AN ANALYSIS OF THE EFFECT OF PRICE ON RESIDENTIAL WATER DEMAND: METROPOLITAN MIAMI, FLORIDA*

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INTRODUCTION

The economic development of any area is tied to its natural resource base. Water, one of the most important of these natural resources, is used for a multitude of purposes including crop irrigation, human consumption, food processing, generation of electricity, transportation, recreation and waste disposal.

Municipal water use is essential in the development of any state. Florida is no exception. One of the first considerations in development of an area's water resources is that of furnishing municipal water for commercial, industrial, residential and public uses.

Increases in demand for fresh water because of economic and population growth are currently being observed in various areas of Florida. In most areas, water for municipal supply is currently adequate; however, with continued increases in demands, shortage and possible deterioration in water quality could occur [4]. Among areas where pressure will be greatest on water resources is the southeastern coastal section of the state (primarily the Miami Metropolitan area).

THE PROBLEM

Many projects have been proposed to increase the supply of water in southeast Florida for prevention of a projected shortage using a "requirements approach". Projected water requirements of Dade County (Metropolitan Miami) for the year 2000 are 2,750 billion gallons. Of this amount, 280 billion gallons are for municipal supply [2].

During 1970, the amount of ground water pumped in the southern and southeastern sections of Florida (which includes Broward, Dade and Palm Beach counties) for municipal water use was 121 billion gallons.

With increased urbanization in Dade County, the problem of allocating water among its alternative uses becomes more acute. There is competition among municipal demands, agricultural demands and those of the Everglades National Park. Within the municipal demand for water, there is competition among residential, commercial, industrial and governmental uses.[1]

Total water use for Dade County in 1970 was 285 million gallons per day (104 billion gallons annually). Irrigation usage was estimated to be 45 million gallons per day (mgd), rural use 18 mgd and industrial use 10 mgd. The major use, however, was municipal, estimated at 212 mgd [3].

To obtain greater insight into uses of water in Dade County demand for water by each class of use must be thoroughly understood; this study analyzed residential use of water in Dade County during 1973 as an effort to contribute to this understanding.

Most economic research on residential water demand has used aggregated data at either national or regional levels. Howe and Linaweaver [2] estimated the response of residential water users to price for the entire U.S. Survey areas were selected according to climate and income levels, all other factors influencing water use being taken at random. At the regional level, North [4] investigated residential water demand in 14 communities

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[1] Commercial use consists primarily of retail and service oriented business, while industrial use consists mostly of manufacturing. Water used by public agencies can be classified as governmental use, for example, water used for street cleaning.

throughout the state of Georgia. In his analysis, price and income had a significant influence on water consumption. In both these studies, average price and aggregated data were used.

This study focused on the household level, utilizing both average and marginal price. Use of marginal price along with micro-data adds significantly to the analysis of residential water demand.

THE MODEL

The general condition for maximization of satisfaction is for a consumer to purchase those quantities of goods and services he desires up to the point where the marginal utility per dollar's worth of one is equal to marginal utility per dollar's worth of all others. It is assumed that the more of a good or service the consumer has, the less value he places on additional units of that commodity. For example, if the commodity is water for residential consumption, the consumer will value initial units more than following units. He will continue to consume water up to the point where marginal utility of an additional unit is equal to the price of this additional unit. If price of water is high relative to other commodities, the consumer will likely restrict his consumption to domestic uses, such as drinking, cooking and cleaning. If, however, the price of water is low relative to other commodities, the consumer may use water for lawn sprinkling, car washing, recreation and other purposes according to his tastes, along with his domestic uses.

The model of residential water demand for Dade County, Florida was formulated based upon economic theory and past studies. Many relevant variables were suggested from past studies of residential water demand. The general framework for this study was categorized into two parts: first, a model using average price; second, a model using marginal price.

Residential water is usually priced under one of three systems of rate schedules. The three systems are flat, step and block rates. All individuals in this study were metered. Water companies used the declining block system to price water.

The declining block system uses a different unit price for varying ranges of water use. Initially, there is some minimum charge for all consumption below a predetermined level. These initial units, therefore, are not priced with respect to quantity. For consumption above the minimum level, price per unit decreases as more water is consumed, but the consumer has to pay the higher rate on the first blocks to get to the lower block rates.

Traditional economic theory suggests that price of a commodity's last unit is the relevant price variable to explain amount consumed. Similarly, the marginal price model utilizes price of the last 1,000 gallons; that is, the unit price of the last step in the declining rate schedule is defined as marginal price. In this regard, then, if an individual consumes less than the minimum amount of water, he is not charged for each 1,000 gallons. He merely pays a fixed fee. In this case, he faces a zero marginal price. It is not, however, analogous to a zero price in a perfectly competitive model, as we would expect consumers to purchase large quantities.[2]

This confusion does not arise in the average price model. Here, total expenditure for water is divided by total consumption to determine average price. The average price and the marginal price models look at different price situations to explain residential demand for water. The marginal price model estimates consumer response to price at the margin or for additional units consumed.

Average Price Model

Average price is specified because it is hypothesized that a consumer may be aware of his total water bill when making decisions concerning consumption. Average price is the price per unit for all water consumed; it is determined for each household by dividing total consumption into total expenditure. The average price model is specified as follows:

[1] $Q = f[AP, I, RS, HWH, D_1, D_2, D_3]$

where:

Q = Household water consumption in thousand gallons

AP = Average price per thousand gallons

I = Annual household income

RS = Number of persons per household

HWH = Percentage of households with hot water heat

D_i = Seasonal shifter variables

All variables except price and zero-one dummy variables are expected to have a positive effect on residential water consumption. The calendar year 1973 was divided into four seasonal periods and analyzed by the use of the seasonal dummy variables.

2 In the sample of residential water users in Dade County, 24.5 percent were found to consume small enough quantities of water to face a minimum fixed fee. The mean consumption of this segment of the sample was 9800 gallons quarterly.

Marginal Price Model

According to economic theory, a consumer makes his decisions concerning additional purchases of goods and services based on the price of the last unit; i.e., the marginal price. Marginal price for each consumer was determined from quantity and price data on consumption. Some consumers had marginal prices of zero, thus a dummy variable was used to differentiate between zero and non-zero marginal price consumers. The marginal price model is given by:

$$[2]\quad Q = f[MP, S_1, I, RS, HWH, D_1, D_2, D_3]$$

where:

- Q = Household water consumption in thousand gallons
- MP = Marginal price per thousand gallons
- S_1 = Zero price shifter
- I = Annual household income
- RS = Persons per household
- HWH = Percentage of homes with hot water heat
- D_i = Seasonal dummy variable

In the average price model, all variables with the exception of marginal price, the zero price shifter and the seasonal dummy variables are expected to have a positive influence on residential water consumption.

The preceding models were used to estimate seasonal residential water demand in Dade County, Florida, for 1973. The four seasons were: February-April, May-July, August-October, and November-January.

Sampling

In 1973, there were approximately 300,000 residential water connections (households) in Dade County. To draw a representative sample from this population, a list of water companies was obtained. Information on consumption and price was utilized to determine a sample size of 355 households.

A random sample was drawn after first stratifying by company-size and then by rate. Within each strata sample size was proportioned according to the number of connections. Approximately 25 percent of the companies (11) were included in the survey.

Households were randomly selected within each company after first being stratified by meter books (which yielded a geographical stratification). In this manner, good coverage of the company's customers was obtained. Information from 355 households on quarterly water consumption and price paid was collected: this amounts to 1,420 observations used in the regression analysis.

Data on other variables in the models, in addition to price (average and marginal) and quantity, were gathered from secondary sources (U.S. Census). Maps were used to coordinate boundaries of water company service areas and census tracts. Addresses of households identified the appropriate census tract or block. Average values for variables on a tract or block (in the case of income) level were utilized and coordinated with individual observations on price and quantity for use in the regressions to analyze seasonal residential water demand.

EMPIRICAL RESULTS

Average Price Model

The result of estimating the seasonal residential water demand function with average price and the dependent variable in the natural log form is presented below:[3]

$$[3]\quad \ln q = 2.02 - \underset{[0.03]}{1.07\,AP} + \underset{[0.000004]}{0.000064\,I} + \underset{[0.02]}{0.29\,RS} + \underset{[1.44]}{3.92\,HWH} + \underset{[0.04]}{0.08\,D_1} - \underset{[0.04]}{0.02\,D_2} - \underset{[0.04]}{0.02\,D_3}$$

$R^2 = .46 \qquad F = 176.37 \qquad d.f. = 1{,}404$

where:

- D_1 = 1 for all observations in season II, 0 otherwise
- D_2 = 1 for all observations in season III, 0 otherwise
- D_3 = 1 for all observations in season IV, 0 otherwise

The coefficient on the second season variable (May, June, July) was significantly different from zero at the 10 percent level. Increased residential water consumption is indicated for this season relative to season one (February, March, April).

The coefficient for number of persons per household variable was estimated to have a positive sign. It is indicated by the value of the coeffi-

[3] Standard deviations are in parentheses beneath the coefficients. For additional regressions and more detail see [1].

cient that on the average, if number of persons per household differ by one individual, residential water consumption will increase by approximately 1,330 gallons per quarter.

Both coefficients on the hot water heat variable and income were positive and significant at acceptable levels. From the estimated value of the coefficient it is indicated that if annual household income differs by $1,000 among individuals, residential water consumption will differ in a direct relationship by approximately 1,060 gallons per quarter. Income elasticity was approximately 0.80 at the mean.

Average price was estimated to have a negative influence on residential water demand. It is estimated that for a 10 cent change in average price of water, there will be a change in residential water consumption of approximately 1,110 gallons per quarter in the opposite direction. Price elasticity was estimated to be —0.62 at the mean price level.

Marginal Price Model

Results of estimating the marginal price model are presented below:[4]

$$[4]\quad \ln q = \underset{}{3.12} - \underset{[0.17]}{1.85\ MP} - \underset{[0.07]}{1.93\ S_1} + \underset{[0.000003]}{0.000040\ I} + \underset{[0.02]}{0.14\ RS} + \underset{[1.26]}{7.79\ HWH} + \underset{[0.03]}{0.06\ D_1} - \underset{[0.03]}{0.03\ D_2} - \underset{[0.03]}{0.03\ D_3}$$

$R^2 = .60 \qquad F = 267.24 \qquad d.f. = 1{,}403$

The variables are as previously defined.

The sign of the coefficient for income was estimated to be positive, agreeing with the hypothesis that residential water consumption is increased directly with household income levels. It is indicated by the value of the coefficient that if annual household incomes differ by approximately $1,000, residential water consumption will differ by approximately 1,490 gallons per quarter. Income elasticity was approximately 0.51 evaluated at the mean income level.

The sign of the coefficient for marginal price was estimated to be negative, agreeing with the hypothesis that residential water consumption is inversely related to marginal price. It is indicated by the value of the coefficient that if marginal price were increased by approximately 10 cents, there would be a decrease in residential water consumption of approximately 1,200 gallons per quarter. Price elasticity was —0.51 evaluated at the mean marginal price. The price shifter variable, a zero-one intercept shifter, estimates the difference in consumption level between the zero and non-zero marginal price consumers. On the average, zero marginal price consumers consume approximately 6,890 fewer gallons per quarter than other consumers. Average values of the variables are presented in Table 2.

Table 2 AVERAGE VALUES OF VARIABLES FOR RESIDENTIAL WATER DEMAND STUDY IN DADE COUNTY, FLORIDA

Household Water Consumption, Quarterly [Q]	31,654 gallons
Household Income [I]	$12,827
Persons per Household [RS]	3.08 persons
Percentage of Households with Hot Water Heat [HWH]	.9%
Average Price [AP]	$0.58
Marginal Price [MP]	$0.28

Comparison and Evaluation of Results

In comparing the average and marginal price models it is important to understand that if consumers are responsive to their total water bill, then the average price model is appropriate. If, on the other hand, consumers are aware of the additional cost of consuming another 1,000 gallons of water, then the marginal price model is relevant. Further comparisons can only be made of statistical properties; final choice of the appropriate model must ultimately rest on the assumption of consumer's response.

In both models, each corresponding variable was significant at the same level. All variables were significant at the .01 probability level in both models except for seasonal zero-one dummy variables. The F-statistic was 176 in the average price model and 267 in the marginal price model, both significant at the one percent level. The coefficient of multiple determination, after adjustment for degrees of freedom, was 0.46 in the average price model and 0.60 in the marginal price model.

The question of effectiveness of price as an allocation tool is important to this study. In the past water has been allocated according to a "re-

[4] Standard deviations are in parentheses beneath the coefficients. For more regressions and additional detail see [1].

quirements approach." At present prices, an inelastic response to price was estimated for residential consumption. Does this imply, however, that price is an ineffective instrument in allocating water use? On the contrary, price can be an effective allocation instrument. This is reinforced by two arguments. First, the consumer's water bill is generally a small portion of his budget, particularly as compared to electric utility bills. Since water consumption is taken for granted at present prices, it cannot be assumed that as prices increase consumer's reactions will remain unaltered. The data set was utilized to determine consumer's reaction to price increases beyond present levels. Price increases, on the average, of about 60 percent in the case of average price and 100 percent for marginal price, show an elastic response. This magnitude is not beyond observed prices in Dade County. While the mean marginal price, for example, is 28 cents, the maximum observed was 58 cents. Thus, to hypothesize consumer reactions for prices 100 percent above the mean requires few additional assumptions concerning their behavior.

The second argument why price may be an effective allocative tool stems from the definition of elasticity: reflecting relative changes. As an example, if the average price of water in Dade County, according to this study, were increased approximately 10 cents (a 17 percent increase in average price), a reduction in consumption of about 10 percent is estimated. This reduction amounts to nearly 330 million gallons per quarter in Dade County, based on 1973 data. True, percentage reductions in consumption are less than percentage increases in price; however, the absolute magnitude of water saved must surely be significant. This reduction in use can be brought about by increasing the average household's water bill by only 60 cents per month. It seems appropriate to conclude that changes in rate schedules can indeed be effective in reducing consumption levels of residential water consumers in Dade County.

SUMMARY

Two models of residential water demand were derived; one with average price and one using marginal price, to determine the effect of price on residential water demand. Price elasticities at mean price levels in the average and marginal price models were inelastic at values of —0.62 and —0.51, respectively. Price can indeed be an effective tool for policy makers in the allocation of residential water.

Information provided by this study allows for a better understanding of the residential water market in Dade County, Florida. Decisions concerning residential water consumption can be made based on expected implication of such policies.

The opinion expressed in this paper is that few, if any, consumers know exactly the point they are on in the rate schedule; i.e., they are not aware of the additional cost of another 1,000 gallons of water. If their water bill is high they will attempt to reduce total consumption in order to achieve a lower per unit cost. To be consistent with economic theory, however, the marginal price model has appeal.

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