Conservation Pricing Of Household Water Use In Public Water Systems In Georgia's Coastal Communities: A Preliminary Exploration

Working Paper #2005-007

By
Ronald Cummings, Jeremy Hill, Ben Thompson and Douglas Wilson*

February, 2005

* Cummings is affiliated with Georgia State University's Northern Georgia Water Planning and Policy Center; Thompson and Hill are affiliated with Georgia Southern University's Coastal Rivers Water Planning and Policy Center. Wilson is the Executive Director of the Georgia Water Planning and Policy Center. The authors gratefully acknowledge financial support for this work received from the Georgia Soil and Water Conservation Service and the U.S. Department of Agriculture. The authors also express their appreciation of Professor Mary Beth Walker's many helpful comments on the paper. Professor Walker is with GSU's department of economics.

Conservation Pricing Of Household Water Use In Public Water Systems In Georgia's Coastal Communities: A Preliminary Exploration

ABSTRACT

The purpose of this study is to explore the effect of price on residential water use in public water supply systems in Georgia's Coastal region. Particular attention is focused on measures for the elasticity of demand for residential water use inasmuch as a showing of price inelasticity may make the wider adoption of conservation pricing more palatable to small communities with concerns that raising water prices will reduce much-needed revenues.

To clarify the nature and importance of the elasticity measure, consider the following simplified example. A community sells 100 units of water for $1.00 per unit. Its' total revenues are $100. Suppose price is increased by 20% to $1.20, and that the units purchased falls by 30% to 70. Total revenues are now only $84.00. In this case, we say that demand is "elastic;" the quantity of water used by folks "stretches" relative to the change in price. With elastic demand, rising prices mean lower total revenues. Suppose, however, that with the 20% price increase, demand fell to only 90 units — a 10% decrease. Total revenues are now $108. In this case we say demand is inelastic — quantity doesn't really "stretch" much when prices rise. If demand is ***in**elastic*, rising prices *means higher revenues*.

From our limited, phase one efforts in these regards, we use aggregate water pricing data from 50 public water supply systems in 28 coastal counties that participated in a survey conducted during late the period 2003-2005. We find strong evidence that, at the margin, residential water use is indeed affected by prices charged for water in this region. We also find what we regard to be reasonably compelling evidence suggesting that residential water demand is <u>in</u>elastic over the range of marginal prices observed in our sample. This latter finding suggests that the use of conservation pricing as a tool for water conservation may not have an adverse effect on community revenues. Indeed, it may well be the case that increasing water prices will increase, not decrease, the community's revenues from the sale of water.

In moving to phase two of this work, a great more will be accomplished in terms of refinements in the nature and quality of data used; greater efforts will be placed on attempts to identify functional forms that will yield best estimates for residential water demand in the state. Our ultimate goal is to be capable of responding to the needs of Georgia communities in the coastal region for information related to how one might improve the design of a community's water rate structure, and to conservation pricing policies that will best serve their interests and the interests of the state.

Conservation Pricing Of Household Water Use In Public Water Systems In Georgia's Coastal Communities: A Preliminary Exploration

I. Introduction

Water scarcity is a reality in Georgia, a reality that has become widely recognized in the State only since the mid-to-late 1990s. For municipalities, in both large and small communities throughout the state, the development of new water supplies for household/residential uses is becoming increasingly costly, and in many parts of the state it is and will become increasingly difficult to obtain new water use permits given current overdrafts on existing ground and/or surface water supplies. As a result, planners at the local level, as well as the state's Environmental Protection Division, are becoming increasingly concerned with the need for regional and state-wide water planning. In the past, water planning focused primarily on supply-side policies: means by which water supplies could be increased at least cost. As sources for new water supplies have diminished (and/or become more costly), attention has shifted to means by which water demands can be managed.

Demand-side management of residential water use involves the search for means by which households can be encouraged to conserve water. Among alternative policies used for these purposes are such things as rationing, requiring the use of low-flow water fixtures for showers, toilets, etc., financial penalties imposed on the waste of water, and financial rewards for reducing water use. A conservation policy which is the topic of considerable debate, not only in the U.S. but world-wide[1], is conservation pricing. Relying on the basic economic principle that the demand for any commodity decreases with increases in the commodity's price, conservation

---

[1] OECD, "household Water Pricing in OEDC Countries, document ENV/EPOC/GEEI(98)12/FINAL (Paris: 1999).

pricing policies call for using water prices as a means for affecting (decreasing) residential water use.

Conservation pricing policies are not universally met with enthusiasm by community planners, however. This is because water pricing may be used to accomplish several goals, not all of which are compatible. Objectives relevant for a community's design of water tariffs include equity, public health, public acceptance and economic growth (a community's use of low utility costs as a tool to attract new businesses) -- all of which may require low prices -- as well as the need for revenues required to cover the water utility's costs[2] (and often, to meet other financial needs of a community) and environmental efficiency, which may then require higher prices. We do not pretend in this paper to offer means by which a community can resolve all of these and other conflicting objectives. The focus of this paper is limited to an initial, preliminary exploration of conservation pricing policies — its structure and potential effectiveness — as they relate to the objectives of conservation and the stability of community water revenues in Georgia's Coastal communities. This study draws heavily from a study that includes public water supply systems in many Georgia counties.[3] As a result of telephone follow-ups following publication of this earlier study, however, 16 public water supply systems in the Coastal region were added to the data set. Thus, data used in this study are taken from 50 systems located in 28

---

[2] Given unusually wet weather, the loss of large water users, and water conservation policies, Durham N.C. is in the process of increasing water and sewage rates in order to meet costs. While one Durham City Councilman laments "We're being penalized for conserving water. That's what it boils down to," conservation is estimated to account for less than half of decreased water use. See *Raleigh News and Observer*, May 26, 2004.

[3] See Water Policy Working Paper #2004-011.

Coastal counties.[4]

Many local planners in Georgia's coastal area appear to be concerned that raising residential water prices will reduce water use, but will also reduce revenues from water service that supply needed funds for maintaining the water system *and*, in many cases, financing other community activities. The extent to which reduced water use from increased prices will result in lower revenues depends on what is referred to as the "elasticity" of demand. Particular attention will be given in this paper to this issue. To anticipate a bit, we find reasonably strong evidence that residential water demand is inelastic (a finding consistent with *many* other studies[5]) which, as we demonstrate below, means that one would expect revenues to *increase*, not decrease, with increases in water prices. Unfortunately, however, this result may suggest that conservation pricing may not be a cost-effective means for promoting conservation in residential water use. This is not to say that we have evidence that establishes that water pricing in the Coastal area is efficient in terms of covering the full costs of supplying water. To the extent that water is not full-costed, the public's best interests are served by increasing prices. For price increases greater than those required to achieve full-costing, however, our results suggest that costs associated with any water saved may be high relative to other conservation programs.

To the ends described above, this paper is organized in the following manner. We refer the reader to the more general Water Policy Working Paper #2004-011 for a sketch of the basic theory or rationale that underlies the expectation that conservation pricing can be effective in

---

[4] Appling, Bacon, Ben Hill, Brantley, Bryan, Camden, Candler, Charlton, Chatham, Coffee, Cook, Emanuel, Evans, Glynn, Jeff Davis, Jefferson, Jenkins, Laurens, Long, Montgomery, Richmond, Rockdale, Tattnall, Toombs, Ware, Washington, Wayne, and Wilcox counties.

[5] See, e.g., Table 1 in Arbues, Fernando, Maria Angeles Garcia-Vilinas, and Roberto Martinez-Espineria, "Estimation of residential water demand: a state-of-the-art review," *Journal of Socio-economics*, 32, 81-102, 2003.

reducing water use. Particular attention in that report is given to the important notion of demand "elasticity" to which reference was made immediately above, as well as to some of the complexities associated with a community's choice for a pricing structure — the use of such things as "block" rates and related issues. In section II we describe data obtained from our survey of 50 community water systems in Coastal Georgia,[6] and discuss the strengths and weakness of these data for purposes at hand. In section III our survey data are used to estimate residential water demand across "average households" in surveyed coastal communities. While, for reasons discussed in section II, the estimated price-quantity relationship is of limited use for practical applications of conservation pricing, estimates for price elasticity are argued to be reasonably robust. Concluding remarks and a description of our plans to extend this work in phase two are given in the final section, section IV.

[6] We received returned questionnaires from more than 51 systems. In many cases, however, data related to household billings and/or price structures were not available.

II. Price-quantity Data For Residential Water Use In Coastal Georgia's Public Water Supply Systems.

A. The Price-quantity Data Set. Beginning in the fall of 2003, the Georgia Water Planning and Policy Center mailed questionnaires to 567 of Georgia's public water supply facilities; 247 of the questionnaires were returned, after several rounds of letter and telephone follow-ups, including 35 systems located in Coastal Georgia counties. The questionnaires included questions about the facility's physical facilities, as well as the quantities of water billed and pumped from ground and/or surface water supplies. Included in these data were questions regarding the quantity of water billed for residential uses during two months: a winter month, January 2002, and a summer month, July 2002. The questionnaire also requested information regarding the community's price structure for residential water supplies. Subsequent follow-up by Mr. Jeremy Hill, with the Coastal Rivers Water Planning and Policy Center located at Georgia Southern University, added an additional 16 systems to the coastal data set.

Data provided by the questionnaires were used to calculate average monthly residential water bills for January and July. Given the total amount of water billed to residential users during a month, we calculate the average amount of water billed per household by dividing the total amount of water billed to residents by the number of occupied households in the community as reported in the 2000 census. With an estimate for average monthly water use per household, we then used the community's pricing structure to calculate two sets of measures. First, for each community, we have average monthly residential water use for months January, q_{i1}, and July, q_{i2}. We then divide the calculated monthly water bill for January and July by q_{i1} and q_{i2}, respectively, to determine the average price (per thousand gallons) paid by the average household -- p_{i1} and p_{i2}, respectively. Second, for each community, we determine the *marginal* quantity of water used by the average household during January and July (mq_{i1}, mq_{i2}), and the price — the marginal price, mp_{i1}, mp_{i2} — paid per thousand gallons at that marginal use. To assure the reader's understanding of these "marginal" measures, suppose the price structure for a community is as follows; all measures are in units of 1,000 gallons. The consumer pays a base charge of $10.00 for which he/she can use up to the base amount of 3 (3,000 gallons). For use beyond the 3,000 gallons, the marginal charge is $2.00 per thousand gallons. Suppose that the average household in this community uses 5,000 gallons in (say) January ($q_{i1} = 5$). The average residential water bill is $10.00 + $2.00 x 2 (2,000 gallons) = $10.00 + $4.00 = $14.00. The average price p_{i1} is $14.00 divided by 5 = $2.80. The consumer's water use is 2,000 gallons beyond the base amount 3,000 gallons. Thus, the "marginal quantity" of water used is $mq_{i1} = 2$ (2,000 gallons). For this marginal use, the consumer is paying $2.00 per thousand gallons; thus, the marginal price mp_{i1} = $2.00.

Consider a second example. The consumer pays a base rate of $15.00 for a base amount of water use up to 5,000 gallons. If use is between 5,001 gallons and 7,000 gallons, the consumer must pay $3.00 for each additional thousand gallons beyond the base 5,000 gallons. If use exceeds 7,000 gallons, for each additional 1,000 gallons beyond 7,000 gallons the consumer must pay $3.50 per thousand gallons. Suppose that average residential water use in this community during January is 8,400 gallons: $q_{i1} = 8.4$. The average monthly water bill equals $15.00 + $3.00 x 2 + $3.50 x 1.4 = $25.90. The average price p_{i1} is $25.90 divided by 8.4, or $3.08. The consumer's water use extends to the second block where the price, the marginal price, is mp_{i1} = $3.50, and the marginal quantity, the quantity of water used in the second block, is $mq_{i1} = 1.4$. Across the 50 communities, the average monthly amount of water used per household in January (July) was 7,200 (8,900) gallons; the average price was $2.80 ($2.40) per thousand gallons. The marginal quantity used in January (July) averaged 4,700 (5,800) gallons, and the marginal price paid by households in January (July) averaged $1.40 ($1.30). Note that the marginal price is less than the average price. This reflects the fact that in every instance, the average price paid for base amounts of water use was higher — usually *much* higher — than prices paid for amounts in excess of the base amount.

Median household income for each community (which averaged $29,064) was obtained by calculating the average for census tracts encompassed by the community (from the 2000 census). For each community we calculate a "difference" variable which is described below.

B. Estimating the demand for water: data sets and their problems. Notwithstanding studies that attempt to estimate the demand for water extending back to the 1960s, there is no consensus among economists as to the "correct" approach for such estimates.[7] Aside from arguments related to the use of linear or non-linear specifications for the demand curve, controversy related to demand estimation centers primarily on the choice of variables to be included in estimation models and their measurement. A great deal of controversy exists concerning the "correct" price and quantity to be used for such analyses, particularly when dealing with block rate tariffs. For example, should one use average prices and quantities or marginal prices and quantities, as these measures were described in the previous section? At the heart of this debate is the question as to how informed consumers are about their water bill (their community's rate structure), and the measure that drives their consumption decisions: average

[7] See, as examples, Arbues, et. al, *Op. Cit*. 2003, and Baumann, D., J. Boland and W. Hanemann, *Urban Water Demand Management and Planning*, McGraw-Hill (New York: 1997).

cost or the cost of an additional (marginal) unit of water.[8] Both measures have been used in earlier studies, however marginal measures are most often used.[9]

Related to the question as to the consumers awareness of prices (average or marginal) paid for water is the general question as to the effectiveness of providing consumers with better price information. A study of eight California water agencies concludes that public information campaigns and retrofit subsidies can significantly affect residential water use.[10] As an example of efforts by a public water agency to improve public awareness of water use and cost, water bills sent to residents in Albuquerque, New Mexico, include a "low use" discount, and highlighted "Conservation Information" that compares the household's monthly water use by month *over the last three years*.

When marginal prices and quantities are used, the "income effect" of the total water bill is effectively excluded. Many studies using marginal prices then make use of a "difference variable," introduced by Nordin,[11] as a way of accounting for income effects. The difference variable, D, is a measure of the difference between the total water bill and the water bill that would result from pricing total water use at the marginal price. In theory, when linear models

---

[8] See, e.g., Bachrach, M. and W.J. Vaughan, "Household Water demand estimation," Technical Report Working Paper ENP 106, Inter-American Development Bank , Productive Sectors and Environment Sub-department of the Environment Protection Division (Washington D.C.: 1994).

[9] See discussions in Chicoine, D.L. and G. Ramamurthy, "Evidence on the specification of price in the study of domestic water demand," *Land Economics*, 62(1), 26-32, 1986. Arguments against the use of marginal prices, based on the premise that consumers do not devote time or effort to study their community's rate structure, are seen in (e.g.) Bachrach and Vaughan, *Op. Cit.* 1994 and Billings, R. B. and D.E. Agthe, "Price elasticities for water: a case of increasing block rates," *Land Economics*, 56(1), 73-84, 1980.

[10] Renwick, Mary E. and Richard D. Green, "Do residential water demand side management policies measure up? An analysis of eight California water agencies," *J. Environmental Econ. And Management*, 40, 37-55, 2000 at p. 50.

[11] Nordin, J.A., "A proposed modification on Taylor's demand-supply analysis: comment," *The Bell Journal of Economics*, 7(2), 719-721, 1976. Nordin's work is based on structures introduced by Taylor, L.D., "The Demand for electricity: a survey," *The Bell Journal of Economics*, 6(1), 74-110, 1975.

are used the difference variable should be equal in magnitude and opposite in sign to the income effect variable. This theoretical expectation is seldom if ever realized, however. There is considerable controversy over the explanation for this outcome, as well as over the use of Nordin's approach in general.[12]

Controversy also exists concerning such things as: whether or not current or lagged prices should be used;[13] how income is to be treated (e.g., household income, or value of property[14]), whether and how weather variables might be used, and types of household characteristics that should be included.

Of particular concern for our purposes is the debate concerning data sets that are appropriate for demand estimation. While problems associated with the use of aggregate data under block pricing are well known, most studies simply ignore these problems and use marginal price, marginal quantity, and the difference variable defined above as they relate to the "typical," or average household in a community; ideally, averages would be weighted by the distribution of users in each block.[15] One would like to use a time series of price-quantity data for individual households. Such data sets are difficult to obtain, and few studies have made use of them.[16] A notable exception is the study by Hewitt and Hanemann[17] which uses panel data with a

---

[12] See, as examples, Billings and Agthe, *Op. Cit.* 1980, Schefter, J.E. and E.L. David, "Estimating residential water demand under multi-tariffs using aggregate data," *Land Economics*, 61(3), 272-280, 1985; and Nieswiadomy, M.L., and D.J. Molina, "Comparing residential water estimates under decreasing and increasing block rates using household data," *Land Economics*, 65(3), 280-289, 1989.

[13] See Young, C.E., K.R. Kingsley, and W.E. Sharpe, "Impact on residential water consumption of an increasing rate structure," *Water Resources Bulletin*, 19(1), 81-86, 1983, and Nieswiadomy, M.L., and D.J. Molina, "A note on price perception in water demand models, " *Land Economics*, 67(3), 352-359, 1991.

[14] See Arbues, *et al.*, *Op. Cit.* 2003 at p. 85.

[15] Schefter and David, *Op. Cit*. 1985.

[16] See Arbues, *et. al*, *Op. Cit.* 2003 at pp 89 and 90.

[17] Hewitt, J.A. and W.M. Hanemann, "A discrete/continuous choice approach to residential water demand under block rate pricing," Land Economics, 71(2), 173-192, 1995.

discrete choice model. The Hewitt-Hanemann work is one of the very few demand estimation studies that finds residential water demand to be very price *elastic* (as noted earlier, the vast majority of water demand studies find demand to be very price <u>in</u>elastic).

Finally, the choice of a functional form to use in demand estimation introduces still further complexities. Linear functions are most commonly used despite criticism of their use on the grounds that results derived from them imply that the change in quantity demanded in response to a price change is the same at every price level; however, linear demand functions also imply that consumers are less sensitive to price at lower prices, an intuitively appealing notion.[18] Another commonly used functional form is the double-log, which yields direct estimates of elasticities; it also, however, leads to a constant-elasticity type of demand, which is at odds with received theory. Especially when attention is focused on elasticity measures, an alternative that yields results consistent with received theory is the semi-log form, where the elasticity measure can be obtained at any price by simply multiplying that price times the coefficient on the price (or marginal price) variable. For our analyses, the semi-log form is used.

Given the many difficulties for demand estimation (based on cross-sectional data) imposed by the complexity of price structures used by different communities, it is common for economists to focus their analyses of demand estimations on measures of elasticity as opposed to demand estimation *per se*.[19] This is to say that, even if the resulting estimated demand function does not provide reliable estimates for quantity demanded at any given price (as reflected by

---

[18] See, e.g., Billings, R.B. and W.M. Day, "Demand management factors in residential water use: the Southern Arizona experience," *Journal of the American Water Works Association*, 81(3), 58-64, 1989.

[19] Arbues, *et. al*, *Op. Cit.* 2003 at p. 83.

small values for the R-squared measure[20]), such forms **can**, however, yield reliable estimates for the elasticity of demand.[21]

Our review of problems and issues associated with the choice of functional form for demand estimations, as well as with the choice of variables and their measurement is not intended to be exhaustive. It's purpose is to provide the reader with some feel for the nature of ongoing controversy related to the estimation of residential water demand. For this phase of our study, we use the semi-log form for estimating demand. We use aggregate data across many different types of price structures. We use the measure of use and price that appears to be the "preferred" measures in the literature: marginal quantities and marginal prices. Thus, our dependant variable is the log of marginal quantity and our independent variables are: marginal price, household income, and the difference variable. We recognize and sketch out above the potential weaknesses associated with this approach to demand estimation. In the concluding section we detail our plans for phase II of our study in which the scope and quality of data used will be markedly improved.

III. Estimating Residential Water Demand And Price Elasticities.

[20] The R^2 measure can be interpreted as measuring the percent of variation in quantity used that is "explained" by the variables (price, income, etc.) in the estimated demand equation.

[21] See, for example, William H. Green, Econometric Analysis, Fifth Edition, Prentice Hall (Upper Saddle River N.J.: 2003).

For our estimates of residential water demand across the 50 coastal communities in our data set, we estimate the following functional form.

(1) $\ln(mq) = a_2 + b_2Y + c_2D + d_2\, mp$

where

mq = marginal quantity (in thousands of gallons)
Y = median household income
D = difference variable
mp = marginal price (per thousand gallons)
ln( ) = the natural log of the variable in parentheses

Our central focus is on estimates for the elasticity of demand which, with the semi-log equation (1), is given by multiplying marginal price times the coefficient $d_{1.}$ Results from our estimates for (1) are as follows. Numbers in parentheses under coefficients are values of the relevant t-statistics, which provide an indication of the statistical significance of the coefficient. Values of t > 1.8 indicate statistical significance at a 95% level of confidence. The R^2 statistic measures the variations in observed values of q (or mq) that are "explained" by the included variables. The number N represents the number of observations included in the estimation.[22]

JANUARY

(1) lnmq = 1.67 - .00001Y - .01D - .43mp R^2 = .38 (N = 43)
(5.95) (-2.28) (-.97) (-4.34)

JULY

(1) lnmq = 0.94 + 0.00000Y - 0.01D - 0.26p R^2 = .18 (N=45)
(3.86) (.63) (-1.20) (-2.93)

A. Results for January 2002. Referring to equation (1) for the month of January, as expected our equation has little in the way of explanatory power. Included variables "explain"

[22] Different values of N reflect differences in the availability of useable data from the 50 systems as they are relevant for estimating a particular functional form.

only 38% of observed variations in lnmq (see the R^2 statistic). Interestingly, the coefficient on Y, while very small in value, is negative; one might expect that, all else equal, water use would be positively related to income. Note also that the coefficient on Y is statistically significant (t > 1.8). The coefficient on D, the "difference variable," is negative, as expected, but is not statistically significant at any conventional level of confidence. These observations are consistent with findings in earlier studies that report relative values for coefficients on Y and D that differ from predictions derived from theoretical models.

Our primary interest, of course, is with the coefficient associated with marginal prices, mp in (1). The t-statistic associated with this coefficient -.43 is -4.34, which provides strong evidence that residential water use in the coastal counties (at the margin, as measured by marginal quantity used) is affected by water prices (again, at the margin: the marginal price). A measure for the elasticity of demand is obtained by multiplying mp times the coefficient on this variables. With the coefficient on mp of $0.43/thousand gallons, residential demand for water will be *inelastic* for all marginal prices below $2.33. Observed marginal prices in our data set are below $2.33 in 94% of the 43 systems for which marginal prices are relevant. In only three of these systems are marginal prices above $2.33 -- $2.69, $2.75, and $3.17 per thousand gallons.

These observations suggest that there is strong evidence supporting the notion that residential water use is significantly affected by prices, and that residential demand for water is price inelastic in all by three communities with marginal prices that are at or above 192% of average marginal prices observed in the region.

B. Results for July 2002. Results obtained for July generally parallel those observed for

January, but there are differences. The R^2 statistic is smaller, and neither the coefficient on Y nor on D is statistically significant. The coefficient on mp is statistically significant at all conventional levels of confidence. Thus, as with our analyses of January data, there appears to be compelling evidence that water use, at the margin, is significantly affected by prices charged.

With the coefficient on mp at -$0.26 per thousand gallons, demand is inelastic at all values of marginal price below $4.00 per thousand gallons, which is well in excess of any observed marginal price in our data set for the month of July. This observation would appear to strengthen the conclusion suggested for January — residential water demand appears to be price inelastic in all but a very few cases.

IV. Concluding Remarks.

In this initial, exploratory phase of our efforts to estimate the demand for residential water use in Georgia's Coastal counties, with particular attention given to the price elasticity of such demand, we find what can be regarded as strong evidence that price indeed affects the demand for residential water use at the margin. Moreover, our results provide reasonably compelling evidence that the demand for residential water use in coastal counties is price inelastic -- an increase in price increases system revenues, rather than decreasing them. At relatively high marginal prices, the inelasticity of demand may be problematic. This caveat alone justifies our concern with expanding our data base so as to enhance the credibility of our characterizations of price-quantity relationships, and associated measures of elasticity.

The primary objective for our phase two research will be to greatly refine our price-quantity data set. We hope to obtain average monthly billings from a subset of coastal communities over a five to ten- year period. The design of our phase two efforts will be guided in large part by the work of Renwick and Green,[23] who were able to derive price-quantify relationships with extraordinary explanatory power (the R^2 measure obtained by Renwick and Green was 97%!). Such expansions will, hopefully, provide more robust measures of price-quantity relationships in our study area.

[23] Op. Cit. 2000.