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ABSTRACT

Based on data from 92 Minnesota cities, the analyses shows that neither marginal price or average price appear as the better predictor of demand. The price elasticity of demand ranges from -.17 for marginal price in the linear model to -.27 for average price in the log linear model. It appears from the analysis that many consumers are unaware of the marginal price of their water. Thus utilities should simplify their pricing structures and present consumers with an easy to understand costs of water such as the cost of six hours of lawn watering.

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Water as a commodity exhibits diverse demand characteristics. Understandably, the demand components for municipal water are quite heterogeneous. A portion of municipal water demand reflects the basic human subsistence need for water, for which no substitute may exist. Other components of municipal water demand, e.g., lawn watering, have a wider range of substitutes and are more price responsive.

Measuring the price responsiveness of municipal water consumers over the past twenty years has been subject to considerable theoretical and empirical debate. Three major polemics can be characterized. The first controversy concerns the correct price specification when block price scheduling is used, i.e., do consumers respond to marginal price or average price under block pricing (Taylor 1975, Nordin 1976, Billings and Agthe 1980, Foster and Beattie 1981, Howe 1982, Opaluch 1982, Polzin 1984, and Chicoine and Ramamurthy 1986). To date only three direct statistical comparisons between average and marginal price under block rate pricing exist (Foster and Beattie 1981, Polzin 1984 and Chicoine and Ramamurthy, 1986). The second

[1]The authors would like to thank M. L. Livingston, Steve Taff, and Jean Kinsey for there insightful comments on earlier drafts.

problem is simultaneity in the demand equation since under block pricing, quantity also determines price (Howe and Linaweaver 1967, Opaluch 1982, and Charney and Woodward 1984). The third problem is bias in aggregate data because the average consumption for a utility may not determine the appropriate marginal price (Schefter and David, 1985).

The objective of this report is to address the three estimation problems outlined above, using survey data from Minnesota municipalities. This study expands the empirical evidence by testing for differences between average and marginal price specifications under block pricing. Problems of simultaneity and bias are recognized in the paper as well. Finally, a test is conducted to determine if differences in demand for water exist between large and small cities.

CONSUMER RESPONSE

All three estimation problems can be traced to the pricing schedules under which municipal water is sold. Water, electricity and natural gas are commonly sold under a block rate or multi-part tariff structure. The resulting non-linear budget constraint faced by a consumer poses several problems for the specification and estimation of a demand function under the neoclassical theory of consumer behavior (Taylor 1975).

The block rate or multi-part tariff structure is a non-linear pricing schedule such that the price per unit changes at pre-specified points in the pricing schedule as the quantity of consumption increases (Figure 1). The resulting pricing blocks may either increase or decrease as quantity consumed increases. In figure 1, two hypothetical households, each purchasing water from different utilities, face two distinctly different pricing schedules. Household 1 faces a declining block price schedule from P_{11} to P_{12}. Whereas household 2 must purchase water within an increasing block rate schedule from P_{21} to P_{22}.

The empirical specification and estimation problems occur when a household consumes in any block but the first, e.g. at Q* in Figure 1. At Q* the marginal price for households 1 and 2 are equal at P_{12} and P_{22}. The average price for household 1 is $[P_{11}Q_1 + P_{12}|Q^*-Q_1|]/ Q^*$ and for household 2, $[P_{21}Q_1+ P_{22}|Q^*-Q_1|]/Q^*$. Although the marginal prices for the two domiciles are equal, the average prices are not.

The income effects for the two consumers are also different as household 1's cost for Q* is greater than that of household 2. Therefore, when empirically estimating demand across households using marginal price as a predictor given block pricing, one must account for the difference in the intramarginal rates, P_{11} and P_{21} (Taylor, 1975).

PRICE SPECIFICATION

Nordin, in 1976, argued for incorporating a D variable to account for the differing income effects of a decreasing block schedule. The D variable was defined as the difference between the actual total bill and the hypothetical bill, had the total quantity been purchased at the marginal price. In Figure 1, the D variable equals $(P_{11}-P_{12})Q_1$ for household 1. The D variable is positive for decreasing blocks and negative for increasing blocks.

Another debate has arisen over the correct price specification: Do municipal users respond to average price or to marginal price/D variable specification under block pricing?[2] (Foster and Beattie 1981, Howe 1982, Opaluch 1982, Polzin 1984 and Chicoine and Ramamurthy 1986). Implicitly, this question addresses the sophistication of the water consumer. If the consumers respond to the marginal price they are assumed to be well informed about the pricing schedule. If the consumers are uniformed about the pricing schedule, they will likely respond to a perceived notion of average price.

Foster and Beattie, Polzin, and Chicoine and Ramamurthy have made direct statistical comparisons between the predictive ability using average and marginal price. Foster and Beattie concluded that the use of average price was justified; whereas Polzin and Chicoine and Ramamurthy found no statistical evidence to support one specification over the other. Polzin did favor

[2] Nordin hypothesized that the estimated D variable coefficient should equal that of the income variable in the demand equation. Early failure of this equality led to speculation that average price may be the correct price variable.

average price as a more efficient predictor as it uses one less degree of freedom than the marginal price/D variable specification without losing any predictive power. Chicoine and Ramamurthy found a decomposed measure of average price to best fit their data.

Chicoine and Ramamurthy employed a model hypothesized by Opaluch (1982) to test the responsiveness of consumers to either marginal price (MP) or average price (AP). The demand function:

$$Q=B_0+B_1P_x+B_2P_2+B_3(P_1-P_2)Q_1/Q+B_4\{(Y-P_2Q-(P_1-P_2)Q_1)\}+\epsilon,$$

where: P_x = an index of relevant prices

P_2 = the marginal price

$(P_1-P_2)Q_1$ = the D variable

Y = average household income

$P_2Q-(P_1-P_2)Q_1$ = the income effect of the water bill

Q_1 = intramarginal quantity

Q = total quantity

P_1 = intramarginal price

ϵ = error term.

This function is employed in instances where the household consumes in the second block of the pricing schedule. However, the model is expandable to household consumption in any n block rate structure provided n does not equal 1 (C/R, 1986). The function uses a decomposed measure of average price where average price (AP) equals, $P_2+(P_1-P_2)Q_1/Q$ or MP+ D/Q. Two tests can then be instituted:

	Test 1	Test 2
	H_0: $B_3=0$	H_0: $B_2=B_3$
	H_a: $B_3\neq 0$	H_a: $B_2\neq B_3$

where: B_2 and B_3 are coefficients from the demand function given above.

Opaluch hypothesizes that four results from the two tests are possible. First, both null hypotheses, H_0, are rejected; in this case, the data is inconsistent with the models of consumer behavior which include either marginal or average price as the price variable. This result suggests, that the above Opaluch model with the decomposed measure of average price is the appropriate specification. Second, if the null hypothesis of test 1 is not rejected, but that of test 2 is, the data support the "well informed" consumer hypothesis, i.e., consumers respond to marginal price. Alternatively, if the null hypothesis of test 1 is rejected, but that of test 2 is not, the "uninformed" consumer hypothesis is supported,i.e., consumers respond to average price. Finally, if both null hypotheses fail to be rejected, two possibilities occur. Either $B_2=B_3=0$, which implies consumers do not respond to price or B_2 may be significantly different from 0 but B_3 is neither significantly different from 0 nor B_2. In this latter case, the data may be weak or some consumers react to average price, while others react to marginal price (Opaluch 1985).

SIMULTANEITY PROBLEM

Opaluch's demand function makes the problem of simultaneity obvious by including total consumption on both sides of the equation. With a block pricing schedule, the problem of simultaneity is pervasive. (Taylor 1975, Nordin 1976, Howe and Linaweaver 1967, Terza and Welch 1982, Opaluch 1984, C/R 1986). In demand theory, price determines quantity consumed. However, with block pricing, quantity consumed also determines the price. The error terms are thus correlated with price, a flagrant violation of the assumptions of Ordinary Least Squares (Weisberg 1985). Although this issue is now well recognized, no consensus exists on how to resolve it.

BIAS IN AGGREGATE DATA

The third issue recently propounded is one of price bias when using aggregate data (Schefter and David 1985). Given aggregate data, the mean marginal price and mean D variable are the appropriate measures for marginal price and the D variable. Most consumer behavior data averages across consumers within one utility to derive the average consumption per household within the utility. The average consumption is then used to determine the mean marginal price in that utility's block-price schedule. Depending on the distribution of households in each rate block, this may or may not be the actual mean marginal price and the mean D variable measure for the utility. Therefore, the measures of marginal price and the D variable may be biased when the average consumption across the utility is used to determine the mean marginal price and the mean D variable.

Schefter and David demonstrate that small changes in the variance of the distribution of households in a rate block, change the measurement of marginal price and the D variable. These changes are sufficient to induce the theoretically expected results that the estimated D variable and income coefficients are equal. Ideally then, when estimating the aggregate demand for goods sold under a block price schedule, an estimate is needed of the distribution of households in each block. Otherwise estimates of the mean marginal price and mean D variable may be biased.

DATA AND EMPIRICAL MODEL

A 1986 Water Rates Survey of all incorporated municipalities in Minnesota provided water use and water rate data for ninety-two municipalities. The aggregate annual, metered residential consumption data per city was reported in the surveys, along with the total number of metered residential water connections. Average water use per connection was calculated and used to determine marginal price, the D variable, average price and the total water bill per billing period.[3]

[3] We recognize the bias in the marginal price and the D variable specifications which may result from using aggregate data across utilities. However, a distribution of households by rate block was not available from the survey.

Further variables included in the model to estimate water demand were average annual income per household by city, the average number of persons per household by city and the mean proportion of youth per household by city[4]. These were all obtained from the 1980 Census. An assumption was made that one service connection represented one household. Problems with this assumption arise when apartment buildings are included in the total residential annual consumption figures of the surveys.

Survey respondents were asked to omit apartments from residential consumption figures; however, some utilities could not separate apartments from residential housing. The result may be that the average daily consumption figures were biased upward for some municipalities. However, the one service connection equals one household assumption was used because many municipal households in Minnesota have private wells, even in the larger cities. Thus, if population or households per city were used to calculate the average daily use per household, the average consumption would have been underestimated. This would be more of a problem than including some apartment buildings.

Two general models were employed to estimate demand:

Estimation I (Marginal price/D variable specification):

$$Q_d = B_0 + B_1 Y + B_2 N + B_3 U + B_4 P_m + B_5 D + \epsilon. \text{ and/or}$$

[4] The Census defines youth as anyone under the age of 18.

Estimation II (Average price specification):

$$Q_d = B_0 + B_1 Y + B_2 N + B_3 U + B_4 P_a + \epsilon.$$

where: P_m = marginal price; Y = average income/household
P_a = average price; N = average # of people/household.
D = D variable; ϵ = error term
U = average proportion of youth/household.
Q_d = average daily water consumption/household

RESULTS AND DISCUSSION

Two functional forms for each estimation were tested: the additive (linear) and the multiplicative (log-linear) model[5]. The linear model was employed in order to construct a model which allowed a change in the elasticity over the range of independent variables. The price elasticity is given by: $\epsilon_e = (\delta q/\delta p)(P/Q)$. The relative ratio of Q and P are important as the partial slope of the demand. In water demand studies, one would expect that the elasticity of demand for water would change between the first and last unit of water.

Linear Model

The linear demand estimations I and II differ in their use of price predictors (Table 1). For estimate I, the price specification is marginal price and the D variable, while for estimate II, the relevant price variable is average price.

[5] A Box-Cox log-likelihood function was calculated for the response following Weisberg, 1985 (Chapter 6). The 95% confidence interval for L(x) contained the log-linear, square root and linear transformations. Of these, the log-linear transformation and linear form were felt to best fit the data.

Estimations III and IV are the same as I and II respectively, except for the inclusion of a dummy variable for large cities[6]. The Dummy variable was included to test for differences in water consumption by city size as the data set encompasses a wide range of city sizes.

Neither price specification appears superior to the other. Notably, the D variable is not significantly different from 0. Also, the dummy variable is insignificant in both estimations, indicating that there is no difference in water demand by city size in Minnesota.

As expected, R^2 is low in all the estimations. This is typical of studies which are based on cross-sectional data. A problem with cross-sectional data is posed by the assumption that differences in demand between cities are confined to the variables in the model. Obviously, this assumption is simplistic because city characteristics such as population density, climate, etc., may also influence water use. Other studies that estimated demand using cross sectional data report R^2's in the same range (Wong 1972, Clark and Asce 1976, Foster and Beattie 1979).

The income elasticity is +0.60 and the price elasticities are - 0.17 and - 0.19 for the marginal and average price respectively. All of the elasticities are computed at the mean and are inelastic. This supports the findings of other studies, as both the price and income elasticities have the hypothesized

[6] A large city is defined as having an excess of 5,000 service connections (roughly 20,000 citizens).

sign and are of similar magnitude to those found in other studies. (Wong 1972, Batchelor 1975, Howe and Linaweaver 1976)

The elasticities do not capture the difference between winter and summer use of water which if it could be included would increase the elasticities. The analysis also does not consider weather effects because of the relative homogeneity of the study area.

The coefficient of the persons per household variable is positive and significantly different from 0. The persons per household variable captures the effect of increasing a household size by one person. This helps explain the estimated negative coefficient of the proportion of youth variable.

A positive correlation between the proportion of youth and water consumption was anticipated. However, the persons per household has captured the size effect, which means the differences in the *proportion* of youth in a household will capture the substitution effect between an adult and a child. As the proportion of youth in a household increases, a reduction in the proportion of adults in the household occurs. The estimated negative coefficient indicates that although children may have less incentive to conserve water, an adult uses more water than a child.

Log Linear Model

The overall goodness of fit of the log-linear model is slightly better than the linear model (Table 2). This is true for the overall F, the R^2 and the adjusted R^2. The t-values of the persons per household coefficients are increased and are now significant at the 90% level, while in the linear model they are significant only at the 80% level. Again, the D variable and the dummy variable in demand estimations III and IV are not significant. There is also no significant difference in the intercept term due to city size.

The price elasticities for the complete sample case are -0.21 for the marginal price and -0.27 for the average price. The price variable is not the sole variable that determines the absolute level of the demand for water. Income is another significant variable with a calculated elasticity of 0.6.

Part of the reason that income and price do not singularly determine the water consumption level is that demographic variables also have an influence. Persons per household and proportion of youth are two of those variables that appear in this model. Persons per household's elasticity is 0.5, which means at the margin, one additional person will increase the total absolute consumption of the household by 50%. The proportion of youth elasticity is -0.43, thus substituting one child for one adult will result in a reduction of the total household consumption by 43%.

The aggregate log-linear model is tested to determine if there is a difference in water consumption by city size.[7] For the larger cities, R^2 is significantly improved over the total while it declines slightly for the small cities (Table 3). In contrast, the computed overall F is significantly reduced. This is due to the fact that the computed F is sensitive to the number of observations while R^2 is not.

The test of stability of the aggregate set of observations is given in Table 4. The low F values for the total model indicate that the null hypothesis (there is no difference between

[7]This is actually a special case of a linear hypothesis with two samples. The first group of cities has T_1 and the second T_2 observations. The unrestricted model is given by:

$$\begin{bmatrix} Y_1 \\ Y_2 \end{bmatrix} = \begin{bmatrix} X_1 & 0 \\ 0 & X_2 \end{bmatrix} \begin{bmatrix} \beta_1 \\ \beta_2 \end{bmatrix} = \begin{bmatrix} \epsilon_1 \\ \epsilon_2 \end{bmatrix}$$

We desire to test whether $\beta_1 = \beta_2$, where β_1 and β_2 are two sets of coefficients under the null hypothesis the model becomes:

$$\begin{bmatrix} Y_1 \\ Y_2 \end{bmatrix} = \begin{bmatrix} X_1 \\ X_2 \end{bmatrix} \beta + \begin{bmatrix} \epsilon_1 \\ \epsilon_1 \end{bmatrix}$$

The sum of squares of the residuals under H_0 will be shown to equal the sum of squares under H_1 ($\beta_1 = \beta_2$) plus the sum of squares of the deviations between the two sets of estimates of Y under these two hypothesis.

The ratio between the latter two sums, adjusted for their numbers of degrees of freedom, will be shown to follow an F distribution if the null hypothesis is true. The F test is given by:

$$F = \frac{(e^{x}{}_1 e^{x} - e^1 e)/q}{e^1 e/(T_1 + T_2 - \#\beta)} \sim F\ (q_1 T_1 + T_2 - \#\beta)$$

Where q is the number of coefficients in the subset, i.e., $\#\beta_1$ or $\#\beta_2$ and $\#\beta_1 = \#\beta_2$ and $\#\beta$'s$= \#\beta_1 + \#\beta_2$. (# = number of) large and small cities) cannot be rejected. However, the individual price and income coefficients of the separate demand functions appear to be different for the large and small cities.

The larger cities are more price responsive than the smaller cities (Table 3). The marginal price coefficient in the larger cities is -.5 (average price -.42) while in the smaller cities the marginal price coefficient is -.19 (average price -.25). The larger cities are also more responsive to changes in income. The income variable coefficient in the larger cities is .92 compared to .57 in the smaller ones. This indicates larger cities are more price and income responsive on the margin than smaller cities.

As a whole, the larger cities tend to have less complicated rate structures, i.e., fewer rate blocks, than the smaller cities. The less complicated rate structures may contribute to the greater price responsiveness of consumers in the larger cities. It could also be that households in larger cities are using a larger proportion of water for marginal purposes such as lawn watering.

THE OPALUCH MODEL

The Opaluch model is also employed to test the households response to marginal or to average price[8]. Recall that a new variable must be created, the decomposed measure of the average

[8]The Opaluch test requires that a household consumes in any block but the first. Only 39 observations from the data set were available for this test.

price. The decomposed measure of average price is MP + D/Q, where D/Q equals Decom in Table 5. In addition, the D variable is subtracted from Y to form a new variable: Incom1. The two tests are:

	Test 1	Test 2
	H_0: Decom=0	H_0: MP=Decom
	H_a: Decom$\neq$0	H_a: MP$\neq$Decom

The results can be summarized as:

	Test 1	Test 2
Linear form:	cannot reject H_0 at 5% level	cannot reject H_0 at 5% level
Log linear:	cannot reject H_0 at 5% level	cannot reject H_0 at 5% level

For both the linear and log linear models neither hypothesis can be rejected. One can conclude that MP=Decom=0, i.e., consumers are not responding to price. Given that only 39 observations were available for the Opaluch model, the data may not be sufficient for the estimation which probably explains the low t-values. The fact that both marginal price and average price are significant in the earlier models when all 92 observations are included would refute the conclusion that consumers do not respond to price at all. At best, we cannot conclude anything concerning which variable is better to use as the price specification in the demand equation. Given the cross-sectional nature of the data, the variance in block rates and the relative insignificance of water bills in relation to income, the conclusion that some consumers respond to average price and some to marginal price seems the most reasonable.

MODEL ADJUSTMENTS

A Cook's distance test is performed to check for outliers or influential cases. Four observations are significant at the 95% level and dropped. Dropping the outliers did not improve the average price estimates but did improve the marginal price estimates (Tables 6 and 7). In fact, the t-value on the average price in the log-linear case decreased. The F and R^2 were improved with both functional forms.

IMPLICATIONS

Neither Polzin, Chicoine and Ramamurthy, nor this study has been able to conclude which price specification (marginal price or average price) is the better predictor for goods sold under a multipart tariff structure. Implicitly this issue involves the consumer's awareness of the rate structure under which the good is sold. In the case of municipal water demand, where any person capable of turning a faucet can consume water, it is reasonable to assume that many consumers are unaware of actual rate structures. For water policy makers wishing to influence water consumption through price, a simple rate structure would be the most desirable. Simple rate structures that do not decline with use would promote a greater awareness of water rates among consumers and perhaps water conservation through pricing. In addition, if water conservation through pricing is wanted, utilities should provide water rate information in a more understandable form to the water consumer, e.g., given this price for water an average lawn watering for one hour with a garden hose costs "X" dollars.

CONCLUSIONS

The low R^2 values suggest that the variables included in the water demand model do not play the major role in Minnesota household water consumption decisions. However, these variables are part of the relevant variables that influence the residential demand for water as demonstrated by their respective t-values.

The average price is a slightly better predictor than the marginal price when the complete sample is used but the marginal price is found to be a better predictor when the outliers are omitted. The Opaluch model produced inconclusive results. Economic theory tells us that the well informed consumer will respond to the marginal price. But within the context of complex block pricing structures, the consumer may not know the marginal price. The statistical results suggest that some consumers respond to average price, while others respond to marginal price. Finally, if utilities and water policy planners desire to affect water consumption/conservation with water pricing, a simple non-declining rate structure combined with consumer pertinent information would be advisable.

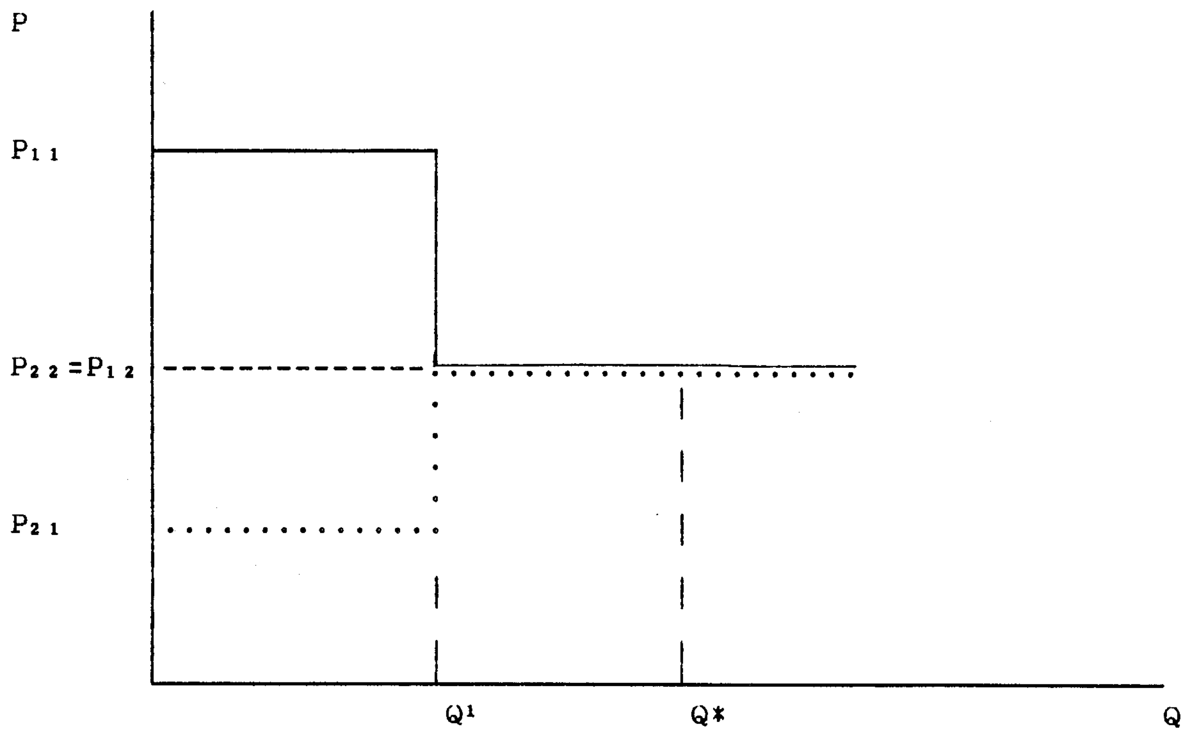

Figure 1: Increasing and Decreasing Block Pricing Schedules Facing Two Hypothetical Households

Table 1

Linear Municipal Water Demand Functions for Minnesota

Variables	Demand Functions I.	II.	III.	IV.
Constant	169.92	178.82	169.93	178.68
	(3.2)	(3.42)	(3.11)	(3.4)*
Income	0.007	0.007	0.007	0.007
	(3.92)	(4.06)	(3.81)	(3.95)
Persons	27.51	27.64	27.51	27.81
	(1.28)	(1.31)	(1.27)	(1.31)
Youth	-369.73	-379.58	-369.74	-379.25
	(-2.37)	(-2.49)	(-2.36)	(-2.48)
Marp	-39.71		-39.7	
	(-2.2)		(-2.12)	
DVar	-3.04		-3.04	
	(-0.74)		(-0.73)	
Avep		-45.88		-46.34
		(-2.58)		(-2.51)
Dummy			0.04	-1.99
			(0)	(-0.1)
D.F.	87.0	88.0	86.0	87.0
Overall F	6.96	9.36	5.73	7.41
Adjusted R^2	0.24	0.27	0.24	0.26
R^2	0.29	0.30	0.29	0.30

*All values in parentheses are t-values.

Table 2

Log linear Municipal Water Demand Function for Minnesota

Variables	Demand Functions I.	II.	III.	IV.
Constant	-1.97 (-1.33)	-1.67 (-1.2)	-2.18 (-1.43)	-1.88 (-1.31)
Income	0.63 (4.24)	0.61 (4.32)	0.66 (4.24)	0.63 (4.33)
Persons	0.5 (1.78)	0.5 (1.81)	0.5 (1.79)	0.5 (1.83)
Youth	-0.42 (-2.42)	-0.44 (-2.62)	-0.42 (-2.38)	-0.43 (-2.58)
Marp	-0.21 (-2.78)		-0.22 (-2.83)	
DVar	-0.003 (-0.67)		-0.003 (-0.75)	
Avep		-0.27 (-3.46)		-0.28 (-3.5)
Dummy			-0.05 (-0.58)	-0.05 (-0.65)
D.F.	84.0	87.0	83.0	86.0
Overall F	9.17	13.39	7.64	10.73
Adjusted R^2	0.31	0.35	0.31	0.35
R^2	0.35	0.38	0.36	0.38

Table 3

Log Linear Municipal Water Demand Functions by City Size

Variables	Demand Functions: Large Cities I.	Large Cities II.	Small Cities I.	Small Cities II.	Total I.	Total II.
Constant	-8.48 (-2.52)	-4.75 (-1.46)	-1.48 (-0.83)	-1.32 (-0.79)	-1.97 (-1.33)	-1.67 (-1.20)
Income	1.24 (3.92)	0.92 (2.96)	0.58 (3.07)	0.57 (1.28)	0.63 (4.24)	0.61 (4.32)
Persons	0.64 (1.79)	0.53 (1.36)	0.53 (1.26)	0.52 (1.28)	0.50 (1.78)	0.50 (1.81)
Youth	-0.69 (-1.78)	-0.27 (-0.72)	-0.41 (-2.07)	-0.45 (-2.33)	-0.42 (-2.42)	-0.44 (-2.62)
Marp	-0.50 (-3.04)		-.185 (-2.09)		-0.21 (-2.78)	
DVar	0.019 (1.85)		-0.007 (-1.33)		-0.003 (0.67)	
Avep		-0.42 (-2.42)		-0.25 (-2.74)		-0.27 (-3.46)
D.F.	16.0	17.0	62.0	65.0	84.0	87.0
Overall F	5.00	4.28	5.60	8.12	9.17	13.39
Adjusted R^2	0.49	0.38	0.26	0.29	0.31	0.35
R^2	0.62	0.50	0.31	0.33	0.35	0.38
R.S.S.	1.12	1.43	5.40	5.44	7.18	7.09

Table 4

Stability of the Log Linear
Municipal Water Demand Function by City Size

	R.S.S.		D.F.		F Ratio	
	I.	II.	I.	II.	I.	II.
Large cities	1.12	1.43	76	17		
Small Cities	5.40	5.44	62	65		
Total	7.18	7.09	84	87	1.33	0.53

Note: $F_{0.95}(6.78) = 2.23$ $F_{0.95}(5.80) = 2.33$
$F_{0.99}(6.78) = 3.05$ $F_{0.99}(5.80) = 3.25$

Table 5

Municipal Water Demand Functions Using
Opaluch's Model

Variables	Linear	Log Linear
	Demand Functions	
Constant	44.12 (0.43)	-1.57 (-0.63)
Incom1	0.005 (1.57)	0.50 (1.79)
Persons	99.766 (2.31)	-0.53 (-2.21)
Youth	-525.17 (-2.43)	1.04 (2.06)
Marp	-25.03 (-0.99)	-0.18 (-1.55)
Decom	-1304.90 (-1.68)	-0.06 (-1.55)
D.F.	33.0	33.0
Overall F	5.01	5.55
Adjusted R^2	0.35	0.37
R^2	0.43	0.46

Table 6

Linear Municipal Water Demand Function
with Outliers

Variables	Demand Functions I.	Demand Functions II.
Constant	128.10 (2.21)	-35.03 (-.66)
Income	.007 (5.03)	.006 (4.59)
Persons	41.27 (2.07)	30.79 (1.52)
Youth	-350.01 (-2.62)	-70.82 (-.50)
Marp	-62.07 (-3.77)	-- --
DVar	-.967 (-.27)	-- --
Avep	-- --	-3.12 (-3.38)
D.F.	82.0	83.0
Overall F	13.37	15.69
Adjusted R^2	.42	.40
R^2	.45	.43

Table 7

Log Linear Municipal Water Demand Functions
with Outliers Omitted

Variables	Demand Functions I.	Demand Functions II.
Constant	-2.31 (-1.91)	-2.18 (-1.7)
Income	0.66 (5.41)	0.65 (4.89)
Persons	0.54 (2.3)	0.45 (1.75)
Youth	-0.43 (-2.94)	-0.16 (-0.99)
Marp	-0.30 (-4.64)	
DVar	-0.001 (-0.35)	
AVep		-0.17 (-2.08)
D.F.	82.0	83.0
Overall F	17.21	14.70
Adjusted R^2	0.48	0.39
R^2	0.51	0.41

Appendix A

DESCRIPTIVE STATISTICS

Variables	Mean	S.D.	N	Median	Min.	Max.
Income	21,130	5,764	93	21,010	10,952	36,110
Persons/HH	2.77	0.47	93	2.69	1.97	4.59
Youth (Prop.)	0.30	0.06	93	0.31	0.14	0.43
Quantity Cons.	236.70	83.83	93	212.70	95.66	454.60
Marginal Price	0.91	0.44	93	0.85	0.30	2.65
Total Bill	21.21	10.85	93	17.19	8.27	78.19
Average price	1.03	0.44	93	0.95	0.30	2.65
D Variable	1.13	1.94	93	0.00	1.25	9.10

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