and MLM were translated as percentage increase over the current water bills, which the households are willing to pay for the improvement in their varying tap water attributes. For example, MRS for movement from satisfactory water quality (TWQ2) to very good water quality (TWQ3) indicates that simple CLM indicates that households are willing to pay 220 %, while in interaction CLM model they are willing to pay 126 %. In simple MLM movement from satisfactory water quality (TWQ2) to very good water quality (TWQ3) indicates that households are willing to pay 685 % and interaction model shows WTP of 572 %, and so it goes with the other water parameters. Such percentage increases in the simple models both CLM and MLM indicates the households WTP over the current water tariff for varying water attributes parameter. Except for TWP2 in simple model all the parameters are positively valued by the households and similarly, results from interaction model indicate that all the parameters in both the two models were significantly valued at either 1 or 5 % levels.

Conclusion

The situation prevailing in the study area as related to the water quality and services of YSWC, and based on findings from this study, indicates that people in Damaturu are already paying more than the YSWC stipulated bills, because of the difficulties involved in sourcing their water. Hence so long as the promising improvement would be affected WTP would be higher. Government should take it as a matter of utmost priority to connect all households with potable water, improve the quality of drinking water by ensuring compliance with national water quality standards; this would justify any further increase over the existing tariff.

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