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Predicting Domestic Water Consumption under Price Affordability

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Abstract – Domestic water demand and supply is one of the basic requirements which expresses decent health, and measurement of standard of living in an area. The geometric explosion form of population increment in most of our cities has been a major stress burgling on domestic water demand and supply. This situation has made water distribution system very poor, high water pricing to the customers without standard water pricing system. This research is aim at investigating and predicting the affordably of water pricing that customers' can pay for effective domestic water supply and used. The study used contingent valuation (CV) measurement method to elicit information from the customers within the Kaduna Metropolis as case study. End Use Analysis (EUA) was then used to understand the components of household water use, price willingness to pay (affordability), and the extent to which commitment of payment. The survey used Random Sampling methods for selecting 10 areas within Kaduna Metropolis, which includes Rigasa, Tudun Wada, Kawo, Ungwa Pama, and Goni-Gora designated as high density, while Gwamina Road, Marafa, Narayi H/C, Ungwa Rimi Low Cost and Challawa as low density. The low-density areas were further demarcated into three enumeration areas, while high density was demarcated into five for good coverage. The average size of household within the enumerated areas was between 5 to 9 person and water consumption patterns ranged from drinking, bathing, toileting, to washing with a required estimated value of about 369.2 litres of water per day per household. Generally, about 93.9% households responded to agreed and willingly accepted to pay between N1500 and N2500 per month across the status considered. The price was regressed against the water consumption, and the statistical analysis shows significant correlation as domestic water consumption rate tends to be high as price moderately predicted. Though the result do not show any reactions from the Agency, but it is enough to say that the customers will be at advantage, hence putting responsibility of government to play and of which if not done prevent society from achieving optimal resources allocation.

Keywords: Affordable price, Contingent valuation, Domestic water consumption, Households, High density, Low density

1. Introduction

Domestic water demand and supply is one of the basic requirements which expresses decent health, and measurement of standard of living in an area. The geometric explosion form of population increments in most of our cities has been a major stress burgling on domestic water demand and supply. This situation has been due to either ineffective water distribution system from the part of government agency, or high water pricing from the agency to the customers due to no standard water pricing, which has given rise to inadequate supply and incapacitated to meet up the supply. Meanwhile, two-thirds of the world's population has been considered to live under water-stressed regions with per capital water less than 1700 m^3 per year by 2025 according to UNEP (2000) report. And over a billion people around the world lack access to safe drinking water while over two billion have little or no sanitation as reported in Nature (2008). Wang *et al* (2010) observed that domestic water use is not a major part of water consumption in the world today, it only plays a crucial role in people's daily life, and it is directly related to social welfare and public health issues. The question is therefore asked, why then the world worried on domestic water use and supply than other consumption sectors? The reason could have been answered by the last two phrases of the Wang et al (2010) on the assertion of "social welfare and public health", on which the explosion population required and demand attentions of the authorities of the various regions and countries. The consideration of potable water as essential resources for the possibility of health life,

regardless of amount or proportion as observed by USEPA (2000) is a factor of fact about domestic water use and demand.

In Nigeria, urban access to potable water is just only 42% as at 2008 (WHO and UNICEF, 2010) compared with the report of National Water Supply and Sanitation Policy document by FMWR (2000) whose report noted only 48% urban settlers have access to potable water. This indicated that there is depreciation and downward improvement of potable water supply by 6% after 8years, whereas the population kept on increasing on geometric progression (UNICEF, 2010). The average potable water delivery to urban population was recently put at $0.032m^3$ per day, while that of rural area was $0.01m^3$ per day with doubtful in quality according to Bichi (2013). The problem has been cuts across the developing countries, and identified in Nigeria to include very low tariffs, low economic efficiency, cost recovery and others as listed by Bichi (2010).

Water pricing is actually associated with identified problems as pointed out in Bichi (2010), on which if water pricing issue is treated for free it may lead to less sustainability; lack of incentive for the distributor to expand networks; might therefore be a bad policy for the poor overall as identified by Minten *et al* (2002); and price has been identified as a modifier for water consumption behavior as it affects supply costs according to Griffin (2001). Water pricing is an effective mechanism to manage water use. Switching to a more appropriate price scheme can adjust inefficient levels of domestic water use by changing household water demand. However, water pricing has been a complex and difficult issue for both governmental and nongovernmental decision makers. Developing countries, who usually suffer from inadequate water supply facilities and lack sophisticated and comprehensive water pricing systems, are in need of more practical and effective water pricing methods.

Despite the difficulties and complexity, many important methodologies for water pricing studying have been widely undergone and many researchers have carried out researches on water pricing. According to OECD (2003a), nine categories of pricing strategies according to the forms and underlying considerations of water tariffs have been include: (1) no water charge, (2) fixed water fee, (3) flat uniform water rate, (4) decreasing block rate, (5) increasing block rate, (6) average cost pricing, (7) marginal cost pricing, (8) two-part tariff, and (9) peak load or seasonal pricing. But due to variation in the water resources availability, market practices, and government institutions, different countries around the world, are applied different household water pricing strategies OECD (2003a). Some of these include Ireland and Northern Ireland which adopt no domestic charges, flat-fee charges (Iceland, Scotland, Norway, New Zealand, and part of Canada), single volumetric charges (Eastern Europe), two-part tariffs (most of OECD Europe), varied volumetric tariffs (the rest of Canada, Australia, Luxembourg, and the United States), and increasing block tariffs (OCED Asia, Belgium, Mexico, and the Mediterranean countries), (OECD, 2003b). Price levels in these countries mentioned above varied due to the availability of water resources, level of government subsidy, and affordability (OECD, 2003b).

Nigeria and other developing countries are far away from what the price levels of water is. Therefore, in order to know how to capture the value of water and determine an appropriate water tariff, current pricing mechanisms, focus on balancing the investment and revenue of the water supply services; and focus on capturing the value of water use to users at their own price deciding, a water pricing prediction for market efficiency is needed which will help to improve water supply and effective water usage. Therefore this study aimed at investigating and predicting an agreeable water prices using the customers' affordable water pricing system for efficient domestic water conservation and effective water agency budgeting.

2. Materials and Methods

2.1. Study Area

Kaduna is the capital of Kaduna State, almost centrally located in Nigeria. It is situated at 10.52^{O} North Latitude, 7.46^{O} East longitude, and 614 meters elevation above sea level. Kaduna and its environs have the population of about 1,582,102 inhabitants (based on 2006 population, though officially not released) at about 3.5% annual increase.

2.2. Model Specification

The concept in this study distinguished between domestic water demand and basic water requirement. According to Inocencio *et al,* (1999), water demand is a function of own price, price of other related goods, income, technologies in water use (e.g. water closet, showers, and washing equipment) and other socio-economic variables. Empirical studies have shown that household water demand is largely determined by changes in the price of water and income growths (Young, 1996), meaning, water demand is inversely proportion to own price, and directly proportion to household income. In the concept of basic water requirement, World Health Organization recommended domestic water consumption requirement to include drinking and sanitation needs according to Zhang (1996), but generally accepted to include four components, namely: drinking, cooking, bathing, and sanitation as in Gleick (1996). Also, Inocencio *et al* (1999) considered the effect of locality, and added a fifth component as water for laundry since wearing clean clothes is a personal hygiene and required some substantial volume of water. The water requirement for laundry varies from the technology type used to hand washing of which 1999 studied has shown between 75 to 100 liters per capita per day or more than double depending on whether a short or a full cycle is used (Inocencio *et al.*, 1999).

The study concept aggregates the household water consumption volume and relates to price affordability with the extent of patronage. Aggregation theory provides an important tool and necessary condition under which it is possible to treat aggregate consumer behavior as if it were the outcome of the single utility maximizing consumer (Deaton and Muellbauer, 1999). In households, consumers are asked to specify what they can afford to pay relatively to their water consume, and of course whether they are ready to patronize the supply. The study set ten pricing blocks ranging from N500 to N5000 per month relative to maximum and minimum basic water requirement of the households consumption, and fortunately this has not been treated in any literatures before.

Given the affordable average monthly price structure, the relationship between the household basic water consumption can be estimated using Multivariate Regression Model (MVRM), because of the dynamic and continually evolving processes on the basis of multi scale interactions nature. The model creates discrete linear segments connected at the empirically or theoretically derived threshold, which is represented by the point of change; changes in price as captured in Athanasiadis *et al.* (2005) and Chu *et al*. (2009); and conservation policies (Chu *et al*., 2009; Ahmad and Prasha, 2010).

Therefore, the basic water requirements for households domestic water consumption, Q_{BWR}, can be study as a function of water price affordability, P_a, the maximum and minimum basic water requirements, Max_{BWR} and Min_{BWR}, respectively (related to household profile and its water use behavior); and patronage extent, P_g, which can be express as:

$$Q_{BWR} = f(P_a, Max_{BWR}, Min_{BWR}, P_g) \quad (1)$$

2.3. Model Validation and Evaluation

A validation dataset from households' survey was used to evaluate how well the model predicts the result in terms of accuracy, consistency, and ease of application. The compiled data was randomly selected and used for validation of the model. The evaluation of the model was further done by comparing two different predicted datasets using the statistical coefficient of correlation, R and determination, R^2 (the range of 1 - 0 - -1).

2.4. Data Collection

Predicting domestic water consumption requires a reliable measured data, in addition to information about factors that are hypothesized to influence it. The major difficulties that arosed in attempting to predict or estimate domestic water consumption in developing countries is lack of water meter, no demand data, and insincerity on the part of government and consumers termed corruption. The research is typically relied on cross-sectional survey of households as suggested in Dagnew (2012) in the community under study. For this study, both primary and secondary data were collected and used. The primary data

gathered from surveyed questionnaires on the detailed of households was supported with individual households discussions, while the secondary data was specifically sourced from government water and population agencies. Also, data were sourced from related literatures from academic publishing and internet materials.

2.5. Survey Design

Questionnaire was carefully designed to target the set objectives. The structure of the survey questionnaire includes introduction; briefly describing the background, aim and objectives of the survey and then partitioned into two, where, Part One formed questions on the demographic, and socioeconomic profile of the households using previous results; Part Two formed household water use behavior, which are further divided into Scenarios 'A' and 'B', respectively, formed the hypothesized questions, which was not used in the previous work (Dagnew, 2012; Athanasiadis *et al.*, 2005) and Chu *et al*., 2009). These scenarios were created on the assumption that government water agency will play their roles and the consumers are motivated to fulfill their commitments. Afterward, several questions were posed and included to supplement the study and enhance the results.

Random Sampling methods were used for selection of 10 areas within the Kaduna Metropolis. The areas include Rigasa, Tudun Wada, Kawo, Ungwa Pama, and Goni-Gora designated as high density, while Gwamina Road, Marafa, Narayi H/C, Ungwa Rimi Low Cost and Challawa as low density. The selected low density areas were further demarcated into 3 enumeration areas, while high density was demarcated into 5 enumerations for easy and simple coverage. Each demarcation was assigned with two enumerators, male and female.

As much as possible, survey methodology has been designed strategically in order to include representative houses from all areas of urban Kaduna. The study followed and used National Population Commission maps (NPC) (2006) for easy identified already enumeration areas. For selecting the primary sampling unit, *i.e.*, houses, the exact location of the selected houses has been identified prior to the field visit, which saves significant amount of survey time. Although, this map does not include houses built in last five years, house location and its additional information became valuable resource as secondary source for different purposes in our study. The sample sizes of 10 enumeration areas were determined considering the limited time and resources to represent the Metropolis. Since ten households were captured, by extension, implied ten questionnaires were administered in each enumeration areas for easy data handling and analysis.

The questions were structures closed and opened; where closed questions are more specific than open ones, and could detect differences among respondents more accurately (Dagnew, 2012). Post survey was also employed to check the reliability and deviation of the data collected primarily from the enumerators.

2.6. Validation and Pretest of the Questionnaire

The questionnaires were validated by appointing three (3) validators with versed experience on water resources management, and pretested on the field to estimate the time of completion, familiarization to the enumeration areas, identify deficiencies, and gain knowledge on probable confusions, questions, pitfall and responses. The team visited one of the randomly selected sample areas. The findings of the pretest were incorporated to final questionnaire.

2.7. Fieldwork Preparation and Implementation

Enumerators were recruited and selected for the implementation of the field survey having considered their previous experience in enumeration. They were then trained on the subject matter including a day field demonstration of questionnaire administration. Coordination and support mechanism in the form of rapid respond corps was established for urgent assistant in case of unexpected and difficulties.

The enumerators were mobilized for the field survey with at least one female within a group so that respondents become comfortable in the present harsh security situation experience in the country. The

enumerators were equipped with reflected jacket, enumeration maps with coded numbers obtained from NPC (2006), file jacket, chalks, biro, pencil, and markers for marking.

2.8. Data Analysis

At the onset, the information from the respondents was preliminary analyzed to identify potential outliers and unreasonable observations. The data were cleaned and missing information was dealt with, the sample size was reduced to a management level. The first batch of the analysis was done on statistical tools of SPSS and later transferred to Microsoft Excel Spreadsheets 2007 for regression analysis.

3. Results and Discussion

3.1. Feedback from the Questionnaire Administration

The survey revealed average size of the household to lies between 5 to 9 persons majorly, of who majorly water consumption depends mostly on hand-dug wells and boreholes as respondent frequency analysis shown 42%, even though they were connected to public water. This population is what constitute and accounts for primary water domestic water consumptions in the study areas.

The assessment of occupational group level indicated that public servant is nearly 46%, while the businesses account for about 23% and others 31%. The result also showed that most households bath twice in a day representing 74%, indicating the highest frequencies of bathing per day. This may depend on the weather of the period as it normally determines the time of bathing and varies from place to place, household to household, or personal habits. The frequency of water use for bathing based on the household using buckets was 68% while shower was 23%, on which the estimated bathing water was computed through a simple means as referenced in China (2010). The quantity of water use for bathing using bucket was estimated at 40 litres per day per person and that of shower was 24 litres per day per person, also at bathing frequency of 2 times. Most respondents to bathing question demonstrated that bathing frequency is twice using buckets resulting from no flow in the pipelines. This indication shows that, averagely the minimum water use for bathing in a household per person is about 5 litres and 45 litres per household as minimum; while 20 litres per person and 180 litres per household as maximum. A total of 360 litres of water per day per household with bathing frequency of twice a day was estimated.

3.2. Flushing Analysis

The average flushing rate of most households was found to be twice per day per person. Daily frequency use of toilet was in the range of 2 to 4 times per day per person. The main group of household who uses the toilet 2 times in a day, representing 59% and constitutes the highest respondents with 10 to 20 litres of water, while maximum time usage was above 5 times, considered very abnormal. The response from the households does not reveal an adequacy counts of toilet frequency, the study indicated that people use toilet frequently but not regularly.

3.3. Laundry

Most households in the study area indicated laundering twice a week with a corresponding frequency show the highest response of 61%, while the closely related was once in a week at 24% frequency. On the average of washing, 1 to 20 pairs of clothes are washed per week on the frequency analysis of 55%, and of which 3 to 6 litres of water were used for a pair. This means that between 60 to 120 litres of water is used.

3.4. cooking

The cooking average per household is twice a day with frequency analysis of 61% among the households enumerated in both classifications. The cooking includes diet cooking process (food parboiling, washing raw food stuffs etc) and washing of the dishes after eating. On average between 5 and 12 litres of water will be required for cooking process at minimum since the frequency analysis indicated 56%, while the maximum is between 17.5 to 28.3 litres with frequency analysis value of 49%.

3.5. Connection to Public Supply

The result revealed that majority of the households were connected to the public supply system but unfortunately the flow of water through the pipe system became inconsistence and erratic. This situation compelled many people to result to private alternatives supply such as boreholes and hand-dug wells. To further erratic water supply affordance, people were see constructing and buying water storage facilities such as over-head tanks, large poly-tanks, buckets, jars, to store water for use.

3.6. Water Pricing System

The price of water is extremely important, not only for those providing the water service, but also for all the people depending on the services. It was inquired whether the people still believed in government water agency and ready to make contribution for the success of their delivery. The survey revealed the people are enthusiastic in public water supply as level of patronage shown the value of 85% with indications of ready to pay if the services and the products can sustain cleanliness, clean and regular. Most of the household are ready to pay as high as N5000 even though the range of N500 to N1000 has highest frequency (31%) followed by N1000 to N1500 (22%). Majority agreed to pay between N2500 to N3000 as maximum and between N500 to N1000 minimum.

On the question of peoples' opinion, they opined that water bills used to be delayed on which they suggest the prompt delivery, control of leakage on the public domain, regular interventions from Government to the Agency, assessment of Agency to local raw materials for water purifications chemicals like alum, chlorine; and routing inspections throughout the treatment plants.

3.7. Predicted Model Result

Figure 1.0 showed the maximum and minimum basic water requirement measured from the use of questionnaire and predicted basic water requirement within the study period, while Figure 2.0 shown the actual and predicted values of the model formulated.

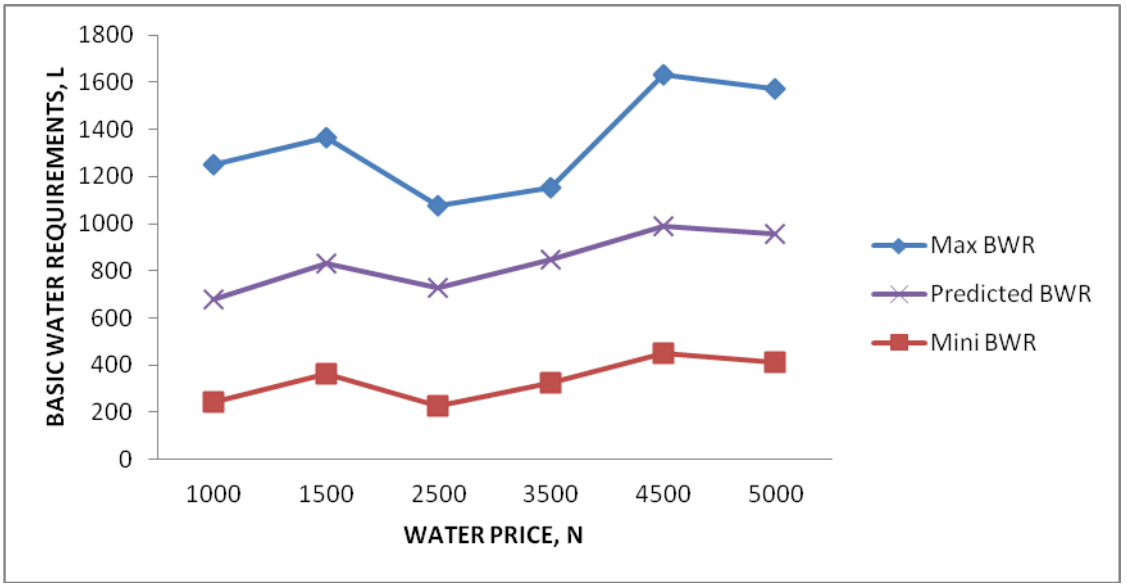

Figure 1.0: Measured and Predicted Basic Water Consumption

There is indication that the higher the affordability of the people to pay for basic water consumption the higher they have assess as shown in Figure 1.0. Between the price of N2500 and N3500 the water consumption remain constant until there is change in price on which it propelled the consumption upward on both maximum, minimum and the predicted values. It is therefore understood that if basic water requirement price could be afforded by the customers, the access to basic water requirement will be

guaranty, and as time progresses, the water consumption may remain constant and price unchanged as presented in Figure 1.0 at the tailed end of the both curves.

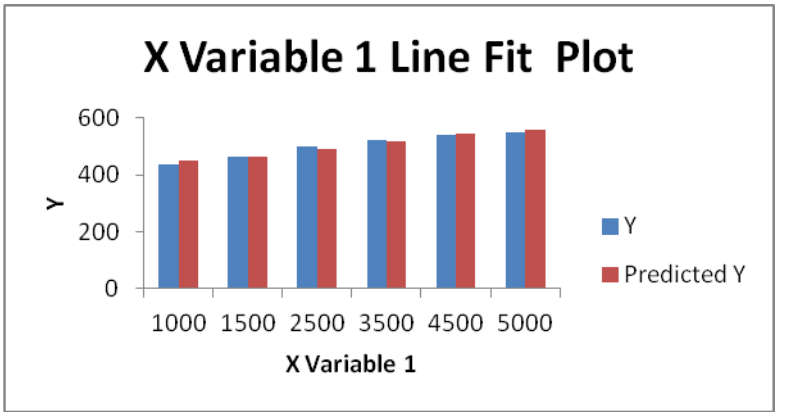

Figure 2.0: Actual and Predicted Basic Water Consumption

The actual data from the field are indicated in blue and the predicted values were shown in purple as presented in Figure 2.0. From the multiple regression, coefficient of determination, R^2 value show 0.96 and coefficient of correlation, R value show 0.98. This shows that the predicted values correlated very well with the measured data. Though, this may not be enough to certify or appraise the model, the authors move further by looking at the ANOVA result of the data. At p-value the estimated regression model was found to be significant at p-value equal 0.000 at the confidence level of 95%. Also, F-value (93.38) of the model was significant at the significant level value 0.01 ($p<0.000$).

4. Conclusion and Recommendation

The present paper identifies the factors that determine basic water requirement in Kaduna Metropolis. We observed that the affordable price by customer predict water consumption well as the price increase consumption tends to increase. It was also observed that the predicted water consumption values lies between the minimum and maximum values, making it significant as earlier mentioned. It is apparently possible to obtain a water price that can be moderately afforded by the customers irrespective of the class, and while also possible for the water agency to adapt to a system of supply as to lower the water losses. From the administered questionnaires, it can be found that the customers are not satisfy with the level of service been rendered by the agency, but there is an indication of willingness to pay and patronize the supply. Although, the level is relatively low when compared with what agency is spending in refining a litre of water (N150/Litre), but since government has a role in providing social amenities to the people, there is a need for defined and proper role to be play.

However, the population ought to know that there is need for them to play a participatory role to sustain the water supply and its existence through deciding what they can afford. The conclusion derived from here be a policy guide to decide on what budge government placed on water supply to its population. The price could be use as water conservation method based on "pay and enjoy supply".

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