Tropical Agricultural Research Vol. 17: 173 - 182 (2005)

Comparison of Residential Water Demand among Rural Semi-Urban and Urban Sectors in the Central Province of Sri Lanka

P.S.K. Rajapakshe and L.H.P. Gunaratne[1]

Department of Social Sciences, Faculty of Social Sciences and Humanities
Rajarata University of Sri Lanka
Mihintale, Sri Lanka

ABSTRACT. *The role of price as a demand management tool in regulating public amenities is debated in the literature. With this background, a study was undertaken to estimate the price elasticities of water demand and to identify the factors affecting the residential water demand in the urban, semi-urban and rural sectors in the Central Province of Sri Lanka. To assess the potential effects of the price policy as a residential water management tool, a water demand function was estimated using aggregate monthly time series data, where average residential water consumption was dependent on marginal price, difference price, temperature and rainfall. Log-log model was found as the best model specification for the demand function in all three cases and all the coefficients had the expected signs, except for the rainfall variable in the rural sector. Estimated price elasticities for marginal price were -0.22, -0.28, and -0.34 for the urban, semi- urban and rural sectors, respectively, which confirm the past findings of residential water demand being inelastic to its price. The study revealed that urban consumers enjoy higher benefits from the present subsidy policy compared to the semi-urban and rural sector consumers. The results suggest that it is important to consider changing the present uniform pricing policy for these three sectors. Although the results of this study indicate that a price increase which may not significantly help to conserve water, low price responsiveness can be used to increase the revenue of the water supply authorities.*

INTRODUCTION

Background

Millennium Development Goals (MDGs) declared by the United Nations recognizes the importance of having access to safe drinking water and adequate sanitation facilities by 2015 for all the citizens in a country. In Sri Lanka, the proportion of households that have access to a reliable water source in 2004 was about 71%, of which, only about 28% had an access to pipe borne water (Central Bank of Sri Lanka, 2004). National Water Supply and Drainage Board (NWSDB), the main national agency responsible for supplying piped water in Sri Lanka has estimated that the investment requirements for the water supply to achieve MDGs would be Rs. 85 billion (Rs. 10 - 12 billion per year). However, the annual

[1] Department of Agricultural Economics and Business Management. Faculty of Agriculture. University of Peradeniya, Peradeniya, Sri Lanka.

allocation by the government for this purpose has been only around Rs. 7 billion (Central Bank of Sri Lanka, 2004). This highlights the need for alternative funding sources as well as economic manipulation of existing resources so as to achieve the MDGs on water supply and sanitation.

The residential water demand in Sri Lanka has grown significantly over the last decade with the spatial and temporal changes in rainfall, population, urbanization and economic development. The two major factors threatening the sustainable management of residential water demand in Sri Lanka are improper pricing and deficiencies in regulations that lead to wastage and over-exploitation. Even though a proper pricing system for water seems a straightforward and simple way to manage this valuable resource, it can be a very complicated and controversial matter in practice, particularly in developing countries due to many reasons. Water is an essential commodity for sustaining human life, and pricing would make it inaccessible or too costly for the poorest. In a developing country like Sri Lanka, depriving the majority of the poor people from a basic essential commodity is not politically and ethically desirable. Therefore, the degree of acceptance of water pricing in developing countries may be much less than that in developed countries (Gunatilake *et al.*, 2001). On the other hand, market forces cannot determine the right price for water, since water is still considered as a free good and there is no clear market for domestic water.

Under-pricing and free provision of water persist in developing countries. Sri Lanka provides water for irrigation free of charge and provides water for residential sector at a subsidized rate based on the increasing block-pricing schedule. Cost of pumping, purification, and distribution of the water for domestic purposes are higher than the revenue collected from the water consumers by the water supply authorities. For example, The National Water Supply and Drainage Board (NWSDB), the main residential water supplier in Sri Lanka spends approximately Rs. 24 to supply one unit (1000L) of treated water (Central Bank of Sri Lanka, 2004). According to the existing increasing block water tariff structure, NWSDB charges are only a nominal price like Rs. 1.25 for the first 10 units (10,000L) of water supplied to the residential sector. Of the total water consumption, about 70% of consumers are in the residential sector, but it contributes only to one third of the total revenue (Central Bank of Sri Lanka, 2004). However, NWSDB covers the part of this additional cost through the water supplied to the commercial and industrial sectors, charging a higher price based on a flat rate system.

Administrative and institutional framework

NWSDB is the main national agency responsible for supplying piped water in Sri Lanka. The NWSDB is responsible for the planning, designing, construction, distribution, and operation and maintenance of most of the urban and rural water supply and sewage schemes in the country. At present there are over 300 water supply schemes under this body and, billing, collection, and other operations and policies implemented through its regional offices. The NWSDB spends a total sum of US$ 38.57 million annually to purify and distribute water with a return of only about US$ 25.72 million (Gunatilake *et al.*, 2001). However, in some areas, the local government authorities such as the *Pradeshiya Sabhas* and Municipal Councils also operate the water supply schemes. The Kandy and Nuwara Eliya Municipal Councils are such local authorities responsible for local water supply to the urban areas.

Table 1. Water supply by The National Water Supply and Drainage Board

Item	2003	2004
Total no. of water supply schemes	280	287
Total no. of new connections given during the year	49,789	57,491
Total no. of connections given (as at end year)	782,724	841,215
Total water production (Mn. Cu. Mt)	357	367

Source: Central Bank of Sri Lanka, 2004

There are two types of pricing mechanisms practiced for water pricing. They are the flat rate (where rate is independent from the quantity consumed) and unit pricing (where price changes with the amount of water consumption). The flat rate system is being currently practiced by the water supply authorities for the industrial and commercial sector. However, the flat rate system lead to excessive use of water since the marginal price of additional water consumption is zero even though marginal cost of supplying water is above zero. The general water bill consists of two categories of charges such as fixed and variable or consumption charges. The consumption charge varies with the amount of water consumption and it can be charged under the flat rate system, increasing block rate system or decreasing block system. The NWSDB and other water supply authorities in Sri Lanka are currently operating a policy of increasing block rate system for residential water consumers in Sri Lanka. However, water consumers in the residential sector are charged uniformly across the country by NWSDB.

The increasing block water tariff is a widespread method of pricing water in most countries. The pricing system begins with a low initial cost of water that increases after reaching the maximum volume specified for a particular block range. This system will ensure affordable water to the poor segment of the country since they usually stay within the initial block range. On the other hand, when the price of water increases from the initial block to subsequent blocks, it would give an incentive for the reduction of wasteful water usage. Therefore, the increasing block rate system can be used as a water demand management tool as it leads to conserve water while increasing revenue from water provision. The water rates set by NWSDB over the past six years are presented in Table 2 and it shows how water prices have gradually increased over the years.

Table 3 shows that there were four price schedules set by the Kandy MC during the 1992-2005 period and these prices have gradually increased. However, it is clear that, in general, the water prices set by the Kandy MC were lower than the water prices followed by the NWSDB.

Table 2. Changes in the tariff structure followed by the National Water Supply and Drainage Board for the residential sector

Block Unit	Rate per unit (Rs.)			
	Aug. '99- Dec. '00	Jan. '01- May '02	Jun. '02- Feb. '05	Mar. '05- to date
Fixed Charge	35.00	40.00	50.00	50.00
1-10	0.00	1.00	1.25	1.25
11-15	2.75	2.00	2.50	2.50
16-20	2.75	5.00	6.50	8.50
21-25	9.50	13.00	20.00	30.00
26-30	18.00	24.00	45.00	50.00
31-40	20.00	30.00	45.00	60.00
41-50	25.00	40.00	45.00	70.00
51-75	38.00	45.00	45.00	75.00
Over 75	40.00	45.00	45.00	75.00

Source: NWSDB

Table 3. Changes in the tariff structure followed by the Kandy Municipal Council for the residential sector

Block Unit	Rate per unit (Rs)			
	Jul. '92 - Dec. '97	Jan. '98 - Dec. '98	Jan. '99 - Aug. '02	Sep. '02 - to date
Fixed Charge	15.00	20.00	30.00	45.00
1-10	0.60	0.60	0.00	1.50
11-20	1.00	1.50	2.50	4.00
21-25	3.00	5.50	7.50	14.00
26-30	3.00	7.00	12.00	22.50
31-37	3.50	7.50	15.00	28.00
38-44	4.50	8.50	18.00	34.00
45-51	5.00	12.00	20.00	38.00
Over 51	7.00	15.00	30.00	43.00

Source: Kandy Municipal Council

Past studies

Numerous past studies have estimated domestic demand for water use. indicating that own-price elasticity of water demand was less than negative one (Billings and Agthe, 1980; Renwick *et al.,* 1998). In Sri Lanka, there were few studies that have estimated the demand for domestic water consumption. Hussain *et al.,* (2002) estimated price elasticity for residential water demand in Sri Lanka using monthly time series for 60 months from January 1994 to December 1998. This study found that the estimated price elasticity for residential demand for water in Sri Lanka was -0.18. Gunatilake *et al.* (2001) have estimated the demand for domestic water in Kandy City using monthly data for 40 randomly selected households for a six-year period. They have used marginal price, difference price, income and household size as explanatory variables. Price elasticity and income elasticity for water in the study area was estimated as -0.34 and 0.08, respectively.

Rationale for the study

Both pricing as well as non-price measures can be used as demand side management tools for water resource management. Most policymakers argue that residential water demand is price inelastic and thus price is a relatively ineffective tool in managing residential water demand. The idea of residential demand as price inelastic is a technical definition; it simply means that a 1% increase in price results in a less than 1% decreases in consumption. Inelastic or elastic must be assessed in relation to a specific range of prices and consumers response to higher prices, but at a rate less than proportionate to the price increase (Renwick *et al.*, 1998). Though there are studies available in this area, none of these had attempted to empirically compare the demand relationship among the rural, semi urban and urban areas in Sri Lanka. This study attempts to fill this gap by systematically analyzing the price responsiveness for water among the rural, semi-urban and urban areas in Central Province in Sri Lanka, based on aggregate time series data. The result of this study will enhance the understanding of the factors influencing urban and rural water demand in Sri Lanka and can be useful to water policymakers in designing urban and rural water pricing policies and in forecasting rural, semi-urban and urban water demand. Therefore, the aims of this study are to determine the price elasticity of residential demand for water of selected rural, semi-urban and urban areas and identify how current water subsidy policy affects to different sectors in Central Province in Sri Lanka. The factors affecting the residential water demand will also be identified.

MATERIALS AND METHODS

Modeling residential water demand

The specification and estimation of a household water demand function under an increasing block rate system has tended to be highly controversial. Most past studies that estimated household demand under an increasing block tariff structure have used average price (AP) as the only explanatory price variable. The AP represents a flat or uniform price regardless of class of user or amount used; hence, the Average Prices and Marginal Prices (MP) are the same (Billings and Agthe, 1980). Most of the earlier studies were based on AP and did not take into account any intermarginal effects caused by the increasing block water tariff structure pricing. Consequently some economists proposed MP as a better price variable due to its ability to account for intermarginal effects under the block-pricing schedule.

As quoted by Billings and Agthe (1980), Taylor (1975) introduced the concept of difference price (DP) along with the marginal price (MP). He suggested that a single price variable, AP or MP is not sufficient for the entire demand schedule stressing the importance of capturing the budget constraint facing the consumers. This concept was further developed by Nordin (1976) who introduced a "difference price" variable, which is referred as the Taylor-Nordin's difference variable. It is the difference between the actual payment for the water and what the payment would have been if the water quantity were consumed at the marginal price. It measures the income effect of the intramarginal price changers under the increasing block rate system (Hussain *et al.*, 2002). The difference variable is an implicit subsidy because the consumer would be paying more if only the entire quantity consumed is charged at a higher marginal price applicable to a higher block point.

Empirical model

It is assumed that the demand for domestic water under the block rate system is determined by a variety of factors. However, based on similar past studies the following factors were used in the analysis. The demand function was constructed as:

WC = f (MP, DP, R, T)

Where:

WC = Average monthly domestic water consumption (in cubic meters)
MP = Marginal Price (in Rs.)
DP = Difference Price (in Rs.)
R = Average monthly rainfall (in mm)
T = Average monthly temperature (in Celsius)

Marginal price variable captures the effect of intermarginal price changes on demand. Since there was no block wise monthly data available on water consumption, MP of water for the domestic sector was calculated based on the block price corresponding to the average monthly water consumption per household. There were three price changers occurring during the study period, which provided adequate variation for the econometric analysis.

The difference price is the difference between the actual monthly bill payment for the water and what the payment would be if all units of water were consumed at the marginal price. This captures the effect of intramarginal rate changes on water demand under increasing block price schedules, in accordance with the "Taylor-Nordin" specification (Renwick *et al.,* 1998). The price variables (MP and DP) were deflated by using Colombo Consumer Price Index (CCPI) to derive the real values. Even though income affects the water demand, it was not included into the model since the sector-wise per capita income data were not available.

Data collection

In order to represent the urban, semi-urban and rural sectors in the Central Province, water supply schemes in Kandy Municipal Council (MC) area, Udu-Yatinuwara and Medadumbara were selected. The NSWDB operates the Udu-Yatinuwara and Medadumbara water supply schemes while Kandy MC operates the water supply scheme in Kandy city.

This study was entirely based on secondary time series data collected monthly for 60 months for rural and semi -urban sectors from January 2000 to December 2004 and for 84 months for urban sector from January 1998 to December 2004. The data on aggregate monthly reseidential water consumption and total number of monthly active connections were obtained from the data base maintained by the NWSDB Central Region Office at

Getambe for the semi-urban and rural sectors, and urban sector data was obtained from the Kandy MC database. The schedules of water price changes over the years were taken from the NWSDB and Kandy MC water tariff records. The average monthly temperature and rainfall data were collected from the Natural Resources Management Centre (NRMC), Department of Agriculture, Peradeniya.

RESULTS AND DISCUSSION

Table 4 presents a summary of all the tabulated data related to the water consumption in the selected rural, semi-urban and urban sectors. It shows that the average monthly consumption in urban sector is about 21.14 units per month, which is higher than the monthly consumption of both rural and semi-urban sectors.

Table 4. Summary of data used for the estimation of household water demand model

Variable	Rural	Semi-urban	Urban
No of connections	2480	14515	16318
Total consumption (units/month)	38317	241434	343689
Average consumption (AC) (units/household)	15.53	16.75	21.14
Average marginal price (MP) (Rs./unit)	3.61	5.07	7.23
Average monthly actual payment- (Rs./household, under increasing block rate- with implicit subsidy)	24.28	29.96	48.23
Monthly payment if water consumed at MP (Rs./household, without implicit subsidy- MP*AC)	57.07	85.82	159.83
Difference price (DP) (Rs./household, implicit subsidy accrued under increasing block rate)	32.79	55.85	111.61
Subsidy (Rs. per unit) (DP/AC)	2.11	3.34	5.27

All the values are averages

It may be the case that people in the rural sector have an opportunity to access other alternative water sources such as wells, lakes, streams rather than totally depend on the water supply of the NWSDB. Above table also shows that in the residential sector, willingness to pay for an additional unit of water consumption is different in different sectors (which are referred as MP). It is highlighted that the marginal prices for water consumption are 7.23 Rs./unit, 5.07 Rs./unit and 3.61 Rs./unit for urban, semi-urban and rural sector respectively. Also, actual monthly payment for water is about Rs. 48.23 per month in the urban sector and this is the highest followed by semi-urban sector. This is simply due to the fact that monthly payment is based on the monthly water consumption units.

The price difference reflects the monthly implicit subsidy obtained by the water consumers for increasing block water tariff structure. The mean difference prices were 112, 56, 33 rupees per month for urban, semi-urban and rural sector respectively (Table 4). This reveals that a higher portion of the benefits of the subsidy is taken by the urban sector water consumers through the current increasing block rate water tariff structure.

Table 5 gives the estimates of the demand models. In this analysis, the linear model, log-linear and log-log models were considered to find out the best model. In all the cases, log-log model appears to be the best specification as indicated by high adjusted R^2 of the selected models as well as satisfactory significant coefficients. No autocorrelation was found with the all the selected models as indicated by the Durbin-Watson statistic. As shown in Table 5, all the relevant coefficients were with expected signs except the rainfall variable in rural sector. However, only the marginal price and difference price are statistically significant at 0.05 significant level for all sectors.

Table 5. Estimates of the residential water demand model

Region	Variable	Coefficient	Standard error	*P*-Value
Kandy (Urban)	Marginal Price	-0.22*	0.07	0.00
	Difference Price	0.27*	0.05	0.00
	Temperature	0.30	0.25	0.23
	Rainfall	-0.004	0.01	0.73
	Adjusted R^2	0.68		
	DW statistic	1.81		
	No. of obs.	84		
Udu-yatinuwara (Semi-urban)	Marginal Price	-0.28*	0.11	0.01
	Difference Price	0.22*	0.06	0.00
	Temperature	0.37	0.22	0.10
	Rainfall	-0.01	0.00	0.23
	Adjusted R^2	0.36		
	DW statistic	1.86		
	No. of obs.	60		
Medadumbara (rural)	Marginal Price	-0.34*	0.10	0.00
	Difference Price	0.25*	0.054	0.00
	Temperature	0.35	0.21	0.11
	Rainfall	0.009	0.01	0.29
	Adjusted R^2	0.54		
	DW statistic	1.97		
	No.of obs.	60		

* indicates statistical significance at $p < 0.05$.

Since the selected specification is a log-log model, the coefficient itself indicates the elasticity (Gujarati, 1995). Price elasticities are -0.22, -0.28 and -0.34 for urban, semi-urban and rural sector respectively. The result shows that for a 1% increase in the marginal price, consumers reduce their water consumption by 0.22%, 0.28% and 0.34% in urban, semi-urban and rural sector respectively. Urban sector indicated low price responsiveness compared to other sectors and this may be due to the water tariff structure followed by the Kandy MC being significantly lower than the tariff structure followed by the NWSDB.

Rural sector price responsiveness for water demand is higher than that of the other sectors. If water prices increases, then rural people reduce water consumption at a rate higher than other sectors. This could be due to inability to afford the higher prices or having access to alternative sources such as wells, lakes, streams and rain water harvesting.

The estimates of price elasticities confirm that residential water demand is inelastic to its price, but not perfectly so. There is price responsiveness on domestic water demand and the estimated results suggest that price is a moderately effective instrument in reducing residential demand within the observed range of prices. The difference price coefficients also exhibit the expected positive sign and this expectation is due to the positive relationship between the implied subsidies given to the water consumers through the increasing block rate system. The coefficients of the price difference are 0.27, 0.22 and 0.25 for urban, semi-urban and rural sector respectively and the positive sign reflect that moderate success of the current water subsidy policy based on the increasing block price structure. This result shows that for a 1% increase in the price difference (implicit subsidy given to the consumers), the demand for water on the average would increase by about 0.27%, 0.22% and 0.25% respectively. However it is clear that the higher benefits of the subsidy policy are accrued by the urban sector water consumers rather than semi-urban and rural sector consumers. This is because the urban households consume more water than other sectors and they are in the higher block range (approximately between 20-25 or 25-30 block range) while rural sector water consumers are in the initial block range (1-10 or 10-15). The current policy of water subsidy implies that a relatively large proportion of the benefits are enjoyed by the upper middle and higher income groups of the country rather than the poorest segment of the country. Even though temperature and rainfall factors are showing expected signs, except rainfall variable in rural sector, both are statistically insignificance at P=0.05 level.

CONCLUSIONS

This study was carried out to estimate the price elasticities and to identify the factors affecting the demand for residential water consumption within the selected water supply schemes, which represent the urban, semi-urban and rural sectors in Sri Lanka. To assess the potential effects of price policy as a residential water resource management tool, an econometric model of residential water demand was formulated and estimated using monthly time series data. The estimated marginal price elasticities confirm that residential water demand is inelastic to its price, but not perfectly so. There is a price responsiveness of residential water demand and the estimated results suggest that price is a moderately effective instrument in reducing residential demand within the observed range of prices. Also, this study reveals that price responsiveness differs among the sectors and thus there is a potential to introduce different water pricing policies for different sectors rather than following a uniform pricing policy across the country. It was revealed that a higher portion of the benefits of the subsidy is enjoyed by the urban sector water consumers from the current increasing block rate water tariff structure. Further, since water consumption is not very responsive to price changes, water supply authorities could raise revenue by increasing water prices.

As these results indicate that pricing policies have a low effectiveness in improving water conservation (since consumption responsiveness to price change is low) relatively large price increases would be needed to significantly reduce residential water use.

However, that could badly affect the poorest segment of the country. Thus, it is important to combine pricing policy together with non-price alternative demand side management tools (such as public awareness programs, education, subsidies, water use restrictions, *etc*) to reduce residential water demand and enhance water conservation. Such an approach would be both effective and socially acceptable than depending solely on water pricing as a demand side management tool.

ACKNOWLEDGEMENTS

Authors would like to extend their deepest gratitude to the officers of the NWSDB Central Regional office at Getambe, the Municipal Council, Kandy and the Natural Resources Management Centre (NRMC). Peradeniya for providing the necessary data to carry out this study.

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