Water Resources Development, Vol. 17, No. 3, 277–288, 2001

The Economics of Household Demand for Water: The Case of Kandy Municipality, Sri Lanka

HERATH M. GUNATILAKE[1], CHENNAT GOPALAKRISHNAN[2]* & INOKA CHANDRASENA[1]

[1]*University of Peradeniya, Sri Lanka;* [2]*Department of Natural Resources and Environmental Management, College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa, 1910 East-West Road, Honolulu, HI 96822, USA. Email: chennat@hawaii.edu*

ABSTRACT *This study estimates the demand for domestic water in a fast-growing city of a developing country. Monthly data for 40 randomly selected households for a six-year period were used for the estimation. There were three price hikes during the study period, which provided adequate variation in the prices for an econometric estimation. A log–log model was selected as a proper specification for the demand function. Marginal price, difference price, income, and household size were used as the independent variables. After correcting the data for auto-correlation and heteroscedasticity, the final model was estimated. Results show all the expected signs with statistical significance. Price elasticity (marginal) and income elasticity for water in the study area are estimated to be − 0.34 and 0.08, respectively. Thus, our findings confirm the previous findings that water is neither price- nor income-elastic. Given these responses, a price hike may not help conserve water in the study area. However, very low price responsiveness can be used to increase water revenues of the municipality.*

Introduction

Water resource management has to deal with quantity as well as quality problems. The quantity problem refers to a steady decline in the physical availability of water in the face of rapidly increasing demand in many parts of the world. The unprecedented demand on water resources during the last half of this century is largely the result of "population growth and urbanization, together with changes in production and consumption" (Sherbinin, 1998). Even if the physical availability exceeds the demand, poor water quality can cause water scarcity. The quality problem is largely due to accumulation of pollutants such as chemicals, dyes, fertilizers, salt, bacteria, and organic wastes.

The water situation in developing countries is extremely dire. This is evidenced by the fact that "over one billion people in the developing world have no access to clean water and two billion lack adequate sanitation" (World Commission on Water, 2000). This inequality in access to water is largely due to inefficient allocation of water resources. Among the many solutions suggested, a proper pricing system for water has been identified as of paramount importance. This is corroborated by the recent report of the World Commission on Water for the 21st Century (2000), according to which "the single most immedi-

* *Correspondence to Chennat Gopalakrishnan.*

0790-0627 Print/1360-0648 On-line/01/030277–12
DOI: 10.1080/07900620120065075

ate and important measure" in correcting the current water situation "is the systematic adoption of full-cost pricing for water services".

Although proper pricing of water seems a straightforward and simple matter, it can be a very complicated and controversial matter in practice due to many reasons. First, water is considered to be an essential commodity for human survival. In developing countries, depriving the majority of the poor people from a basic essential commodity is, in general, not politically feasible. Second, due to similar reasons, water is a highly politicized commodity. Third, when poor farmers and households do not make adequate surpluses from their economic activities they fail to pay water prices. Therefore, the degree of acceptance of water pricing in developing countries may be much less than that in developed countries.

As a result of various practical and ethical reasons, under-pricing and free provision of water is widespread in developing countries (Wichelns, 1991; Rogers, 1993; DeShazo, 1998). Sri Lanka is not an exception in this regard as irrigation water is free of charge and household and industrial water supplies are, generally, under-priced. Costs of pumping, purification, and distribution of the urban water projects are higher than the income they collect from the consumers. For example, it costs the National Water Supply and Drainage Board (NWSDB), the main residential water supply body in Sri Lanka, US$0.25 to purify one cubic meter of water. But the existing tariff system charges only a nominal price of US$0.042 for the first 20 units of water supplied to residences. Likewise, NWSDB incurs an average expenditure of over US$714.28 in the provision of new water supply connections. Consumers, however, are actually paying a price much less than (generally less than US$285) the cost of provision of water connections. The National Water Supply and Drainage Board spends a total sum of US$38.57 million annually to purify and distribute water with a revenue return of only about US$25.72 million.

Water provision authorities such as NWSDB and municipalities (in some areas municipal councils are responsible for provision of water) gain less revenue by provision of the service. Consequently, adequate amounts of resources are not allocated for the maintenance of the water supply systems resulting in their deterioration and a reduction of both the quality and quantity of water. Ultimately, it is the poor who suffer, since they cannot afford any alternatives (such as purified bottled-water). Therefore, it is not worthwhile to provide water freely or at highly subsidized rates, because, it eventually leads to the low-level equilibrium traps such as that described above (DeShazo, 1998).

Against the above background, this study attempts to find out the factors determining the demand for domestic water in Kandy, a fast-growing city in Sri Lanka. A description of the site and explanation of the water tariff system in the Kandy Municipal Council (KMC) area is followed by a discussion regarding some relevant issues in water pricing and the specifics of the demand function for domestic water. There is then a description of the data, and a presentation of the results from which the conclusions are drawn.

Water Supply in Kandy Municipal Council (KMC) Area

In many parts of Sri Lanka, the National Water Supply and Drainage Board (NWSDB) is responsible for the domestic water supply. However, in some areas the local government authorities such as the municipalities, town councils and village councils are entrusted with this task. The Kandy Municipal Council (KMC) is one such local authority responsible for local domestic water supply. The KMC is located in the central highland district of Kandy. Kandy is situated approximately 100 km (62 miles) NE of the capital Colombo, it is between 500 and 700 feet above sea level and falls into the "wet mid-country climatic zone" since its annual rainfall exceeds 1000 mm. The KMC occupies an area of approximately 25.6 km^2 and in 1997 its population was estimated to be 137 400 and growing.

Four main water schemes have provided water to KMC residents in the past. They were the Gatambe, the Roseaneth, Heerassagala, and Hantana water projects. The Roseaneth and Heerassagala water pumping stations have long been abandoned and are only used to get water to the Gatambe with the use of booster pumps. The Gatambe scheme provides the KMC area with 90% of its supply to the KMC area. Water purification adheres to World Health Organization (WHO) standards. Water consumption in the KMC area is estimated to be about 206 litres/day/capita. Water is pumped into the purification centre located at Gatambe from the Mahaweli Ganga River (Figure 1). Purified water is then taken along the Kandy–Colombo road to the main distributing reservoir (the R2 reservoir) near Kandy town. From there, water is distributed to all lower elevations in the Kandy township and outskirts through gravitational flow. There is another municipal reservoir located near to the R2 reservoir, where water can be purified at the standby treatment plant in emergencies. The R3 reservoir, a service reservoir, is used to distribute water when the R2 reservoir is closed for cleaning and purification purposes.

There are a few isolated areas that cannot get water from the R2 reservoir through gravitational flow because of their elevated locations. They are Bahirawakanda, Mapanawatura, Uplands, Peris Watta and Primrose (Figure 1). Of these, Primrose distributory reservoir gets water directly from the major pumping and purification centre at Gatambe. The others rely on booster pumps to boost the water pressure in the gravitational flow and relocate the water to reservoirs at even higher altitudes where water can again be distributed through gravitational flow. Elagolla is a separate pumping station, which operates independently from the main Gatambe pumping intake. It gets water from a tributary flow from the nearby mountain and provides water primarily to Dangolla and its suburbs.

In general, the cost of pumping, purification, and distribution of water is higher than the revenues collected from the consumers in the KMC area. Average total water use in this area is estimated to be 18 335 m^3/day, whereas the total water production is 31 641 m^3/day. The excess water production is distributed as "non-revenue" water (in communal pipes, which do not have meters). The non-revenue water supply in the KMC area accounts for 42% of the total production. KMC is trying to reduce its non-revenue water supply to 25% by the year 2015. Municipal officers say that water provision to the domestic sector generates no profit because they do it as a service. The main source of profit is from the non-domestic (industrial and commercial) water supplies, where high tariffs are charged on a flat rate basis.

KMC charges the water using an increasing block rate system. The rates vary depending on the type of end user, be they domestic, commercial, religious institutions, or government schools. Domestic water charges also differ according to the source. Water from the Gatambe plant is charged a higher price due

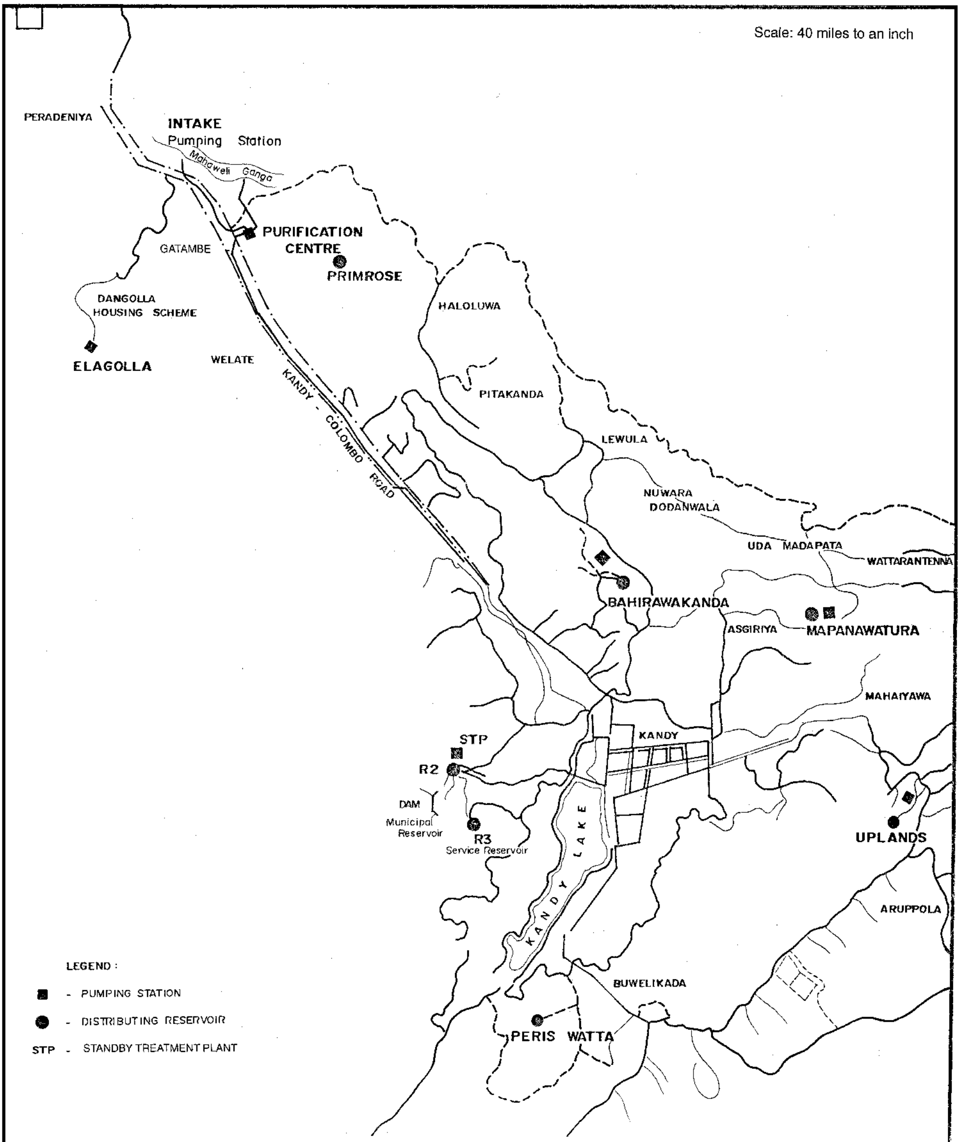

Figure 1. Main water distributory channels, pumping stations and distributing reservoirs in the KMC limit.

to the high quality of water. Water provided through the Hantana, Heerassagala and Roseaneth reservoirs incur lower fees. Previously, domestic water was charged from the first unit onwards in an increasing block rate system and water bills were collected on a monthly basis. Now, the KMC does not charge for the first 10 units, which means that if a household can maintain its water consumption within 10 units (10 000 litres) it does not need to pay the tariff (Personal Communication, 1999). Since 1992, the KMC water tariff structure has seen some revision. These changes are presented in Table 1.

Table 1 shows that there were three price schedules during the 1992–99

Table 1. Changes in the tariff structure of KMC, 1992–99

	Price in US dollars ($)		
Units of water	1992–1998	1998	1999
1–10	0.009	0.009	0.000
11–20	0.014	0.021	0.036
21–25	0.043	0.079	0.107
26–30	0.062	0.100	0.171
31–37	0.050	0.107	0.214
38–44	0.064	0.121	0.257
45–51	0.071	0.171	0.286
>51	0.100	0.214	0.429

period. From 1992 to 1998, the initial 10 units of water were charged at a rate of US$0.009 per unit. The charges gradually increased up to US$0.1 per unit when consumption exceeded 50 units. In 1998 the charges for all the units almost doubled except for the first 10 units (which remained at US$0.009 as a concessionary rate for the poor). This price structure underwent further revision in 1999 and remains in operation to date. Under the current system, prices per unit of water practically triple at each block consumption level, but the initial 10 units are now provided free of charge. These domestic price hikes described above provide a good set of data upon which to check the price responsiveness of domestic water consumption in the study area. Tourist hotels and other business establishments are charged a flat rate of $0.38 per unit and religious institutions are charged a rate of $0.035 per unit.

Conceptual Framework

Neoclassical economic theory asserts that at equilibrium, marginal cost for a product should be equal to the price in order to ensure the efficient allocation of resources. In addition to accounting costs, the economic costs include the opportunity cost of resource utilization. To obtain the full cost, the price of a resource should include the opportunity cost of consuming that resource. In the case of water, marginal costs are made up of three components: marginal production cost (MPC), marginal user cost (MUC), and marginal environmental cost (MEC) (Hartwick & Olewiler, 1998). Marginal production costs are the costs incurred directly by the utility such as for labour, energy, and capital treatment of the water, collection and distribution. Marginal user cost is the net benefit foregone by a future user, due to consumption of a non-renewable resource at present. Though water is generally considered as a renewable resource, if it were overexploited (for example, water will be overexploited when recharge is less than the rate of extraction), it would behave as a non-renewable resource. Under such circumstances, the present use of water precludes the use of the same amount of water by future generations. The cost incurred by the present users on future users is the MUC. The marginal environmental cost is the cost/damage caused to the environment, which can be due to negative externalities of production and consumption of water (DeShazo, 1998; Sterner, 1999).

Depending on the situation, water price should reflect relevant components of the above-described marginal costs. There are two main types of pricing mechanisms for water in practice. They are the flat rates (where rate is independent of the quantity used) and the unit pricing (where price is dependent on the quantity used). Under the flat rate system, charges are the same for all users, regardless of quantity consumed; for instance, households that use 100 units of water or, say, 1000 units would be charged the same price. This type of pricing would lead to inefficiency, since the marginal price of additional use of water would be zero, even though the marginal cost of the additional water units is not zero.

There are two types of unit pricing: declining block pricing and increasing block pricing. Under the declining block pricing system, the initial amount of water is valued at a high price and subsequent prices become lower. This system of pricing may lead to overexploitation of the resource and people who consume less subsidize those who consume more. Therefore, from a water conservation point of view, declining block rate systems are not very appealing. This price structure is used mainly due to the economies of scale in production and distribution of water. From a pure economic point of view, the supply of initial units will cost more compared to the later units. Hence, the declining block system may be appealing from a purely economic efficiency point of view (Sterner, 1999; Stevens *et al.*, 1992).

In contrast to the declining block pricing system, the increasing block rate system sets the price of the initial blocks of water at a low rate and gradually increases the rate according to increased rates of consumption. This has some advantages over the other system. When marginal price of water increases from the first to subsequent blocks, it may induce the reduction of wasteful water use. Moreover, increasing block rate pricing helps to accommodate the low-income consumers since they usually stay within the initial block consumption category (Stevens *et al.*, 1992; Hartwick & Olewiler, 1998). It may also lead to increased revenue from water provision and promote water conservation.

In many earlier studies, residential water demand was estimated without considering the block rate pricing system. For example, studies by Wong (1972), Young (1973), Gottlieb (1963) and Foster & Beattie (1979) used the average price disregarding the block structure. The average price represents a flat or uniform price regardless of class of user or amount used; hence, the average and marginal prices are the same (Billings & Agthe, 1980). Having understood that the average price does not accurately represent the changes in demand, some economists proposed the use of marginal price as a better price variable. The marginal price, however, does not take into account the associated income effects. In the work of Taylor (1975) and Nordin (1976), difference price was introduced as an alternative to the marginal price. Billings & Agthe (1980) showed that proper specification of the demand function requires inclusion of both the marginal and difference prices. Taking the evolution of the specification of the demand function for domestic water one step further, Shin (1985) and Nieswiadomy & Molina (1991) used a perceived price specification. A more recent development on this subject was by Hewitt and Hanemann (1995) who developed a discrete/continuous choice model for residential water demand.

This study uses a demand function that uses both marginal and difference prices. Using the average price (AP) alone in the demand function tends to produce large estimates of price elasticity in the block rate system (Billings & Agthe, 1980). This problem is severe when marginal price (MP) increases, while intra-marginal rates remain constant. If only the marginal price is used, income effects of a change in inter-marginal rate with constant intra-marginal price will not be properly accounted for. Difference price, as mentioned earlier, is included in order to account for this income effect. When a block rate schedule is used for the pricing of water, consumers are subsidized with respect to different blocks corresponding to their MP of water being consumed. As shown by Billings & Agthe (1980) and Terza & Welch (1982), if the MP had not been taken into account, it would have led to biased estimates in the price elasticity of demand. Since subsidy influences the income of the consumers, in return it causes an income effect. Theoretically, the value of the difference price (DP) and the income coefficient are expected to be equal whereas the signs are opposite. However, empirically it is not always true due to external effects.

Based on the theory of water demand under the block rate system, the demand function was specified as follows:

$$\text{Dw} = f(\text{MP}, \text{DP}, \text{I}, \text{H})$$

where

Dw = Household demand for water
MP = Marginal price
DP = Difference price
I = Income of the household
H = Household size

Data

This study uses a panel data set to estimate household demand for water in the KMC area. Time series data were collected from the bill records available at the water supply division of the KMC. Monthly bill data on the quantity of water used (Dw), the total payment, and household size (H) were collected for 40 randomly selected households using the billing records available at KMC office. The 40 households were selected as follows. First a list of all the households in the KMC was collected. Then a number was assigned to each household and a random number table was used to select the 40 households. The above-described data were gathered from January 1994 to December 1999 for each month. Altogether, the total number of observations available for this period was 2880. However, many observations were dropped as a result of inconsistent or erroneous data, for example, in households where the monthly water bills have not been issued and aggregated bills were generated, or where a water meter was either not installed immediately upon connection or had broken and a flat rate for consumption charged. In all, only 1451 observations were used for the estimation of the demand function.

Monthly water consumption data were directly obtained from the water bill records. Marginal price and difference price variables were calculated based on the bill information. Difference price was calculated as the difference between the actual payment for the water (bill payment) and what the payment would be if all units of water were sold at a marginal price. All 40 households were visited in order to establish income data for the period of 1993 to 1999. In addition to household income, data on the other variables that may possibly affect water consumption were also collected. These data included household

Table 2. Summary of data used for the household water demand model

Variable	Average	Standard deviation	Minimum	Maximum
Quantity consumed (units)*/month	29.49	18.59	0.10	140.0
Marginal price (US$/unit)	0.0771	0.0892	0	0.4285
Difference price (US$)	−2.505	5.1652	−60.0	0
Income (US$/household/month)	245.08	220.64	51.21	1542.86
Household size	4.25	1.15	2.00	7

Note: * 1 unit = 1000 litres.

size, number and type of toilets, garden area, number of vehicles owned by the family, availability of swimming pools, and presence of cottage industries that used water. These data were used in a cross-sectional demand model using the discrete/continuous choice model concept of Hewitt & Hanemann (1995). Most of the above variables, except household size, do not explain the variation in the water quantity demanded. Therefore, the results of the cross-sectional model are not presented here. A summary of the data used for the estimation of the final panel data model is presented in Table 2.

The average water consumption calculated from our sample equated to 29.49 units of water per month. This figure is very close to the overall average monthly water consumption of a household in the KMC area (27.8 units). This indicates that the 40-household sample is representative. Only 98 (6.75%) observations out of the 1451 observations indicated a consumption of less than 10 units of water per month. Thus, only a few households benefited from the subsidy provided through no charges for the first 10 units of water. On average, a household received US$2.505 as a subsidy due to the existing block rate pricing system. The distribution of the implicit subsidy is given in Table 3.

Model Estimation and Results

Previous researchers have used different functional forms in the estimation of demand functions for water. For example, linear specification was used by

Table 3. Distribution of the implicit subsidy due to the increasing block rate system

Difference price ($)	Number
0–0.36	500
0.37–0.71	276
0.72–1.43	208
1.44–7.14	338
7.15–14.28	69
> 14.28	60

Table 4. Diagnostic tests on heteroscedasticity

Test	Test statistic chi-square	Degrees of freedom	Critical value
BP–G* test	411.97	4	7.82
Arch test	72.09	1	3.84
Harvey test	32.69	4	7.82
Glejser test	407.16	4	7.82

* BP–G = Breusch–Pagan/Godfrey test.

Hanke (1970), Young (1973) and many other researchers. Log linear models were used by Young (1973), Danielson (1979) and Nieswiadomy (1992). Log–log models were used by Morris & Jones (1984) and Howe (1982). All these functional forms were tried in the present study and the log–log model was found to provide better statistical results.

A specification test was carried out to find the true specification of the model, applying the MWD test (Gujarati, 1995). The log–log model was run and the estimated values of the dependent variable were converted to anti-log values. Then the estimated dependent variable values were subtracted from these anti-log values. This new variable was incorporated into the log–log model and a *t*-test showed that the null hypothesis could not be rejected at a 0.05 significance level. The rest of the analysis was carried out for the log–log model. The log–log model provided the highest R^2 (0.75) and correct signs for all the variables. Since logarithmic functions are defined with only a positive domain, zero values of the difference variable were eliminated from the sample. Difference price assumes either zero or negative values. Since the negative values cannot be converted to log values the difference price was multiplied by –1 (minus 1) and then converted to the log values. Finally, the demand model was estimated for 1385 observations.

The initial run of the model using the ordinary least squares (OLS) technique to identify the data problems and violation of assumptions indicated an R^2 value of 0.75. Thus, the regression model explained about 75% of the variation in the quantity of water consumed. All the dependent variables, except for the income variable, showed expected signs and they were significant at 0.05. Diagnostic tests on auto-correlation showed a Durbin–Watson statistic of 1.12 indicating the presence of positive auto-correlation. A series of tests on heteroscedasticity also indicated the presence of heteroscedasticity. Table 4 presents the details of the heteroscedasticity diagnostic tests. As indicated by all the test statistics, homoscedasticity assumption is violated.

Following the methodology suggested by Greene (2000), the data were first submitted to a Prais–Winsten transformation to correct for auto-correlation. An OLS estimation then provided a Durbin–Watson statistic of 1.989 indicating no auto-correlation. The HET command in the SHAZAM program was then used to assess the model using the maximum likelihood method. The HET procedure does not provide a goodness of fit measure like R^2. However, the squared correlation between the observed and predicted values of the model was 0.66 and the log of the likelihood function was –3863.2. The final results are presented in Table 5.

As shown in Table 5, all the variables are significant at a 0.05 significance level and they all show the expected signs. Note that the difference price variable

Table 5. Final results of the demand model

Variable	Coefficient	Standard error	*T*-ratio	*P*-value
Marginal price	− 0.3365*	0.0169	− 19.88	0.000
Difference price	0.3454*	0.0058	59.39	0.000
Income	0.0800*	0.0158	5.07	0.000
Household size	0.3825*	0.0380	10.05	0.000
Constant	0.4295*	0.0815	5.27	0.000

* Indicates significance at 0.05 level.

should generally show a negative sign. This expectation is due to the positive relationship between the implied subsidies given to the consumer using the increasing block rate system. Recall that the difference variable assumes negative or zero values; therefore, the expected sign is negative. However, since we have multiplied the difference variable by –1, before converting it to log values in this regression, we should expect a positive sign.

According to Young (1973), Danielson (1979), Billings & Agthe (1980), Hanke & de Mare (1982) and Howe (1982), water demand is price inelastic. The present findings provide further empirical evidence on inelastic response to price variation. Since our model is a log–log model, the coefficient itself is the elasticity (Greene, 2000; Gujarati, 1995). The results show that for a 1% increase in the marginal price, consumers reduce water consumption by only 0.33%. This may further explain the essential nature of the commodity in consideration. Income elasticity of water is positive, but inelastic (0.08). As suggested by the results, the income increase will only have a marginal impact on water consumption. The current income range in the KMC area does not include extraordinarily high-income groups. When very rich people are in the sample, excessive water use for luxury items like swimming pools may result. Absence of such high-income groups may be the reason for the very low-income elasticity. Household size also explains a significant portion of the water consumption in the KMC area. The result with respect to household size also indicated the essential nature of water as a commodity.

The overall results suggest that water consumption is not very responsive to price changes. Under this circumstance pricing policies have limited scope in changing water consumption and hence water conservation. However, the inelastic nature of water consumption provides opportunities for revenue increases for the municipality by increasing water charges. Such water charges should, however, accommodate the poorer strata of the community. The scope of the analysis of this paper does not permit exact increases of water prices; hence we are not in a position to discuss the budget balance after a price increase. However, another important aspect of water price increases is that they may lead to changes in water consumption patterns and the income and elasticity of water use. If such a change takes place, then increasing the price of water may ultimately help conserve water.

Summary and Conclusions

This research was carried out to determine the factors affecting the demand for urban domestic water consumption within the KMC area. Time series data

(1994–99) for 40 households were collected. The data were incorporated into a heteroscedastic model after correcting for auto-correlation. All the expected signs were observed with statistical significance. Elasticity with respect to the marginal price was estimated to be -0.34. Income elasticity of water consumption was estimated to be 0.08. Thus, both income and price elasticity were inelastic as observed by many researchers before. It appears that the consumers in the KMC area treat water as a basic essential commodity.

Currently, in the KMC area water is provided at subsidized rates. Continuous supply of water at the current rates may eventually lead to low-level equilibrium traps and the collapse of the water supply system. The estimated inelastic relationships indicate that price increases will not lead to a significant reduction in water consumption. Therefore, a price hike may not be a good tool to achieve water conservation. However, the inelastic consumption responses indicate that price increases can be used as a tool to increase revenue collected from water sales. Such price increase, however, should be accompanied by adequate measures to ensure provision for poorer households.

References

Billings, R.B. & Agthe, D.E. (1980) Price elasticities for water: a case of increasing block rates, *Land Economics*, 56(1), pp. 73–84.

Danielson, L.E. (1979) An analysis of residential demand for water using micro time-series data, *Water Resources Research*, 15(4), pp. 763–767.

DeShazo, J.R. (1998) The economics of water resource management: avoiding low-level equilibrium traps, Environmental Economics & Policy Analysis Workshop, Harvard Institute for International Development, Harvard University.

Foster, H. & Beattie, B. (1979) Urban residential demand for water in the United States, *Land Economics*, 55 (February), pp. 43–58.

Gottlieb, M. (1963) Urban domestic demand for water: a Kansas study, *Land Economics*, 39 (May), pp. 204–210.

Greene, W.H. (2000) *Econometric Analysis*, 4th edn (New York, Macmillan Publishers).

Gujarati, D. (1995) *Basic Econometrics* (New York, McGraw Hill, Inc.).

Hanke, S.H. (1970) Demand for water under dynamic conditions, *Water Resources Research*, 6(5), pp. 1253–61.

Hanke, S.H. & de Mare, L. (1982) Residential water demand: A pooled, time-series cross-section study of Malmo, Sweden, *Water Resources Bulletin*, 18(4), pp. 621–625.

Hartwick, J.M. & Olewiler, N. (1998) *The Economics of Natural Resource Use*, 2nd edn (Addison Wesley Publishers).

Hewitt, J.A. & Hanemann, M. (1995) A discrete/continuous choice approach to residential water demand under block rate pricing, *Land Economics*, 71(2), pp. 173–192.

Howe, C.W. (1982) The impact of price on residential water demand: some new insights, *Water Resources Research*, 18(4), pp. 713–716.

Howe, C.W. & Linaweaver, F.P. Jr. (1967) The impact of price on residential water demand and its relation to system design and price structure, *Water Resources Research*, 3(1), pp. 13–32.

Morris, J.R. & Jones, C.V. (1984) Instrumental price estimates and residential water demand, *Water Resources Research*, 20(2), pp. 197–202.

Nieswiadomy, M.L. (1992) Estimating urban residential water demand: effects of price structure, conservation and education, *Water Resources Research*, 28(3), pp. 609–615.

Nieswiadomy, M.L. & Molina, D.J. (1991) A note on price perception in water demand models, *Land Economics*, 67, pp. 352–359.

Nordin, J.A. (1976) A proposed modification of Taylor's demand analysis: comment, *The Bell Journal of Economics*, 7, pp. 719–721.

Rogers, P. (1986) Water not as cheap as you think, *Technology Review*, 89(8), pp. 30–43.

Rogers, P. (1993) Integrated urban water resources management, *Natural Resources Forum*, 17(1), pp. 33–42.

Sherbinin, Alex de, V. Domka (with L. Bronley) (1998) *Water and Population Dynamics: Case Studies and Policy Implications* (Washington, DC, American Association for the Advancement of Science).

Shin, J. (1985) Perception of price when price information is costly: evidence from residential electricity demand, *Review of Economics and Statistics*, 67, pp. 591–598.

Sterner, T. (1999) The selection and design of policy instruments: applications to environmental protection and natural resources management, unpublished manuscript, Department of Economics, Gothenburg University, Sweden.

Stevens, T.H., Miller, J. & Wills, C. (1992) Effect of price structure on residential water demand, *Water Resources Bulletin*, 28(4), pp. 681–685.

Taylor, L.D. (1975) The demand for electricity: a survey, *The Bell Journal of Economics*, 6, pp. 74–110.

Terza, J.V. & Welch, W.P. (1982). Estimation demand under block rates, *Land Economics*, 58(2), pp. 281–288.

Wichelns, D. (1991) Motivations reductions in drain water with block rate prices for irrigation water, *Water Resources Bulletin*, 27(4), pp. 584–592.

Wong, S.T. (1972) A model on municipal water demand: a case study of Northeastern Illinois, *Land Economics*, 48, pp. 34–44.

World Commission on Water for the 21st Century (2000) *Report of the World Commission on Water* (Paris, France).

Young, R.A. (1973) Price elasticity of demand for municipal water: case study of Tucson, Arizona, *Water Resources Research*, 9(4), pp. 1068–1072.