Analyzing Willingness to Pay for Improved Tap Water Quality: A Case of Kathmandu Valley of Nepal

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Abstract

Solving chronic drinking water shortage problem of Kathmandu Valley has been finally achieved after arduous two decades of effort of Melamchi Water supply project. At this moment, though it is futile to ask economic worthiness of this national pride project but there is still ample room to investigate ability and willingness to shoulder such lumpy financial burden by ultimate beneficiaries of potable water in Kathmandu valley. Accordingly, this paper intends to measure and investigate the factors affecting household's willingness to pay for improved water supply. The study enumerated 4941 households falling under Kathmandu Upatyaka Khanepani Limited (KUKL) service areas during 2015 to 2016 period. It incorporated contingency valuation (CV) tools to estimate willingness to pay by residents. We applied ordinal logistic regression model to analyze the major determinants of WTP for improved water supply system and measured different elasticity on the base of simple OLS using STATA version 12. The findings show that a third of households are headed by females, while the average family size and families per building are 5.2 and 9.6 persons respectively; all above national average. The reported major source of water by residents in the study area are Kathmandu Upattyaka Khanepani Limited (KUKL) (36%), jar water (20%), tanker (15%); and well/Kuwa and handpump (20%); while total expenditure in Nepalese Rupees (NRs) is 1314 per household per month. The willingness to pay for KUKL's improved water by the household is NRs 404, just over 2.5 times the mean current KUKL tariff (NRs. 155) per month. The ordinal logistic regression result shows household current quantity of water utilization, price of jar water, income and perceived water quality and waterborne diseases as major determinants of WTP for improved water supply. The odds of paying higher WTP for improved water supply are significantly positive for aforementioned factors except the price of jar (which affects negatively). The income inelastic (<1) demand for KUKL's water demand signifies water as basic necessity commodity and proportion of income spent is small. The negative signs of coefficients of cross elasticity of KUKL water demand with respect to prices of jar water and tanker supplied water indicates that jar water and tanker water as strong substitutes of KUKL supply system. The study concluded that the low WTP for improved KUKL's water supply in comparison to current total water expenditure is 'wait and see' signal for KUKL authorities and government. The study infers that KUKL needs to win confidence of its consumers in terms of sufficiency, regularity and quality before scaling up water tariffs.

Key words: *contingent valuation, water resources, sustainable development, Willingness-to-pay*
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1. INTRODUCTION

The Sustainable Development Goal (SDG 6) ensures availability and sustainable management of water and sanitation for all (UNDP, 2015) and safe drinking water is an essential component of primary health care and have vital role in poverty alleviation. But around 785 million people lack basic drinking-water service; 2 billion people use drinking water source contaminated; by 2025, half of the world's population will be living in water-stressed areas (UNICEF & & WHO, 2019). In Nepal, especially, Kathmandu Valley with 3.1 million population, exhibits, rapid urban growth, high population density, and lack of sustainable water sources (Udmale et al., 2016). The decadent lumpy Melamchi mega water project for Kathmandu Valley was a big strain due to its delays coupled with growing financial burden for the government.

In recent years economists are inclined to solve problem of water resource management applying the tools of economic theory and econometrics. There are two basic theoretical approaches a) indirect - uses data on observed water use behavior; b) direct - to ask an individual how much he or she would be willing to pay for the improved water services, are popularly used to estimate economic value of natural water resources like water (Whittington et al., 1990). His preliminary investigation in Haiti, proved contingent valuation method (CVM) surveys to be viable method of collecting information on individuals' willingness to pay for a wide range of public infrastructure projects and public services in developing countries.

The CVM is also referred to as Stated Preference approach, as information on the value of an environmental benefit is obtained by posing questions to consumers about their willingness to pay (WTP) for a resource or their Willingness-to-Accept (WTA) compensation for losing the resource (Twerefou et al., 2015).

CVM was applied to estimate Dhaka Slum-dwellers willingness to pay for safe drinking water and the major determinant of water demand were location and source of water by Chowdhury (1999) and (Haq et al., 2007). But in another study in Pakistan, they found income and education had significant effect on WTP for improved potable water.

A study in Ghana indicates income, time spent to fetch water from existing sources, level of education, quality of current water supply, sex of the respondent and marital status as the main determinants of willingness to pay (WTP) for improved water

(Twerefou et al., 2015). Similar study from Nigeria found distance from main source to house, adequacy of supply from main source, quantity of water used per person per day, quantity of water purchased per day from vendor as the major determinants of WTP for improved water supply (Olajuyigbe, 2010). An another study conducted in Mexico also reveals that the WTP for better water quality is influenced by variables related with distrust of the water quality provided by the City and the organoleptic characteristics of the water supply, as well as spending on bottled water or water purification technologies (Rodríguez-Tapia et al., 2017).

Generally public infrastructure policies are driven by supply side financing and intervention approaches which overlook or underestimate the importance of demand side interventions. Understanding household water need from demand side gives an idea for appropriate tariff rate as well as segregation of users on the basis of their ability to pay. In most cases water supply infrastructure is expensive and characterized by natural monopoly. Therefore, analysis of water demand and forecasting optimal future level of water use are crucial in formulating policy.

So, matching households' demand, their willingness and acceptability of cost matching tariff is very important. Depending on consumer utility maximizing approach, now a day's contingent valuation methods have gained firm ground to value non-marketed and non-tradable natural resources. Based on the assumption that a consumer would choose best option from among the given options which would optimize their utility from the last penny spend. There is need to estimate demand and hint probable price that a consumer would be happy to part with.

The main objectives of this study was to estimate current water demand from major sources; and estimate WTP for improved water supply of KUKL. The estimated WTP prices are assumed to be proxies to scale up water tariff for the policy makers.

2. DATA & METHODOLOGY

Data source

The study depends on cross sectional survey data collected during 2015-16 in Kathmandu valley. Of the total 86865 house-buildings connected to KUKL services areas, a total of 4941 households across 11 distribution network improvement (DNI) units of KUKL were surveyed using structured questionnaire schedule. The systematic sampling design was followed regarding the selection of sampled households from target house buildings located in KUKL service areas considering block distribution system (BDS), distribution network improvement (DNI) and district meter (DMA) as water supply distribution system.

Model for CVM

As per the existing array of literature two theoretical approaches (direct and indirect) were used to estimate household's WTP for improvement in service and quality of water: the direct approach uses stated preference in which simply directly asking individual how much he or she would be willing to pay for the improved water service; it is also known as contingent valuation method (CVM); and the indirect approach uses data on observed water use behavior (revealed preference) for averting the effects of inefficient and unsafe water qualities to estimate WTP (Haq et al., 2007; Whittington et al., 1990).

The study applied contingent valuation method (CVM) as used by (Haq et al., 2007), a non-market valuation method to measure WTP for water. Individuals have preferences over goods; both market and non-market, preferences of individuals are represented through utility functions. The household wants to maximize his utility from quantity and quality of goods and services given his budget constraint. It is expressed as below:

Utility function: U (z, q) ………………………………….. (1)
Where, q = water quality; z = composite of all market goods
Budget Expenditure function: e (p, q, U) ………………… (2)
Here, p = price of other goods, q = quality of water service

The budget or expenditure function measures the minimum amount of money the household must spend to achieve the given level of utility. The expenditure function is increasing function of 'p' and 'U' and decreasing function of 'q'.

Household wants to stay with the same utility, it is appropriate to use expenditure minimization problem.

Min (p.q +z) s.t U = U (q, z)…………………………….. (3)
here price of composite goods (Pz) are equal to one.

Equation (3) can be solved using Lagrange's multiplier, leading to Hicksian demand for respective commodities.

Hicksian demand: hi = hi (p, q, U) …………………..(4)

So minimum expenditure can be calculated as

e = e(p, q, U) -------------------- (5)

WTP for the change in water services is the integration of marginal WTP to achieve water quality from q to q* is

$$WTP = -\int_{q}^{q^*} \frac{\partial e(q,\ U^*)}{\partial q} dq \quad \text{......................................} (6)$$

In equation (6) WTP indicates the maximum amount of money consumer would give up for improvement in quality of water. The additional money spent for improvement in quality of water can extracted as,

$$WTP = e(p, q^*, U) - e(p, q, U) \quad \text{..............................} (7)$$

Here, q is an initial (degraded) level of quality and q* is an improved level of quality.

The expenditure difference in equation above indicates compensating surplus if the household remains in the initial utility and equivalent surplus with reference to final utility. WTP depends on current prices of KUKL, price of tanker water, price of jar water, income, opinion, current KUKL water quality, perceived waterborne diseases, household education level and gender of head. WTP for improved water is dependent variable which takes three ordinal values as

WTP (Rs. 0- 400 = 0, Rs. 401 - 800 = 1, Rs. 801 - 1000 = 2) and values are ordinal 0<1<2 but according to (Hosmer & Lemshow, 2000) there are three types of regression models while tackling afore logistic regression: adjacent category, continuation-ratio and the proportional odds ratios. Since we are systematically categorizing a continuous WTP variable into categories at naturally increasing sequence, proportional odds ratio would be appropriate.

In the ordered logit model, there is an observed ordinal variable, Y, but it, in turn, is a function of another unmeasured continuous latent variable, Y* (whose values determine what the observed ordinal variable Y equals).

As per (Wooldridge, 2017) assuming that a latent variable Y* is determined by

$Y^* = x\beta + e, \qquad e|x \rightarrow \text{Normal } (0,1)$

The continuous latent variable Y* has threshold points (*k, kappa*) as here, it takes values 0, 1, 2, defined as

$Y_i = 0 \, if \, Y_i^* \, is \leq K_1$

$$Y_i = 1\, is\, \alpha_1 \leq Y_i^* \leq K_2$$

$$Y_i = 2\, if\; Y_i^*\; is \geq K_2$$

For example, if the unobserved latent variable Y* was Rs. 0 to 400, the observed Y would be 0; similarly if Y* = Rs 401 to 800 then, Y =1, and if Y* Rs. 801 to 1000, Y would be 2.

So in the population, the continuous latent variable Y* is equal to

$$Y^* = \sum^{k} \beta_k x_{ki} + \varepsilon_i =$$

There is a random disturbance term, ε_i, which, has a standard logistic distribution N(0, 1) is often used so relevant variables may be left out of the equation as adopted from (Williams, 2015).

The Ordered Logit Model estimates part of the above

$$Z = \sum_{k=1}^{k} \beta_k x_{ki} = E\left(Y^*\right)$$

The βs are parameters to be estimated. x's are explanatory variables like (Pi = prices of current main sources of water (current KUKL, Tanker, jar water); Hi = Households characteristics (Highest education level of the HH, income level of the HH); Di = Households demographic characteristics; Si = Service characteristics (opinion about KUKL quality, perceived waterborne diseases)

The study calculated price, cross and income elasticity of a) total water demand and b) KUKL water demand with the help of STATA version 12.

3. RESULTS

The Descriptive Analysis

In the given table, household head mean age (57.4 years), gender of household head (1/3rd females), household size (5.2) and number of residence in the building (household family+ renters = 9.6) and mean income of family are demographic and economic factors which determine households willingness to pay and demand for water.

Table 1: Demographic and Socio-economic profile of Households

Variables	Mean/%/NRs/ liters
Mean age of household head, years	57.4
Percentage of female household head, %	30.5%
Family size (no of people)	5.2
Family size of house-building (no of people)	9.6
Mean Monthly household income, NRs/month ($)	NRs 44,237 ($442)
KUKL Source monthly cost, NRs/month	NRs 155
Main source as KUKL (N = 1764)	35.9%
Main source as jar (N=968)	19.5%
Main source as Tanker (N=721)	14.5%
Main source as well/ kuwa (N=588)	12%
Main source as handpump/tube well (N=400)	8%
Main sources as others (N=499)	9.9%
water consumption per capita per day (family size 5)	180 litres
water consumption per capita per day (house- building 9 persons)	97 liters
Mean expenditure on water per HH per month	NRs 1314.5(3% of Income)
Opinion satisfactory KUKL water quality	39.7%
Household perceived water borne diseases	10.3%
Willingness to pay (WTP), mean	NRs 405
Households WTP NRs 0 to 400 (N =3706)	75%
Households WTP within NRs 401 to 800 (N=741)	15%
Households WTP within NRs 801 to 1000 (N=494)	10%

Source: Field survey, 2015/16

The primary sources of drinking water are KUKL (36%), jar (20%), Tanker (15%) and Well/Kuwa & hand pump (20%) etc. It indicates that around 66% of water requirement is managed via sources other than KUKL, so quantity of water utilization via jar, tanker, well/ kuwa, handpump/ tube-well are substitutes of KUKL water source. Among these substitutes we considered only jar and tanker sources for inferential analysis because Well/Kuwa, and handpump/ tube well generally requires capital cost once only and operation cost is meager. The overall water consumption is 180 liters and 97 liters per person per day for household and building respectively.

The mean monthly cost is NRs. 1314.5 per month. Around 60% respondents opined that water quality in terms of availability and services is poor and bad, and around 10.3% perceived that current water supply leading to waterborne diseases.

The average willingness to pay for improved KUKL water supply in Kathmandu valley is NRs. 405 per month per household while the KUKL's current water bill is Rs. 155. So the consumer surplus for KUKL water is (NRs 405 – 155) NRs 250 per month per households. It means the total consumer surplus at current number of households connected to KUKL service would be (86865households x NRs 250x12) NRs 260,595000 (NRs 2.6 billion) per annum. So, there is an ample scope for the government to raise tariff rate.

Regression Result

For inferential analysis, ordinal logistic regression model was run owing to ordinal nature of dependent variable; the WTP for improved water services by households was categorized into three bids: Rs. 0 to 400, Rs. 401 to 800 and Rs. 801 to 1000, respectively. The inbuilt multi co-linearity detection in STATA helped determine multi co-linearity in the model. The R2 value does not give clearer idea regarding goodness of fit in case of logistic regression. So a Haussmann test (Archer & Lemshow Stanely, 2006) was carried out to test whether (Ho) the difference in coefficients not systematic (see annex below). The null is rejected so the logit regression exhibits good fit in the model. The ordinal logistic regression is run along odds ratio (OR). It means the values of coefficients (odds values) greater than 1 (OR>1) are positively affecting, otherwise (OR<1) they are negatively affecting the dependent variable.

Table 2: Regression Result

	WTP 0= 0 to 400, 1=401 to 800, 2 = 801 to 1000		
Variables	**Odds Ratio**	**[95% Conf.**	**Interval]**
current_water (consumption)***	3.564	2.452	5.181
ln_income***	1.935	1.180	3.173
ln_price_kukl	1.003	0.580	1.734
ln_price_tank	1.768	0.666	4.697
ln_price_jar***	0.448	0.350	0.574
0.kukl_qualy (ref0=satisfactory)**	1.593	1.020	2.489
1.disease (ref1=don't perceive)***	3.583	1.599	8.024
head_edu (ref0= basic)			
upto secondary	0.820	0.408	1.648

higher secondary	1.286	0.598	2.765
undergraduate above	1.204	0.637	2.276
1.male_fem (ref1= female)	0.999	0.633	1.577
Log Likelihood	-344.596		
Pseudo R2	0.2059		
Number of Observation	464		
LR chi2(11)	178.74		
Prob>chi2	0.00		

Source: Self compilation from field survey data, 2015/16

The result shows that current quantity of water consumption, income, prices of jar, stated quality of KUKL water supply, perceived waterborne diseases are statistically significant at 1% level, are the main determinants of household's WTP for improved water supply by KUKL in the valley. The WTP for improved water is likely to increase by three times for one unit increase in water consumption by the household. It means households currently consuming higher quantity of water are highly likely willing to pay higher tariffs. The odds of willingness to pay are likely to increase by around two-fold with additional increase in income level of households. It means households economic status and WTP are positive.

The price of jar water and WTP are negatively associated as the coefficient is statistically significant (1% level) and <1. The odds of WTP for KUKL water is likely to decrease with increase in price of jar water or conversely the odds of WTP is likely to decrease by 45% for a 100% increase in price of jar water. Other two variables, opinion about quality of KUKL water service and perceived waterborne disease are also statistically significant at 1% level. The odds of WTP is likely to increase by 1.5 times by households having unsatisfactory opinion about quality of KUKL service with reference to households having satisfactory opinion. Similarly, households who perceived waterborne diseases are highly likely (3.6 times) willing to pay more for improved water supply system than those who do not perceive waterborne diseases. The other demographic variables like education level and gender of head are not statistically significant.

In order to calculate elasticity of total water demand and elasticity of KUKL water demand with respect to prices of KUKL, tanker & jar water, OLS was fitted before computing price elasticity, cross elasticity and income elasticity.

Table 3: Elasticity of demand for total quantity of water (all sources sum) and KUKL water

With respect to factors	Total water demand		KUKL water demand	
	ey/ex	Std. Err.	ey/ex	Std. Err.
KUKL_ price***	0.102	0.012	0.276	0.018
Income***	0.318	0.025	0.204	0.035
Tanker_price***	0.071	0.007	-0.093	0.010
Waterjar_price***	-0.032	0.009	-0.092	0.013

Source: Authors estimation

From the table above, we infer that all the factors are statistically significant at 1% level. The +ive sign of KUKL_price and tanker price indicates that elasticity of total water demand are related in the same direction but their impact on demand is small. But coefficient of elasticity of demand for jar water price is negative, signifying an opposite relationship. The positive sign of income elasticity of total water demand with coefficient <1 indicates water as basic necessary commodity. In the 4th column elasticity of demand for KUKL water with respect to its own price, income, and related commodities shows that tanker water and jar water are fair substitutes as the signs of coefficients are –ive.

4. FINDINGS AND DISCUSSION

The study found average WTP for KUKL improved water supply per month per family in Kathmandu valley is NRs. 405, which is over three times less than what they are currently spending on all sources of water. The current mean monthly expenditure by a household for all the sources is NRs. 1314 ($ 13) is actually equal to (Pattanayak et al., 2005) estimate of WTP of $14 for improved water supply in the valley. Our study exclusively investigated WTP for KUKL's improved water, so owing to various factors; residents are reluctant to pay beyond $4 for KUKL supply. But another study performed by (Twerefou et al., 2015) in Ghana findings shows that households are willing to pay seven times more than what they were currently paying.

The households total amount of monthly expenditure on water for various sources like KUKL, tanker water, jar water, tube well, pump, etc. accounts round 3 percent of total income which is quite higher than study done by (Rodríguez-Tapia et al., 2017) in Mexico (water bill 0.22% of the average family income) income. But exhibiting inelastic income elasticity of demand (coefficient <1) indicates water as necessary basic commodity and moreover proportion of income spent is insignificant from Kathmandu residents' perspective. The inferential finding shows that household's current quantity of water consumption, income and perceived quality of KUKL water, and perceived waterborne diseases, determine WTP for improved KUKL water supply. The findings are similar to studies by (Rodríguez-Tapia et al., 2017) in Mexico, (Haq et al., 2007) in Pakistan and (Twerefou et al., 2015) in Ghana. Current volume of water consumption, income and perceived waterborne diseases are strong positive determinants of willingness to pay for improved KUKL's water supply, while negative sign of coefficient of jar water price would impact negatively on consumers' WTP for improved water. It indicates consumers are less likely willing to pay for improved KUKL water if price of jar water hikes in the market. It indicates that jar water is very strong substitute of KUKL water supply. Lastly, the price and income elasticity of KUKL water demand are inelastic though statistically significant; signifying water as basic necessary commodity. The negative signs of cross elasticity of KUKL water demand (with respect to price of tank water & jar water) indicates that tanker water and jar water sources are fairly strong substitutes of KUKL water supply.

5. CONCLUSION

The study shows that the willingness to pay for improved water supply by the residents of Kathmandu valley is just over two and half times the average current KUKL water tariff but it is three times less than their current total water expenditure from all the sources. It indicates that the people have higher dependence on tanker and jar water than KUKL supply. So, even though a large consumer surplus accrues for scaling up tariffs in order to finance the debt of Melamchi mega project but haphazardly levying higher tariffs (>NRS 405) might cause dissatisfaction among the residents. So KUKL Board first needs to solve water supply sufficiency, water quality assurance and regularity to win confidence of residents before hiking tariff rates.

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