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## Price-setting for Residential Water: Estimation of Water Demand in Lahore

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### 1. INTRODUCTION

The population of Lahore has roughly doubled over the past twenty years, and an increase of two million is expected by the year 2020 [UN (2005)]. This has important implications for city planning as demand for housing, electricity, water, sanitation, public health, education, and infrastructure grows accordingly.

Water and Sanitation Agency (WASA), the city's official water supplier, has often responded to the growing demand by offering the supply-side solution: augmenting supply capacity by exploiting new water resources.<sup>1</sup> Such investments are costly, but in view of the *public good* nature of water, WASA has kept tariffs well below the cost-recovery level, relying on heavy loans and subsidies. While this arrangement may have worked in the past, it is now becoming increasingly unsustainable, because (1) WASA is facing severe financial constraints and which has led to poor service and underinvestment, and (2) the environmental cost of extracting water is increasing.

With its low tariff rates and continually increasing costs, the WASA Lahore is unable to meet even its operation and management (O&M) costs [WASA (2007)]. WASA has been receiving financial assistance from the provincial and Lahore district governments as well as international donors in the form of grants and loans with the grant element gradually diminishing over the passage of time. In 2007, WASA currently owed Rs 5.6 billion to these agencies [WASA (2007)]. Deteriorating financial situation has also led to short-term planning, reactive operational strategy, and underinvestment in asset maintenance, future capacity, IT equipment, management and accounting information system, and training [IFC (2005)]. Consequently, WASA has shown suboptimal performance: low pressure and irregular supply, leakages, poor customer service, etc.

Secondly, indiscriminate and unplanned exploitation of water resources may result in severe water shortages in future. Water supply in Lahore depends essentially on groundwater pumped through privately or publicly-owned tubewells and hand pumps.

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<sup>1</sup>In line with the demands of the growing population, WASA has continuously expanded its supply capacity in the past. Currently, WASA produces 350 million gallons of water per day with its 400 tubewells. Over 25 more tubewells have been approved under the 2007-08 budget of the agency [WASA (2007)].

However, groundwater is a limited resource, recharged only once a year during the monsoon. Reportedly, the groundwater table has been falling.<sup>2</sup> Falling water tables increase the cost of pumping, as more energy is required to pump deep water. Furthermore, the International Water Management Institute has predicted severe water shortage in the country by the year 2025, that will even threaten the sustainability of agriculture [IWMI (2000)]. Relentless extraction of water may also lead to an irreversible decline in the ability of the region to store water in the ground [Gleick (1998)]. Since water is under-priced, it is under-valued. People demand more quantities of water than they would if they were made to pay the true environmental and supply cost of water. Clearly, the supply solution discussed earlier is not the best answer to the growing demand.

Instead, WASA should be looking at *demand management* that involves pricing policies and rationing (notionally allocating a fixed amount of water to each household, based upon lifeline and household size considerations). However, though rationing brings a definite change in demand, it is difficult to implement and may not be widely acceptable. Pricing policies, on the other hand, have been successfully implemented in countries like Brazil, Canada, France, Spain, the United Kingdom, and the United States.

Through pricing policies existing demand patterns are modified to achieve various objectives, such as cost recovery, conservation, and equitable allocation of water among different income groups. To implement such a policy successfully, the value that consumers place on water must be known. This value is reflected by the *price elasticity of water demand*—the percentage change in demand that will be caused by a percentage change in price. If the demand is inelastic, it shows that price has little or no effect on the quantity of water consumed. On the other hand, if elasticity is high, consumers indicate a willingness to reduce/increase the use of water with changes in its price. And if tariff is increased, they would shift a part of their expenditures elsewhere. Clearly, this information is fundamental in deciding the manner in which tariffs should be structured.

### 1.1. Background

Lahore is one of the oldest cities of South Asia and is the provincial capital of the Punjab. The Lahore district spreads over an area of 1,772 square kilometres with a population density of over 3,566 persons per thousand square kilometres [Punjab (2005)]. Population-wise, Lahore is the second-largest city in Pakistan, fifth-largest in South Asia, and 23rd in the world [World Gazetteer (2007)]. The current urban population is over 6.6 million and is expected to exceed eight million by the year 2020 [UN (2004)].

The Lahore Development Authority (LDA) is the chief municipal body responsible for preparation and implementation of schemes for environmental improvements, housing, slum improvement, solid waste disposal, transportation and traffic, health and education facilities, and water supply and sewerage in Lahore City area under the LDA Act, 1975. The chief water supplier in urban Lahore is the WASA, formed under the LDA Act, 1975.

<sup>2</sup>Over the year 2002-03, the groundwater table in Punjab fell on average by 0.61 percent [Punjab (2005)]. More recent estimates were not available.

The WASA service area extends to 350 square kilometres, supplying water and sewerage services to a population of over five million [IFC (2005)]. Other private water suppliers also exist in Lahore City, but there is no official record of their number and coverage. For administrative purposes, the area covered by WASA is divided into six blocks called 'towns': Allama Iqbal Town, Aziz Bhatti Town, Ravi Town, Shalimar Town, Ganj Baksh Town, and Nishtar Town. Each town is further divided into O&M sub-divisions (see Table 1).

Table 1

<i>WASA Administrative Division</i>	
Town	O&M Sub-divisions
Allama Iqbal Town	Allama Iqbal Town, Samanabad, Johar Town, Ichhra
Aziz Bhatti Town	Taj Pura, Mustafabad
Ganj Baksh Town	Ravi Road, Krishan Nagar, Shimla Hill, Mozang, Gulberg
Nishtar Town	Green Town, Industrial Area, Township, Garden Town
Ravi Town	Shahdara, Data Nagar, City, Farkhabad, Misri Shah, Shadbagh
Shalimar Town	Baghbanpura, Mughalpura

Though located along the bank of River Ravi, water supply in Lahore depends on groundwater, the river being the most polluted in the entire country.<sup>3</sup> For Lahore, groundwater is an ideal source of water because it is relatively free of impurities and therefore little or no treatment of is needed before it is put to household use.

### **Water Pricing**

Water is charged volumetrically where the connection is metered, while unmetered connections are charged on the basis of the annual rental value (ARV) of the house.<sup>4</sup> The ARV is divided into nine bands ranging from Rs 400 to Rs 4, 500 and above. However, since ARV-based charges do not directly affect consumption, only metered households are included in this study.

Currently, only 30 percent connections are metered, but WASA is making substantial efforts to meter all existing connections [WASA (2007)]<sup>5</sup> and no new unmetered connections have been issued since January 1997. Metered connections are charged with a two-part tariff: a variable volume-based part and a fixed part. The fixed part includes monthly connection fee of Rs 12 plus a flat charge of Rs 3 per month. The volume-based charges are divided into three ascending volumetric blocks, that is, consumption in each succeeding block is charged higher than the previous block (see Table 2).

<sup>3</sup>River Ravi is the most polluted river in Pakistan, receiving 47 percent of the total municipal and industrial pollution discharged into all rivers in the country. According to the World Wildlife Fund, extreme pollution has destroyed around 42 fish species that the river was home to. Even contact with the river water has been reported to cause severe skin diseases. The water is certainly unfit for drinking. [EDC News: <http://www.edcnews.se/Cases/PakRaviriver.html>]

<sup>4</sup>Annual Rental Value (ARV) is defined as the gross annual rent at which a land or a building might be expected to be let from year to year, less deductions for repair and maintenance. [World Bank and The Urban Unit, Lahore (2006)].

<sup>5</sup>WASA allocated Rs 29 million for the procurement of domestic water meters in 2007-08. [WASA Budget Document (2007)].

Table 2

*Water Tariff Structure for Domestic Metered Connections*

Consumption (Gallons)	Rate (Rs per 1,000 GPM)	
	January 1998	May 2004
Up to 5,000	9.20	12.88
5,001-20,000	14.90	20.86
20,001 and above	19.50	27.30

Source: WASA, Lahore.

WASA water tariffs are apparently based on cost-considerations, but are well below the cost recovery level. The objective is seemingly to recover an acceptable portion of the cost rather than the full costs, that being a compulsion due to political considerations.<sup>6</sup> Tariffs for both metered and unmetered connections have been revised thrice over the past decade: in July 1997, in January 1998, and then in May 2004. No annual inflation adjustments are made.

The paper is organised as follows: section two reviews literature on water demand. The methodology is explained in section three. Results are presented in section four, followed by policy recommendations in section five, the last section.

## 2. LITERATURE REVIEW

The estimation of urban residential water demand has been an area of wide and growing interest world-wide for the past three decades. However, most of the existing literature pertains to the developed world: the United States and Europe [Agthe and Billings (1987); Arbues and Villanua (2006); Batchelor (1975); Chicoine and Ramamurthy (1986); Foster and Beattie (1979, 1981); Hansen (1996); Headley (1963); Hewitt and Hanemann (1995); Nauges and Thomas (2000); Neiswiadomy and Molina (1989, 1991); Renwick and Archibald (1998); Wong (1972)]. So far, no comprehensive study has been conducted in Pakistan to estimate the urban residential water demand and neither has the researcher come across any such study of similar-income countries. Therefore, the reviewed literature has limited usefulness in many aspects. What follows is an analytical review of the methodologies and data types used in previous studies and a brief assessment of the suitability of these methods in the present context.

Water demand estimation studies have used various sorts of data: time-series [Agthe and Billings (1987), Hansen (1996)], panel [Arbues and Villanua (2006); Nauges and Thomas (2000); Neiswiadomy and Molina (1989, 1991); Renwick and Archibald (1998)] and cross-sectional [Chicoine and Ramamurthy (1986); Foster and Beattie (1979, 1981); Headley (1963); Wong (1972)]. Time-series data is useful to study the effects of a policy change, such as restructuring of block-rates, rationing of water supply, or the introduction of a new water-related appliance. Time-series data also captures the effect of weather. A drawback of such data is that it is aggregate: summing or averaging quantities, such as consumption, income, and prices, for the entire community. For this reason, results derived from time-series data have limited usefulness. Cross-sectional data on the other hand can be

<sup>6</sup>The City District Govt. has not allowed WASA to raise tariffs for the past three years in spite a 10 percent increase in the electricity rates [WASA (2007)].

collected for disaggregate units, such as individuals, households, or localities. This data holds more information than time-series data, and is appropriate for estimating demand across different groups. However, cross-sectional units may have too much variability which can cause heteroscedasticity, in which case the OLS estimators have high variances.<sup>7</sup> The most useful approach is perhaps the panel data, because it combines elements of both cross-section and time-series: more variables can be studied while time effect is also captured. Panel data also increases the number of observations, and hence the accuracy of the model. For these reasons, this study has used panel data.

Urban water is usually priced under 'block-rate' schedules: a volume-based rate consisting of a sequence of marginal prices for different consumption blocks. Water use in each billing period is divided into successive blocks with use in each ascending block charged at a different price. The block rate schedules can be progressive or regressive with increased consumption. The schedules are established to ensure efficient use of resource, as well as to achieve equity, environmental conservation, cost recovery, and public acceptability. An important point of contention in water demand studies has been the specification of the price variable in the model [Charney and Woodard (1984); Chicoine and Ramamurthy (1986); Foster and Beattie (1981); Opaluch (1982, 1984)]. Water demand studies use two alternative types of price specifications:

- (1) Marginal price of the block under which the consumer falls plus a 'difference variable' [following Taylor (1975) and Nordin (1976)]. The difference variable is calculated as the difference between what the consumer actually pays and what he would have paid had all consumption units been charged at the marginal price of the last unit of consumption.
- (2) Average price—the total water expenditure by the consumer in a billing period divided by the total water consumed in that period.

Proponents of the difference variable specification [Agthe and Billings (1987); Renwick and Archibald (1998)] argue that the consumer is well-informed and therefore responds to the marginal price and difference variable. On the other hand, those who favour average pricing argue that the consumer does not devote time to study the tariff structure and only has a rough idea of what he pays for his consumption [Foster and Beattie (1981)]. Nieswiadomy and Molina (1991) and Opaluch (1982) have suggested statistical tests to determine the price to which the consumers actually respond. The advantage of one test over the other was not readily apparent. This study has used the more recent Nieswiadomy and Molina (1991) price specification test to determine the correct price specification.

It has been further argued that ill-informed consumers react to past rather than current prices [Charney and Woodard (1984)], and hence the appropriate specification of price would be the lagged (average) price. The lagged-price specification has not been used in the present study because the WASA tariff schedule is rather uncomplicated (only three blocks) and has been revised only once since 1998. However, past bills may have some impact on the consumers' decision-making; a lagged consumption variable has therefore been added as a regressor.

<sup>7</sup>Heteroscedasticity is defined as non-constant variances of residuals. In the presence of heteroscedasticity, OLS estimators remain unbiased and consistent but they no longer have minimum variance.

With multi-part block rates, prices are endogenously determined by the quantity demanded, and hence the model is based on simultaneous equations. Under simultaneity, the OLS method yields biased and inconsistent estimates. Most water demand studies have used either instrumental variables [Nauges and Thomas (2000); Neiswiadomy and Molina (1989, 1991)] or two-stage least squares [Agthe and Billings (1987); Renwick and Archibald (1998)] to remove the ‘simultaneity bias’. Arbues and Villanua (2006) have used a dynamic panel model which is applicable to cases where the price is lagged to a degree such that it is no longer correlated with the error term in the current period. Hewitt and Hanemann (1995) have used a discrete/continuous model that builds on the discontinuous nature of the budget constraint faced by the consumer under block-pricing. The OLS method has been used in studies where uniform rates were charged [Hansen (1996)] or the demand function was formulated under restrictive assumptions [Chicoine and Ramamurthy (1986); Foster and Beattie (1979); Headley (19630; Wong (1972)]. This study has used two-stage least squares method for estimation.

Different functional forms have been used in domestic water demand studies, including linear [Agthe and Billings (1987); Batchelor (1975); Renwick and Archibald (1998); Nauges and Thomas (2000); Neiswiadomy and Molina (1989)]; log-linear [Foster and Beattie (1979, 1981); Hewitt and Hanemann (1995); Neiswiadomy and Molina (1991); Wong (1972)] and semi-log models [Hansen (1996)]. However, there is no evidence to indicate the most appropriate form. Linear models are easy to estimate while double-log models are useful because the coefficients give estimates of elasticities.

### 3. METHODOLOGY

#### 3.1. The Model

The domestic demand for water arises from its use in sanitation, bathing, washing clothes, cleaning homes and cars, cooking and drinking, watering lawns, cooling, and recreational activities. As price changes, this demand may either contract or remain constant, in the latter case it being inelastic. Other factors, such as income, the prices of water-related appliances, household size, house size, and weather, etc. are also expected to have some influence on water demand. Based on these considerations, a model for domestic water demand is presented below.

As discussed previously, the *price effect* under block-rate pricing enters the demand equation indirectly. If consumers are well-informed and enough concerned with the price structure, they respond to the marginal price (MP), that is, the price of their final consumption block. But fully informed consumers are also aware of the benefit that they gain by having paid less on the initial blocks. This benefit enters the demand equation as the difference variable—the difference between what the consumers actually pay and what they would have paid had all units been priced at the marginal price. The difference variable (DV) is computed as follows:

$$DV = [P_1Q_1 + P_2Q_2 + P_3(Q-Q_1-Q_2)] - [P_3Q] \quad \dots \quad \dots \quad \dots \quad (1)$$

Where  $P_1$ ,  $P_2$ , and  $P_3$  are the respective prices charged under the successive blocks.  $Q_1$  and  $Q_2$  are the respective consumption limits for the first two blocks.

Alternatively, if the consumers are not fully aware of the block-rate schedule or tariffs are too low to cause concern, consumers approximate the average price of water by dividing the total water expenditure in a billing period by the quantity of water consumed in that period. The average price (AP) is computed as:

$$AP = [P1Q1 + P2Q2 + P3 (Q-Q1-Q2)] / Q \quad \dots \quad \dots \quad \dots \quad \dots \quad (2)$$

The correct specification of price is largely a circumstantial question. For example, in Zaragoza, Spain, where the tariff rate consists of 205 consumption blocks, it is reasonable to assume that consumers cannot be fully aware of such a complex tariff structure, and therefore AP specification can be used.<sup>8</sup> In the present case there are only three blocks and, analogously, it can be argued that the MP specification is suitable. On the other hand, tariffs are low, and consequently many consumers are not likely to be sufficiently concerned with their water bills to be induced to study the tariff schedule. However, a more rigorous approach can also be adopted.

As discussed in the literature review, Nieswiadomy and Molina (1991) have proposed a test to determine the correct price specification in the model. Under increasing block rates, the perceived price ( $P^*$ ) must lie somewhere between the average and marginal prices. Let ' $k$ ' be a parameter that measures *price perception*. We may write,

$$P^* = MP (AP/MP)^k$$

The value of ' $k$ ' will lie somewhere between zero and one. If ' $k$ ' is found to be zero, then MP is the perceived price. If it is equal to one, the perceived price is AP. If neither case holds, then the perceived price lies between AP and MP.

To test the value of ' $k$ ', the following equation is estimated:

$$\ln Q = a_0 + a_1 \ln MP + a_2 k \ln (AP/MP) + \text{Sai} X_i \quad \dots \quad \dots \quad \dots \quad (3)$$

Where  $X_i$  denotes predetermined variables.

Table 3

*Descriptive Statistics*

Variable	Mean	S.D.	Min.	Max.
Consumption (1,000 gallons per billing period)	17.9	14.9	2.0	155.1
Average Price (Rs)	17.7	2.4	9.2	26.0
Household Size	6.3	1.8	2.0	11.0
Plot Size (marlas)	8.7	13.9	1	160
Property Value (Rs lacs)	29.4	35.5	2.0	250.0
Water Expenditure (Rs)	340.1	373.6	18.4	4033.9
Temperature (Celsius)	30.4	6.2	18.5	38.6

<sup>8</sup>Arbues, Fernando and Villanua Inmaculada (2006) Potential for Pricing Policies in Water Resource Management: Estimation of Urban Residential Water Demand in Zaragoza, Spain.

Standard t-test was applied to test the value of 'k'. The results of this test turned out to be inconclusive. Our own judgement of the study area and the fact that the water tariffs are exceedingly low, advocated the use of AP specification.

Household water use is expected to increase with increase in income. More affluent households are likely to use water less vigilantly than low income households. They are also more likely to use water for washing cars, watering lawns, and swimming pools. A strong relationship has also been found between use of water-based appliances and household water demand [Batchelor (1975)]. However, reliable data of these indicators can be difficult to obtain. Therefore, information about the house value was used as an indicator of wealth, a proxy for income, hoping that it would also take into account some of the other related variables.<sup>9</sup>

The size of the dwelling and the number of residents is also expected to influence water use. Larger houses need more water for cleaning and irrigation of lawns, thus water use should increase with the house size. The relationship of demand with the number of residents is, however, not so direct. Generally, high income families are smaller than low income families. Per capita water consumption may, therefore, be lower in low income families, in which case there may be a negative relationship between household size and water consumption.

Three water-related activities are predominantly influenced by weather: watering lawns, using room-coolers, and bathing. As temperatures rise, these activities become more frequent. The average temperature over the billing period has been included in the demand model to capture this effect.

Past bills, and therefore consumption patterns, are likely to have some influence on consumers' decision-making in the future. Moreover, this effect is likely to decline with time: older bills wielding lesser influence than more recent bills. In such a situation, Koyck (1954) has proposed substituting the lagged explanatory variables by one single lagged dependent variable that appears among the regressors.<sup>10</sup> Following this proposition, a lagged consumption term has been included. The coefficient of this variable must be positive and must not exceed one.

Table 4

*Notation and Variable Description*

Variable	Description
Qt	Quantity of water in gallons consumed in billing period <i>t</i>
AP	Average price in Rupees
W	Property value in Rupees.
NR	Number of residents
L	Plot size in <i>marlas</i>
T	Maximum average temperature in degree centigrade during period <i>t</i>
Dmo	Meter ownership dummy
Dait	Dummy for residence in Allama Iqbal Town
Dabt	Dummy for residence in Aziz Bhatti Town
Dgbt	Dummy for residence in Ganj Baksh Town
Drt	Dummy for residence in Ravi Town
Dst	Dummy for residence in Shalimar Town

<sup>9</sup>Following Batchelor (1975), and Nieswiadomy and Molina (1989, 1991).

<sup>10</sup>See Koutsoyiannis (1972) *Theory of Econometrics* (2nd ed.). pp. 304-6.



Meter reading is carried out by WASA with a back-lag of two months: that is, for the billing cycle March-April, the meter is read in the last week of February. For the subsequent cycle, May-June, the meter is read in the last week of April. In this way, the March-April bill is based on January-February consumption, and May-June bill is based on March-April consumption. The dependent variable used in this study is the *consumption during the billing period*, i.e., the previous month’s meter-reading, rather than the meter-reading recorded in the billing period. Eighteen meter readings were recorded per household.

As discussed above, many factors cause variability in demand patterns across households: household income, per capita income, ages of residents, lawn size, car ownership, and use of water-related appliances. However, not all these variable could be included in the demand model. To estimate these differences across groups, a fixed effects model (FEM) is used, based upon dummy variables assigned on the basis of geographical location. Five intercept dummies have been introduced for Aziz Bhatti, Allama Iqbal, Ganj Baksh, Ravi, and Shalimar towns. Nishtar town is the benchmark category.

As discussed in the literature review, there is no theoretical basis for adopting any specific functional form. Past studies have used linear, semi-log, and double-log forms. The MacKinnon, White, and Davidson test (MWD test) was used to choose between linear and logarithmic forms. The results recommend logarithmic functional forms. However, there were no *a priori* grounds for choosing between semi-log and double-log functions, and therefore, both functions were estimated. Double-log models have the advantage that their estimators give the elasticities of the variables, thus simplifying interpretation. Semi-log models are useful to estimate elasticity across different population groups, as the coefficients give ‘semi-elasticity’: elasticity of the dependent variable with respect to varying values of the regressors. The following demand model was estimated:

$$AP = [P_1Q_1 + P_2Q_2 + P_3(Q - Q_1 - Q_2)] / Q \quad \dots \quad \dots \quad \dots \quad \dots \quad (4)$$

*Semi-log:*

Table 4

*Results*

Variables	Coefficient	t-stat
R <sup>2</sup>		0.57
F-Stat		290.67
Constant	1.66	(17.41)*
AP	0.01	-1.9
Dmo	0.02	(-0.64)
L	0.002	(4.22)*
NR	0.03	(8.45)*
Qt-1	0.02	(35.28)*
T	0.005	(5.05)*
W	5.57E-09	(2.33)*
<b>Fixed Effects</b>		
Dabt	0.08	(3.50)*
Dait	0.17	(6.75)*
Dgbt	-0.04	(-1.50)
Drt	0.07	(2.90)*
Dst	0.12	(5.26)*

\*= significant at 5 percent level.

$$\ln Q = \beta_0 + \beta_1 AP + \beta_2 T + \beta_3 W + \beta_4 NR + \beta_5 L + \beta_6 Dmo + \beta_7 Dabt + \beta_8 Dait + \beta_9 Dgbt + \beta_{10} Drt + \beta_{11} Dst \quad \dots \quad \dots \quad \dots \quad \dots \quad (5)$$

Since price is endogenously determined in the model, a simultaneous equation bias is likely to arise. The Hausman test was used to check if the simultaneity problem existed. Results showed that both price variables, as well as the difference variable created a simultaneous equation bias under OLS. The 2SLS technique was used to eliminate this bias. In the first stage, an instrumental variable was created for price, by separately regressing AP on all pre-determined variables as well as the three block prices. In the second stage, OLS was used to estimate equation three by replacing AP by the calculated instrumental variable.

### 3.2. Sample

The sampling frame consists of all domestic households that were metered prior to the beginning of the study period, i.e., January 2004. The correct number of such connections was not available, but an estimate was made using the available information. In 2007 the number of residential connections provided by WASA stood at 480,000. Out of these, only 30 percent were metered, with 24 percent metres being functional.<sup>11</sup> Therefore, in 2007, there were 34,560 effective metered domestic connections. Back in 2004, this number would have been even smaller.

As we go back in time, the number of metered connections, and hence the sampling frame, becomes smaller. Moreover, socio-economic and demographic characteristics, such as household size and income, would have significantly changed for each sampling unit over a long time frame. Variation in these variables is difficult to measure and would have created considerable errors in the data.

It was intended that the time frame should include at least one tariff change, in order to better capture the price effect. However, as mentioned earlier, tariffs have remained unchanged since May 2004. Before that, tariffs were last increased in January 1998. In order to include both (or more) tariff changes, the initial timing would have to be set earlier than 1998. But that would not have been viable due to the reasons discussed above.

Because of these considerations, a sample of 156 functional meters was selected and studied for a period of three years, i.e., 2004 to 2006, to include one tariff change while allowing for consistency of socioeconomic and demographic variables of each unit over this period.

## 4. RESULTS

The estimated demand model explains 57 percent variation in water consumption and is statistically significant. Plot size, household size, property value and weather have been found to significantly influence the household demand for water. The price variable turned out to be insignificant in the model, indicating an inelastic demand for water (see Table 4).

<sup>11</sup>Dysfunctional meters are often not timely repaired. When a meter stops working, subsequent bills are based on the last correct reported reading.

The most significant impact on consumption is that of number of residents. Elasticities calculated on the basis of averages showed that a one percent increase in household size increases consumption by 0.19 percent. That is, a household with eleven members consumes 1.9 percent more water than a ten-member household.

Temperature has the second largest impact on water demand with a ten percent increase in temperature leading to 1.5 percent higher consumption. However, the impact of plot size and property value on water consumption was negligibly small.

## 5. POLICY RECOMMENDATIONS

Since the demand for water is inelastic to prices, consumption will remain constant in the face of a tariff increase, adding to the revenues of the WASA. The data shows that the average household consumes 8,900 gallons of water per month, with monthly water and sewerage costs amounting to Rs 248. If tariffs are increased across the board by 10, 30, or 50 percent, water bill still remains affordable (see Table 5).

A drawback of these computations is that they are based on current average consumption patterns, and do not give any indication of how the tariff increase will affect households with varying socioeconomic settings, particularly income levels, and under higher tariffs. For example, at higher tariffs, household water demand may not remain unresponsive to price changes. For low income households, demand may be sensitive even at the existing tariff levels.

The effect of a pricing policy may not be uniformly felt across all income groups. Past studies have found that indiscriminate tariff increase affects lower income households more than higher income households [Agthe and Billings (1987); Renwick and Archibald (1998)]. If this disparity gets large enough, it can threaten the lifeline supply of vulnerable households.

Table 5

### *Average Monthly Household Bill*

Avg. Bill	Rs 248
After Tariff Increase	
10%	Rs 273
30%	Rs 323
50%	Rs 372

As a rule, water expenditure should not exceed five percent of the household income [WASA (2005)]. The average household size in the sample was 6.3 with per capita lifeline requirement being 13.1 gallons per capita day. This gives the approximate lifeline water requirement for an average-sized household equal to 2,800 gallons per month costing a bill of Rs 62. For a household with Rs 5,000 monthly income, this expenditure amounts to a bare 1.2 percent. If the tariff in the first block is increased by 50 percent, the lifeline consumption cost will amount to only 1.8 percent of the expenditures of a household with above-mentioned features (see Table 6).

Table 6

*Cost of Lifeline Consumption*

Avg. Bill	Rs 62
After Tariff Increase	
10%	Rs 68
30%	Rs 80
50%	Rs 92

The non-volumetric part can also be effectively used to increase revenues. Currently the monthly non-volumetric charge consists of a connection fee of Rs 3 and meter charge of Rs 12, that is, all households indiscriminately pay fixed charges of Rs 15 per month. The connection fee can be increased, uniformly or discriminately, varying increasingly with the household's ability to pay. The best measure of ability-to-pay is household income, but it is difficult to oblige people to provide correct information about their incomes. Alternatively, non-volumetric charges can be based on property value, ARV, or plot size. Summing the discussion on pricing policies, one can see that there is significant room for increasing tariffs to achieve cost recovery objectives without risking lifeline supply.

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