Water Conservation From User Charges in Multifamily Rental Housing

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Abstract

In many states and local jurisdictions, utility regulations prevent apartment owners and managers from charging residents directly for their water usage. Instead, the property's water and sewer costs must be recouped through the rent. One important consideration in weighing the regulatory options for water is the amount of water likely to be saved if apartment residents are separately charged based on their water consumption, rather than through a fixed increment to rent that varies little, if at all, with the individual resident's water usage. While the literature on residential water demand is substantial, little of it is directly applicable to this question.

This paper reports results of research to project the likely water savings per apartment and in the aggregate when apartment residents go from paying zero marginal price for water to paying market rates based on their personal usage. Using household data from the 1995 American Housing Survey and water/sewer pricing information for 57 local jurisdictions nationwide, the research first specifies models of residential water consumption and estimates the models using data on homeowner households in the AHS who pay separately for their water sewer usage. The models' calibration is then applied to apartment residents to project their water usage under different pricing schemes, controlling for differences in the demographic characteristics and geographic locations of homeowner and apartment renter households. Finally, the paper relates the findings to previous research and current regulatory policy.

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I. Introduction

Most apartment residents pay for their water usage through their monthly rent. In 1995, only 7 percent of the nation's residents of multifamily rental housing reported that they paid separately for water and sewer service. This is in contrast with payments for electricity, which in 1995 were separate from rent in 83 percent of all apartments (National Multi Housing Council, 1998).

The relative infrequency of separate billing for water has several explanations. In the past, water prices were low and it was either prohibitively expensive or technically infeasible to monitor usage and bill apartment residents separately for water. Furthermore, some state and local jurisdictions have restricted property owners' ability to charge apartment residents separately for water and sewer.

In recent years, the economics and technology of residential water use in multifamily housing have been changing dramatically. Between 1990 and 1998, the cost of water and sewer to consumers increased 45 percent, as measured by the Consumer Price Index. This rise is almost double the 25 percent increase in consumer prices in general during that period.

As water prices have been increasing, the technology of water metering has been improving and the equipment is becoming less expensive. Meters that are installed in each apartment are becoming smaller, and methods for reading the meters electronically without entering the apartment are being introduced (McDonald, 1998).

Despite these technological advances, in some apartment communities it still is not economically feasible to retrofit apartments with water metering equipment. This is especially the case in older mid- and high-rise properties, where metering would require major structural work. At some of these properties, managers are allocating some portion of the property's total water bill among residents, using one of a number of formulas that have come to be known as RUBS, for re-allocation (or ratio or resident) utility billing system. With RUBS, the property bills residents for water and sewer separately from their rent. The property's water bill is allocated among residents based on the square footage of the apartment, number of occupants, number of taps, number of fixtures, or some other quantitative measure. Increases and decreases in the property's water bill are passed through to the residents, using the allocation criteria to determine the share paid by each apartment household. Sometimes the property management bills residents directly, but often separate specialized companies are hired to bill the residents and remit the proceeds to the property management.

In contrast to the rapidly changing economics and technology of water monitoring and billing in multifamily rental housing, many jurisdictions retain longstanding regulatory restrictions on property managers' ability to charge for water or sewer separately from rent. In some jurisdictions, apartment properties that bill separately for water are viewed as public utilities that are selling water, even if residents are charged only what the property pays the water authority. In these locales, apartment owners may be subject to the same water quality monitoring and other regulatory requirements as the city's own water authority.

This regulatory treatment of residential water billing contrasts with the government approach toward electricity. In response to the energy crisis of the 1970s, federal legislation was enacted in 1978 that encouraged states to require that most newly constructed apartments be separately metered for electricity. The Public Utility Regulatory Act of 1978 suggests that states restrict the use of master metering (that is, one meter for the entire apartment property) to cases where the owner could demonstrate that the costs of individually metering apartments exceeded the lifetime cost savings from reduced electricity usage from individual metering (16 U.S.C. 2623, as cited in Manley, Taylor, and Formby, 1990).

Many jurisdictions are now evaluating their regulation of residential water pricing and billing. One of the important pieces of information in evaluating the regulatory options is the water savings likely to accrue if apartment residents are charged directly for water consumption. Especially in jurisdictions where the existing water and sewerage treatment facilities are approaching capacity, water conservation can delay or eliminate the need for costly new facilities to be built.

The purpose of this study is to estimate the amount of water likely to be saved by charging apartment residents directly for water usage. The research produces estimates for the nation overall as well as for three large states. While there is a fairly extensive literature on the economics of water consumption, the research reported here makes three contributions: (1) the data are national in scope, coming from 57 geographically diverse cities; (2) the data, from 1995, are more recent than in most existing studies; and (3) the analysis and estimates focus on water consumption in multifamily rental communities.

This report describes the construction of a new data set that combines information from two sources and then specifies and estimates economic models of consumer demand for residential water. Next, the results from those models are used to estimate the price responsiveness of residential water consumption. The estimates are then combined with information on the characteristics of apartment residents to generate estimates of the amount of water that will be consumed by the typical apartment resident, and by apartment residents in the aggregate, when faced with different prices for that water. Results are provided for the nation overall, with additional detail for three large states.

The findings can be summarized as follows:

1. Water consumption is sensitive to the price consumers pay. Our findings using recent national data corroborate most previous studies. The findings are clearest empirically and theoretically for the marginal price, which is defined as the additional charge to the customer for additional water usage. The estimated response of consumption to marginal price implies a price elasticity of approximately 0.7; that is, a one percent increase in the marginal price of water results in a 7/10 of a percent decrease in water usage.

2. Fixed monthly charges also affect water consumption. Consumers in jurisdictions with higher fixed charges (that is, a price that is paid monthly just for being connected to the local water supply, in addition to a per-gallon price for water actually used) use less water than consumers in jurisdictions with lower fixed charges. However, the results hint that the estimated fixed charge influence is due at least in part to conservation and consumer education programs that likely are more prevalent in jurisdictions with high fixed water charges.

3. Characteristics and locations of consumers influence their water consumption. As might be expected, water consumption increases with family size and income. Significant variation in residential water usage is found also by region and state, indicating climate influences and perhaps other unmeasured effects correlated with location.

4. The results of the estimation for households that now pay for their water and sewer implies that the nationally typical apartment household will eventually reduce its water consumption 52 percent if it shifts from paying a zero marginal price to paying the national average marginal price. In interpreting this large projected reduction, it is important to note that it is a long-run response after consumer behavior adjusts completely to the pricing and water-conserving appliances are installed on normal replacement cycles.

5. Multiplying the per apartment saving by the number of apartment households nationwide who are not currently paying separately for water suggests monthly savings of roughly 9.4 billion cubic feet (or 70 billion gallons) of water. This amount represents perhaps 4 percent of total national residential water use. At the local level, percentage reductions of this magnitude may permit postponement or cancellation of planned municipal capital outlays for water and sewerage treatment facilities.

6. The analysis generates separate estimates for several large states that take into account each state's profile of apartment renters and average water prices. The results indicate that in California, the typical apartment resident would eventually decrease consumption 56 percent when they went from paying zero marginal price to paying the state average price for water. Statewide the monthly water savings would be 2.2 billion cubic feet. In Texas, the typical apartment household would reduce consumption 58 percent, resulting in statewide savings of 1.1 billion CF monthly. In Florida, the water usage reduction per apartment is projected at 65 percent and statewide savings at 0.9 billion CF monthly.

7. The per-apartment water savings projected here are larger than most results reported by apartment operators who have begun charging their residents for water: Properties that have submetered report that water consumption reductions of 25 to 40 percent (Walter, 1997). One possible reason for the larger reduction in this study is that owners of submetered properties may not be charging for water at rates as high as the state average, unlike in our projections. Another reason is that our estimates, as noted above, are of long run impacts, which could take several years to be fully realized.

8. The results for fixed charge effects suggest that RUBS cost allocation programs can lead to significantly reduced water usage, even if apartments are not separately metered or submetered. Separate billing heightens awareness that water is not a free good and perhaps makes consumers more open to conservation possibilities. But the results also suggest that significant water savings from RUBS are conditional on other conservation measures and education programs being implemented at the same time as the conversion to RUBS.

9. At apartment properties where water costs are now being recouped through rent, total housing costs (rent plus utilities) might even go down for the typical resident, as everyone uses less water once they begin paying based on usage and the majority of residents who are moderate users no longer subsidize extravagant usage by a few.

10. All of the quantitative estimates from this research should be viewed as approximations. As with all statistical economic analyses, the results depend on the accuracy of the underlying data and are affected by decisions on model specification and estimation methods. Nevertheless, the price responsiveness and apartment consumption projections are based on conservative assumptions, and the empirical results are reasonably robust under alternative specifications. Furthermore, the results of this analysis are generally consistent with those of previous studies, where comparisons are possible.

Overall, the analysis provides strong evidence that significant water savings are likely if apartment residents are charged separately for their water usage. Even if the actual reductions are only half of those projected here, the water savings will be substantial. Technology is making this separate monitoring and billing increasing feasible, and the economics are making these innovations financially compelling.

The remaining sections of this report 1. review previous studies of residential water demand; 2. describe the data used in this analysis; 3. specify and estimate models of water consumption; 4. use the model results to estimate the water savings from billing apartment residents separately, and 5. develop state-level estimates of aggregate water savings.

II. Previous Research

Residential demand for water has been a topic of study for resource economists and others for more than a quarter century. A bibliography of studies consulted in connection with this investigation appears at the end of this report. While a few of those studies are national in scope, far more common are studies that accessed data available for only one city or water district. And few studies have used data from the 1990s. Several of the studies in the bibliography include literature reviews. Here we will only briefly highlight a few issues from previous studies that are particularly pertinent to our study.

The first issue is the set of variables that determine residential water demand. Of most importance for this study is the price consumers pay for water. Most studies have found a substantial price effect: The more consumers have to pay for water, the less they use. theoretically and empirically, the marginal price is the most important. It measures the additional cost to the consumer for additional water. Marginal price "elasticity" estimates generally range from -.26 to .-82 in the studies surveyed by Nieswiadomy (1992) and earlier research reviewed by Foster and Beattie (1979). That is, a one percent increase in the price per cubic foot (or gallon) of water results in a decrease of 0.26 to 0.82 percent in the quantity of water consumed.

Some studies have refined the analysis of marginal price effects by examining the influence of "block" pricing schemes, in which the marginal price depends on the level of consumption. Under an increasing block pricing scheme, the marginal price increases in steps, as the level of consumption increases. With decreasing block pricing, the marginal price decreases as consumption increases. As might be expected, increasing block schemes have been found to result in stronger marginal price effects on consumption than do decreasing block schemes (-.64 versus -.46, as estimated by Nieswiadomy and Cobb).

Many jurisdictions also charge residential water users a fixed monthly charge for being connected to the water system. This fixed charge is paid even if no water is used during that month. Actual water usage is billed per gallon in addition to the fixed charge. The literature offers little evidence on the effects of these fixed charges on water usage.

Most jurisdictions charge separately for water and waste water, but residential users typically pay both bills based on water intake, because outflow is not separately measured. The relevant price variable then is the combined charge for water and sewer usage.

Regardless of what water and sewer prices actually are, it is consumers' perception of those prices that affects their consumption. Average price -- including both the fixed monthly charge and the marginal price for water used -- has been found in some studies (Martin and Wilder, 1992, is one) to influence water consumption. Average price often is more visible to consumers on their water bill than is marginal price. As a result, even though average price is theoretically inferior to marginal price (and dependent too on the amount of water used, causing statistical difficulties in model estimation), average price may be what some consumers respond to.

Several variables in addition to price have been found to influence water consumption. Not surprisingly, larger households use more water, and most studies find that water usage and income are positively correlated. The presence and size of a yard and garden also matter. Studies undertaken across jurisdictional boundaries have found significant locational effects attributable to climate and perhaps other location-specific influences such as conservation and consumer education programs.

In choosing a functional form for estimating demand equations and other models of water usage, analysts trade off simplicity against completeness and statistical purity. Most studies assume linearity, that is, a unit change in an independent variable causes a fixed change in the dependent variable, regardless of the levels of the independent and dependent variables. And most models assume additivity, that is, the effect of one independent variable on the dependent variable is not influenced by the level of any other independent variable.

A final dimension in the literature is geography. Some studies have focused on individual jurisdictions because of their policy importance or the availability of unique data. Single-jurisdiction studies can estimate price effects by looking at water usage changes over time as prices are changed. Fewer studies have used data from multiple jurisdictions or the nation overall. The cross sectional results from multi-jurisdiction studies are particularly useful for estimating longer term responses to changes in water prices.

III. The Data

The analysis in this study combines consumer information from a national household survey with information on water prices in 57 large and mid-size cities nationwide. The household information comes from the public use data files of responses to the1995 American Housing Survey (AHS). The AHS provides information on resident demographics and housing characteristics for a probability sample of approximately 50,000 occupied housing units, including both owners and renters, in single-family and multifamily structures (U.S. Bureau of the Census, 1997). Region of residence and local climate information is provided for all surveyed households, and residence in over 100 large metro areas is separately identified. In the AHS, households that report that they pay for their water and sewer are asked what their annual expense is for these utilities.[1] In this analysis the annual estimates are converted to monthly figures by dividing by 12.

The water price information comes from the *1996 Water and Wastewater Rate Survey*, a publication of Raftelis Environmental Consulting Group. This widely used reference provides data that were current as of the latter part of 1995, matching the timing of the AHS household survey, which was fielded between August 1995 and February 1996. The Raftelis survey includes information on water and wastewater rates in 112 cities. For these jurisdictions, monthly charges to residential users are given for three levels of monthly water consumption: 0 cubic feet (CF), 500 CF, and 1,000 CF. (Note: 1,000 CF = 7,480 gallons). Separately, the Raftelis survey provides monthly wastewater charges for those same three use levels.

The 57 cities covered in our analysis are those for which (1) complete price information is available from the Raftelis Survey, (2) geographic identifiers are available from the 1995 AHS to permit the appropriate price information to be appended to each of the household records, and (3) at least one AHS sample household reported that they paid separately for water and sewer and provided the amount they paid. The cities included in the analysis are listed in Appendix Table 1. The approximately 2,500 household observations used in much of the analysis below cover the full range of population characteristics, all regions of the country, and a variety of water pricing

[1]The question wording is: “In the past 12 months what was the total ANNUAL cost for water supply and sewage disposal?”

systems. The data set should permit a good calibration of the effects of different variables on water consumption.

-- Water Quantity and Price Variables

The Raftelis data set permits construction of both fixed and marginal price variables. The fixed charge is the amount of the monthly bill for residential accounts using no water in the month. In some of the 57 cities in the analysis the fixed charge is zero, but in most it is positive. The Raftelis data also provide figures for the total bill for 1,000 cubic feet of water per month. A marginal price variable can be constructed by subtracting the monthly fixed charge from the monthly total bill for 1,000 cubic feet of water. (In jurisdictions with block pricing schemes, the marginal price variable is more precisely an average of the marginal prices within the first 1,000 cubic feet of monthly water usage.) The fixed charge, marginal price, and total bill for 1,000 CF are summarized in Table 1.

In this analysis, the quantity of water used, or consumed, by a household is calculated as follows. First, from each AHS household's estimate of its monthly water bill, we subtracted out the fixed monthly charge reported for that jurisdiction by Raftelis. The remainder is then divided by the marginal price to get the quantity used. [2] For example, the mean monthly expenditure for water and sewer among the 2,527 households that say they pay for it separately is $29.60, as recorded in the AHS (and using the AHS sampling weights). Subtracting the fixed charge, if any, in the household's water district gives an average remainder of $22.09. The marginal price of 1,000 CF for these households averages $21.82. Calculating consumption using each household's values for these variables yields a mean monthly quantity of 1,515 cubic feet (11, 474 gallons) per household and a median quantity of 986 CF (7,375 gallons).

Water consumption in our sample, as estimated above, is broadly consistent with national averages estimated in other studies, increasing our confidence in the estimation method. For example, Nieswiadomy (1992, Table 2) presents regional averages ranging from a low of 6,917 gallons monthly in the Midwest to 13,544 gallons monthly in the West. Independently, the U.S. government estimates that public supply domestic water deliveries in 1990 averaged 105 gallons a day for each person served (U.S. Geological Survey, 1996). At 2.6 persons per household (the national average in 1995) and 30 days in a month, that estimate becomes a mean monthly household consumption of 8,190 gallons, which falls between our estimate of the median and mean.

IV. Model Specification and Estimation

Several models of water demand were specified and estimated as part of this study. The

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[2] The total monthly bill (TB) equals the fixed charge (FC) plus PQ, where P is the marginal price and Q is the quantity of water used. Therefore, Q = (TB-FC)/P .

specifications were based on previous research, the characteristics of our data set, and the study objectives. This section presents results from the preferred model. The next section summarizes results from alternative specifications. Subsequent sections then use the model results to project apartment resident water usage at different prices.

The preferred specification takes the log of water consumption to be a linear additive function of the marginal price to the consumer, the fixed cost to the consumer, household income, household size, structure type, and location. This multivariate specification allows the separate effects of the several variables to be estimated. Mathematically, the model is:

$$\ln Q = a + b_1 MC + b_2 FC + \Sigma k_i X_i + \Sigma d_j D_j + e$$

where

lnQ is the natural log of the monthly water consumption (measured in 1,000 cubic feet);

MC is the marginal price (or cost) to the consumer of 1,000 cubic feet of water per month;

FC is the fixed monthly price (or cost) to the consumer for being connected to the local water/sewer system;

Xi is a set of i continuously measured characteristics affecting water demand (income and household size),

Dj is a set of j "dummy" variables representing discrete characteristics (structure type, climate zone, and state/city of residence);

Σ indicates summation over i or j ;

b, k, and d are parameters, and

e is a stochastic error term.

The dependent variable is specified in logs to allow the effect of price on consumption to vary with the level of price as well as with the values of the other independent variables. The interpretation of the coefficients in this "semi-logarithmic" specification is that a one unit (e.g., dollar or person) change in the independent variable increases or decreases the dependent variable by a fixed percentage. The semi-logarithmic specification is a standard functional form in demand analysis because of its attractive economic and statistical properties.

Marginal price is expected to negatively influence water demand, and the effect of fixed charge is anticipated to be either zero or slightly negative. Income and household size are both expected to positively influence water demand. Townhouse structure type is used as a proxy for not having a large yard that needs watering, and should have a negative influence. Finally, location, both region and some large states within some regions, are used as proxies for climate and for other location-specific influences, such as consumer attitudes and non-price regulations affecting water usage.

The model is estimated for single-family homeowners (including townhouse owners, who account for about 8 percent of the homeowner subsample used for the model estimation). Because homeowners pay their own water bills, in their entirety and directly to the water utility, this sample restriction should improve the accuracy of the estimated price effects. The data base also includes several hundred renters and owners in multifamily structures who report that they pay separately for water, but these observations have not been used in the calibration. One reason for the exclusion is that it is not clear that their billing is based on their personal usage, because these units may not be separately metered or submetered. In addition, the condo association or rental property management may pass on only part of the property's total water/sewer bill directly and recoup the balance through rent increments or general condo fees.

--Estimation Results

Results from the estimation are generally consistent with expectations (Table 2). Looking first at the non-price variables in the "without city effects" columns, both household size and income have statistically significant positive relationships to water consumption. (Note: The "t ratio" is the ratio of the estimated coefficient to its standard error. Values of the t-ratio of 2.0 or higher in absolute value are usually taken to indicate effects that are significantly different from zero, that is, a non-zero relationship is likely to exist in the entire population as well as in the sample being analyzed.) In addition, water usage is less, all else equal, in townhouses, where yards and gardens generally are small or nonexistent.[3] Location also matters, independent of household characteristics and housing type: Several states and regions have water consumption that is significantly different from the national averages.

As for the price variables, both marginal price and fixed monthly charges are negatively associated with residential water usage. Beginning with the marginal price measure, the coefficient indicates that each one dollar increase in the price of 1,000 cubic feet of water reduces consumption by 3.36 percent. Evaluated at the mean marginal price of 21.56 per 1000 CF(from Table 1), the "elasticity" is - 0.72; that is, a one percent increase in the marginal price brings a 0.72 percent decrease in water usage.

The coefficient on the fixed charge variable is also negative and significant. Its value in the

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[3]Effects of categorical variables are measured through "dummy" variables that take the value 1 if the characteristic is present in the sampled household and zero otherwise. The regression coefficient gives the incremental effect of having that characteristic on the value of the dependent variable.

"without city effects" column implies that a $1 increase in the fixed monthly charge reduces water consumption by 2.91 percent, an effect just slightly less than that of the marginal price increase. Evaluated at the mean fixed charge of $7.83, the fixed charge elasticity is - 0.23; that is, a one percent increase in the fixed charge brings a 0.23 percent decrease in water usage. The standard error of the fixed cost variable, however, indicates that the fixed charge effect is not estimated with as much precision as is the marginal price effect. Nonetheless, the estimate is significantly different from zero by standard statistical tests, and its magnitude is, frankly, surprising. Fixed costs would not typically be expected to affect the amount of consumption, because the fixed amount paid does not depend on the amount consumed.

The fixed charge effect appears, however, to be capturing the influence of local effects that are correlated with fixed charge. The evidence comes from the second set of regression results presented in Table 2, under the heading "with city effects". This specification is identical to the one just described, except that independent variables have been added that indicate the presence in each of the 57 cities. Inclusion of these dummy variables captures the net effect of other, city specific, influences not represented by any of the other independent variables in the equation. Note that adding these city variables does not significantly change the effect of the marginal price or household characteristics. In contrast, the fixed charge effect pretty much goes away under this alternative specification. The estimated coefficient on fixed charge barely exceeds its standard error (that is, the t-ratio is just over 1.0), and so we cannot say with any confidence that the fixed charge effect is not zero.

One city-specific effect likely to be positively correlated with fixed water charges is the presence and extent of water conservation and consumer education programs. Jurisdictions with high fixed charges also tend to have high marginal prices, and it seems likely that these jurisdictions would have the most pressure from consumers for help in reducing their monthly water bills.

These results for the fixed charge variable hint that RUBS programs for allocating water costs among apartment residents may lead to reduced consumption even if water usage in apartments is not separately metered. (RUBS is similar in operation to a fixed monthly charge for water, in that the water bill to the apartment resident is only slightly dependent on their personal usage that month.) The separate billing of water, common in cost allocation programs, makes water costs more visible to apartment residents, similar to the bills received by homeowners from their utility. This visibility may be a psychological effect on consumption, even if the resident pays essentially zero marginal price for his or her own consumption.[4] The regression results in Table 2 suggest that cost allocation systems, when combined with consumer education and other conservation

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[4]The marginal price is close to, but not exactly, zero in RUBS-style cost allocation systems. For example, in a property with 100 equal-sized apartments that divides the property's water bill among apartments based on square footage, any one resident will pay (or save) only 1/100 of the cost to the property of any increase (or decrease) in her water usage. If the property includes common areas where water usage is charged back to residents, the linkage between usage and billing will be even less.

measures on the apartment property, could result in substantial water savings.

It is important to note that the price effects estimated here are long-run. Sample households in the cross-sectional data set typically have been paying prices different from those sampled households in other jurisdictions for a long time. The price responses estimated here probably would take several years to be completed, as consumers gradually adjusted their water usage to changes in the prices they were paying in their monthly or quarterly bills.

Various diagnostic statistics increase our confidence in the models in Table 2. As mentioned, the independent variables are generally statistically significant and have plausible estimated effects on water consumption. The overall fit of the model, as measured by the adjusted R-square statistic, is respectable for cross-sectional microdata such as used here.

Lastly, on the important marginal price variable, examination of the residuals from the regression indicates no tendency to under- or over-predict water usage at extreme values of marginal price. This property of the model is important for the projections, presented later, of likely consumption responses when apartment residents go from paying zero marginal price to a market average price. If, for example, consumers were insensitive to marginal price when marginal price was low, the models of Table 2 would tend to overpredict water consumption at very low prices. The residuals from the regression indicate that this overprediction does not occur.

–Alternative Specifications

The model above was chosen to balance theoretical and statistical correctness against simplicity in interpretation. But the results appear robust, in that they are corroborated by several other models that were estimated.

A simpler alternative to the model in Table 2 is identical in all respects except that the dependent variable, monthly water usage, is measured in cubic feet rather than in the logarithm of cubic feet. Results from this estimation are in Appendix Table 2. The coefficient on the marginal price variable suggests indicates that a $1 increase in the price per 1,000 cubic feet reduces monthly water usage by 58 cubic feet. The implied price elasticity, evaluated at the means of the price and usage variables, is -0.82. This value is similar to the -0.72 price elasticity estimate generated by the preferred model in Table 2. The fixed charge effect estimated from the specification in Appendix Table 2 also is similar to that in the preferred model. In particular, the fixed charge effect goes from negative to statistically insignificant when the city effects are added to the model.

Another common model specification converts all variables into logarithms before estimation of the regression. This double-logarithmic specification allows the estimated regression coefficients to be interpreted as elasticities. One disadvantage of the double-logarithmic form is that it becomes unwieldy, and the results difficult to interpret, when the number of independent variables is large or when the independent variables are categorical or take on negative values. For these reasons, the double-logarithmic model estimated has a reduced set of independent variables (Appendix Table 3). Nonetheless, results are consistent with those of the preferred model in Table 2. In particular, the coefficients on the marginal price and fixed charge variables indicate elasticities of -0.772 and -0.111 respectively, very close to those of the Table 2 models.

Other models tested the influence of other independent variables. Climate was measured by variables indicating heating and cooling degree days. Inclusion of these variables did not significantly alter the estimated effects of marginal price and fixed charge, but the coefficients of the geographic identifiers were affected because of the strong correlation of location with weather. This multicollinearity resulted in unstable estimates of location effects, and climate effects too.

Alternative versions of the price variables were tested as well. Marginal price was measured for usage of between 500 and 1000 CF monthly, instead of for the first 1,000 CF. Average price (fixed charge plus marginal price) for 1,000 CF was substituted for the price variables in Table 2. And dummy variables were used to indicate jurisdictions with increasing and decreasing block pricing. The results from all of these alternatives were similar to those described above.

V. Water Savings: National Estimates from User Charges for Apartment Households

The models described above were estimated on homeowner households that pay directly for their water. Most apartment residents do not currently pay separately for their water. But the results can be applied by matching on household characteristics. That is, if we know how homeowner households of a size, income, structure type, and location respond to an increase in water price, when they have to pay for their water usage, then we can use our results to project how apartment renters fitting that same profile would respond to a change in water pricing if they had to pay.

Table 3 gives the characteristics of the nation's apartment residents that are used in this exercise. The means of the location variables give the proportion of all U.S. apartment households that reside in that jurisdiction. For example, 24.4 percent of all apartment households are in the Northeast. These average values can be combined with the parameters (that is, the estimated coefficients) of the model in Table 2 to generate projections of the typical apartment resident's consumption of water at different prices. (Actually, the calculations produce projections of the log of consumption, which I have then converted into arithmetic units.)

Table 4 gives the results of this exercise for different levels of marginal price, and the results are also plotted in Chart 1. The exercise results in large projected water savings when apartment residents go from not paying for water based on their usage to paying marginal prices equal to market rates. For example, the projected reduction in consumption is 52 percent when residents go from paying zero marginal price to the national average of $21.56 for the first 1,000 CF. These estimates separate out the effects of income, family size, and the other non-price characteristics in the regression and so give an estimate of the "pure" effect of marginal price for the typical apartment household.

The line in Chart 1 shows how the consumption of that typical household would change if the marginal price changes but all other characteristics are held constant. Note that the line in Chart 1 is curved. This is because of the semi-logarithmic form of the model estimated in Table 2, which allows the effect of a $1 change in price on water consumption to vary with the level of the price. Specifically, the model specifies that as water prices increase, the resulting declines in water consumption become smaller, which makes sense. For orientation, note also that the chart shows a level of usage corresponding to zero price. This point in the chart is the 1,365 cubic feet estimate shown in Table 4.

As a check on our estimates, the usage levels at zero marginal price in Table 4 were compared with figures from an independent source of water statistics, the *1997 Income and Expense Survey for Conventional Apartments* (Institute of Real Estate Management, 1997). Because of reporting differences, precise comparisons are not possible, but it appears that the mean water/sewer cost per apartment (including common areas) from the IREM survey is between $20 and $25 per month. The $22.50 midpoint of this range can be converted into a water quantity by subtracting the average national fixed charge of $7.83 (from Table 1) and dividing the remainder by the national average marginal price of $21.56 per 1,000 CF (also from Table 1). This conversion results in a monthly consumption level of 680 cubic feet. Although lower than our zero-price projection of 1,365 cubic feet, for several reasons the two estimates appear broadly consistent.[5]

--Are the Water Savings Overestimated?

Our projected average water savings from charging based on usage exceed most anecdotal reports of actual experience in properties that have installed meters or submeters. Those estimates range

[5]One reason for the lower estimate of water usage from the IREM survey is that, because the IREM properties are professionally managed and newer on average than the nation's apartment stock, they likely have more water-efficient appliances and closer management attention to leaks than do apartments in general. Also, some of these properties are metered or submetered, which would also reduce consumption relative to the 1,365 CF estimate above. Furthermore, the IREM averages include vacant apartments, where water use should be negligible, and this survey feature lowers the IREM average of 680 CF compared to our estimate, which refers to only occupied apartments. In addition, the model in Table 2 may result in slight overstatements of apartment water consumption at all prices (that is, an upward bias to the line in Chart 1) if our townhouse identifier variable does not totally remove the effects of yard and garden on water usage. Finally, in some jurisdictions apartments pay for water at lower bulk rates available to commercial users. The Raftelis data indicate that the per gallon water/sewer cost for apartments paying the non-manufacturing commercial rate averages approximately 10 percent below the residential rate. In these jurisdictions the actual average water consumption would be higher than the 680 CF estimate above.

from 25 to 40 percent (Walter, 1997), well below our projected average water savings of 52 percent. This difference requires some investigation, despite the fact that our results seem robust under alternative functional forms and variable specifications.

First is the estimated responsiveness to marginal water pricing. As mentioned already, it is important to note that the projected savings are long-run responses that can be expected only after residents have fully adjusted their water consumption to the price they are paying. As for the long-run response, this study's estimated price elasticity of 0.7 is within the range of previous estimates, although this study and most others calibrate the response on home-owner households. If watering of the lawn and garden is a significant part of the water usage by residents of single-family housing, and if this component of residential water usage is the most price elastic, then the price elasticity of apartment water usage will be less than that of single-family housing usage. However, various tests of the effect of lot size on price elasticity, conducted by estimating variants of the model in Table 2, did not indicate that this lawn-and-garden influence is significant.

Another consideration in estimating water price elasticities on homeowners is that the long-run price response reflects hardware alterations as well as behavioral change. Water usage reflects, for example, not only the number and length of showers, but also the size of the shower nozzle. Homeowners facing high water prices should be the most likely to install water-saving appliances. Applying the elasticity estimated on homeowners to apartment residents assumes that apartment property managers who begin charging their residents directly for water and sewer usage will respond over time with water-saving appliances as if they were homeowners paying directly for the water used. Because it is not known how much of the price responsiveness in this study or previous analyses was hardware-related, the possible bias from this effect cannot be estimated, but this consideration may account for some of the excess in our projected water savings above those from recent anecdotal reports.

Water usage in common areas of apartment communities is another consideration. Comprehensive estimates of apartment water usage for swimming pools, grounds and gardens, health facilities and community rooms are unavailable. Anecdotal reports suggest, however, that common area usage could account for 10 percent of total water usage of the property, especially in garden apartment properties in warm climates. Because apartment managers are already paying for this water and controlling its usage, no further price response in common area usage would be expected when residents are charged directly. However, our water saving projections are for direct usage by apartment residents and do not assume any common area savings. The issue is one of labeling of the results. For example, the analysis projects that apartment *residents* will eventually reduce their water consumption by an average of 52 percent if they start paying the national average marginal price. Because of common areas where water usage may not change, the percentage reduction for apartment *properties* would be slightly lower.

A final element in the calculations is the assumption that water pricing will go to the national average marginal price of $21.56, as estimated from the Raftelis 1996 survey. If this figure overstates the true national average, or if apartment managers decide to charge residents less than the price the local water authority charges, then our projected water savings are overstated. But there is no reason to expect that the Raftelis estimate is too high. Although our sample includes predominantly large water authorities, the Raftelis survey indicates that water and sewer pricing are not correlated with authority size. And although some property managers may, for competitive reasons, choose to charge residents less than what the property pays for water, anecdotal reports suggest that the most common practice is to bill residents at a rate very similar to that charged by the water authority.

The focus in this analysis is on projections of water savings that would be implemented through metering or submetering of individual apartments, in which residents face a positive marginal price and pay for water based on their personal usage. As explained above, the statistical results indicate that RUBS systems also can lead to substantial water savings. However, those savings apparently are dependent on consumer education and conservation programs being enacted when RUBS is implemented. Because these programs and their effects are difficult to define within the quantitative framework of this analysis, it is not possible to project numerical RUBS influences on total water consumption.

But as for the marginal price effect on water consumption, the above discussion, combined with the similarity of our results to those of related studies of water usage and price elasticity, increase our confidence in our findings. Specifically, the long-run responsiveness of apartment residents' water usage to changes in marginal price, as estimated in Table 4 and pictured in Chart 1, appears to be a reasonable projection of the likely magnitude of the marginal price effect on apartment resident water usage.

--Aggregate Water Savings for the Nation.

The estimates of water consumption and savings for the typical apartment household can be projected to a national total by multiplying the per unit amounts by the national number of apartment households not yet separately charged for water and sewer. (Because of non-linearities in the functional form used to estimate the price effects, the projection of national totals is not strictly derivable by this multiplication, but the approximation should be quite close, given the moderate extent of the non-linearity, as shown in Chart 1.) The monthly water savings in Table 4 from increasing marginal price from zero to the national average is 704 cubic feet (calculated as 1,365 CF-661 CF.). As of 1998, there were 15.4 million apartment households nationwide (National Multi Housing Council, 1998b). Of these, the most recent estimate (from 1995) is that 93 percent (or 13.3 million households) were not charged separately for water and sewer service (National Multi Housing Council, 1998a). Applying the 704 CF water saving to each of these 13.3 million households yields monthly water savings of 9.4 billion cubic feet.

For perspective, this projected national water saving can be expressed as a share of total U.S. residential water usage, although available data permit only rough estimates. But the following back of the envelop calculation suggests that charging apartment residents for water the same way that owner-occupants pay for water could reduce national residential water consumption by 4 percent. Here is how: Apartment residents reduce their water consumption by 52 percent. Assume that apartment residents who currently do not pay for their water use only 60 percent of the national average household consumption (because of smaller household size, less income, and no yard to water). This 60 percent estimate is conservatively low, so as not to overstate the savings. The 13.3 million apartment households not currently charged separately for water and sewer account for 13 percent of all U.S. households (National Multi Housing Council, 1998b). Therefore the percentage reduction in total U.S. residential water usage is:

(52 percent) x (0.6) x (0.13) = 4.1 percent.

As explained above, these are long-run savings that will occur when consumer behavior has fully adjusted to separate pricing of water and sewer.

VI. Water Savings in Texas, California, and Florida

The method used to develop estimates of water consumption and savings for the nation’s average apartment resident and apartment residents in total can be applied to produce the equivalent estimates for certain large states that have sufficient households and cities in the sample. We have generated projections for Texas, California, and Florida.

To produce these state level estimates we combine the estimated coefficients from the first regression in Table 2 with the mean values of the independent variables for that state. For the characteristics of apartment renters by state, the analysis uses data from the Census Bureau’s *Current Population Survey* (U.S. Bureau of the Census, 1996), which is designed to generate representative state-level estimates of population characteristics. The average water price for the state is approximated by taking the weighted average price of all the jurisdictions in the state for which prices are available from the Raftelis data, with the number of households in the jurisdiction being the weights. The “dummy” variables in the model are all set to zero or one, depending on the state (and region) being estimated. The values of the independent variables for the state analyses are summarized in Table 5.

Results for the 3 states are summarized in Table 6 and in Chart 2. The projected water savings per apartment from charging for usage are similarly substantial in the three states. Looking at the marginal price effect, the eventual reduction in usage when the marginal price goes from zero to the state average is 58 percent in Texas, 56 percent in California, and 65 percent in Florida. Note that in all three states the projected usage is higher than the national average, at every price. This result is consistent with the location effects estimated in Table 2 and probably reflects climates warmer than the national averages. In addition, two of the three states have incomes and household sizes above the national apartment averages, and this too boosts water usage. The projected percentage reduction in water usage in each state also exceeds the national estimate, because the marginal water price in each state exceeds the national average.

State aggregate water savings can be projected by multiplying these per-apartment savings by the number of apartment households in the state. As in the national projection, we will use the per-apartment savings in Tables 6 in going from zero marginal price to the state average marginal price, combined with estimates of the number of apartment households from National Multi Housing Council (1998b). As in the national projection, the number of apartment households is reduced by 7 percent in each state to approximate the number not yet paying separately for water and sewer. The calculations for this projection are in Table 7. They show very large monthly water savings in each state: 1.1 billion CF in Texas, 2.2 billion CF in California, and 0.9 billion CF in Florida. As in the national projections, these are long-run impacts that may not be fully realized for several years.

VII. Implications for Water Pricing and Billing at Apartment Communities

These results indicate that substantial water savings can be expected if the residents of apartment communities are charged directly for their water usage. The estimated responsiveness of water usage to the price borne by consumers, when combined with information on the characteristics and locations of apartment residents, indicates that water consumption by apartment residents might eventually be cut in half if residents who currently have their water costs included in their rent start paying the average market price for each gallon that they use, as monitored by submetering or individual metering of apartments. Although the statistical results and their interpretation are clearest for this marginal price effect, the findings also suggest that RUBS or other systems for allocating the property's water costs among residents and billing for water separately can also result in substantial water savings, if the cost allocation program is accompanied by consumer education and conservation programs at the apartment community.

The findings from this research are generally consistent with those of previous studies of residential water demand. Specifically, the projected levels of water usage by apartment residents at different prices are in line with estimates from other sources on the level of water usage and its responsiveness to price. Our results also are maintained under alternative model specifications, increasing confidence in the findings. However, even if the actual water savings from directly charging apartment residents for water usage are only half of those projected here, the savings per apartment and in the aggregate will be substantial.

The findings have implications for apartment owners, residents, and public officials. The results should help apartment owners determine whether the water cost savings from metering, submetering, or cost allocating at their property justify the cost involved in converting from their current practice of including water costs in rent. For many residents of properties where water costs are currently recovered through rent, conversion likely will reduce their total monthly cost of rent plus utilities, as they reduce their water usage in response to direct billing. And in jurisdictions where apartment owners' ability to charge separately for water, the findings are relevant for public officials concerned about availability of water to their community and the costs of building additional water and sewer treatment facilities to meet increased demand.

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Table 1
Residential Water/Wastewater Prices in 57 Jurisdictions Nationwide

	minimum	maximum	mean
fixed monthly charge	$0	$26.70	$7.83
total bill for 1,000 cf/month	$8.98	$67.60	$29.39
marginal price for 1,000 cf/month	$0	$56.29	$21.56

Note: Prices are combined charges for water and wastewater; means are weighted by number of households in the jurisdiction.
.
Source: Raftelis (1996) for fixed charge and total bill; author's calculation of marginal price as total bill for 1,000 cf minus fixed monthly charge.

Table 2
Model Results
(dependent variable: natural logarithm of monthly water usage)

Independent Variable	Without City Effects		With City Effects	
	Coefficient	t-ratio	Coefficient	t- ratio
marginal price	-.0336	-13.88	-.0352	-3.82
fixed monthly charge	-.0291	-4.60	.0225	1.12
household monthly income ($'000)	.0331	4.38	.0259	3.52
persons in household	.0951	5.81	.1117	7.05
townhouse (1=yes, 0=no)	-.1526	-1.61	-.0955	-0.96
Northeast (1=yes, 0=no)	.2774	3.04	-.8099	-0.77
South (1=yes, 0=no)	.0418	0.53	-.0414	-0.08
West (1=yes, 0=no)	.7496	8.31	-.0166	-0.04
Texas (1=yes, 0=no)	.3920	3.75	.4355	1.08
California (1=yes, 0=no)	-.3910	-4.16	-.3223	-1.17
Florida (1=yes, 0=no)	.1286	0.90	.4824	-0.89
City Identifiers Included? (1=yes, 0=no)	no		yes	
constant term	.2124	2.37	.1407	0.24
regression statistics	N = 1766 F(11,1754) = 38.79 adj R-squared = .191		N = 1766 F(58,1707) = 12.31 adj R-squared = .271	

note: water usage in 1,000 CF; marginal price is for first 1,000 CF; Midwest is omitted regional category

Table 3
Characteristics of the Nationally Typical Apartment Household
(used in projections of water consumption at different marginal prices)

monthly household income	$2,116
number of persons in household	1.96
fixed monthly water charge for residential users in local jurisdiction	$8.37
multi-unit structure (1=yes, 0=no)	1.0
Northeast location (proportion of U.S. total)	.244
Midwest location (proportion of U.S. total)	.194
South location (proportion of U.S. total)	.318
West location (proportion of U.S. total)	.244
Texas location (proportion of U.S. total)	.072
California location (proportion of U.S. total)	.160
Florida location (proportion of U.S. total)	.067

Table 4
National Projections:
Monthly Water Consumption for the Typical Apartment Household at Selected Marginal Prices

Marginal Price (per 1,000 cubic feet)	Projected Monthly Water Usage (in cubic feet) per Apartment Household
0	1,365
$5	1,154
$10	975
$15	824
$20	697
$21.56 (national average)	661
$25	589
$30	498
$35	421
$40	356
$45	301
$50	254

Table 5
Values of Independent Variables for State Projections

	Texas	California	Florida
monthly apartment household income	$2,051	$2,655	$2,601
number of persons in apartment household	2.09	2.31	1.97
average fixed monthly charge	$5.89	$6.08	$3.24
average marginal price per 1,000 CF	$25.71	$24.33	$31.04

Sources: 1996 Current Population Survey; Raftelis (1996)

Table 6
State Projections:
Monthly Water Consumption for the Typical Apartment Household at Selected Marginal Prices

Marginal Price (per 1,000 cubic feet)	**Projected Monthly Water Usage (in cubic feet) per Apartment Household**		
	Texas	California	Florida
0	1,802	1,732	1,506
$5	1,524	1,464	1,273
$10	1,288	1,237	1,076
$15	1,089	1,046	910
$20	920	884	769
$24.33 (California average)	---	765	---
$25	778	748	650
$25.71 (Texas average)	760	---	---
$30	658	632	550
$31.04 (Florida average)	---	---	525
$35	556	534	465
$40	470	452	393
$45	397	382	332
$50	336	323	281

Table 7
Calculation of Projected Total
Monthly Water Savings for States

state	water saved per apartment	occupied apartments (millions)	total state water savings (million CF)
Texas	1,042 CF	1.10	1,066
California	967 CF	2.46	2,212
Florida	981 CF	1.03	939

note: (water saved per apartment) x (occupied apartments) x (.93) = total state water savings

The 0.93 adjustment is to correct for the estimated 7 percent of apartments that are already billed separately for water and sewer.

Chart 1

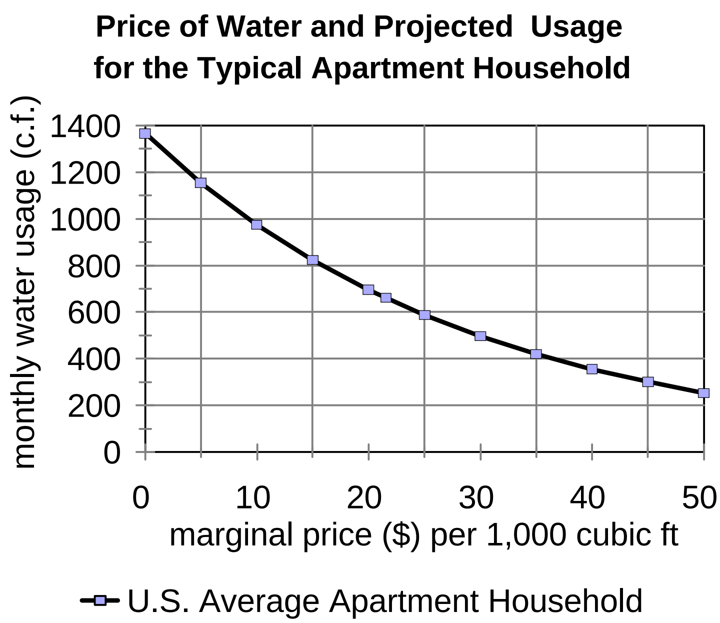
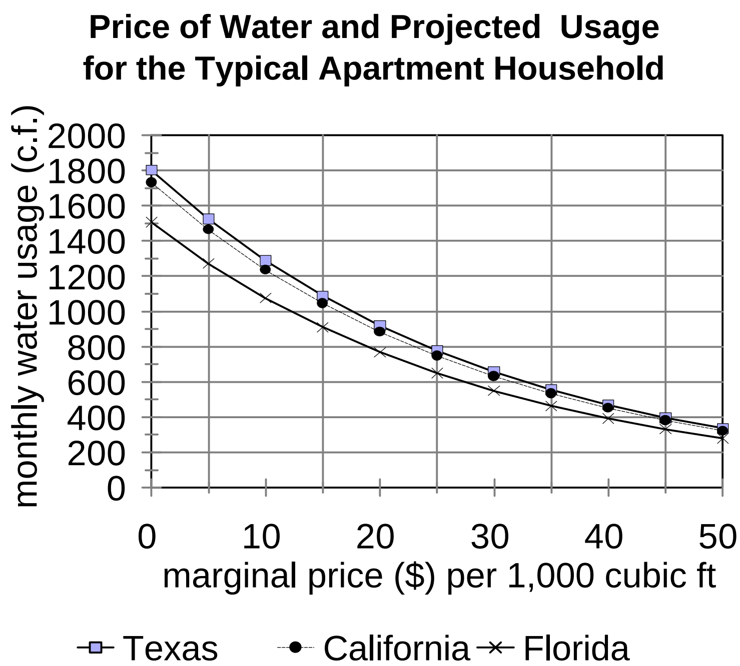

Price of Water and Projected Usage
for the Typical Apartment Household
monthly water usage (c.f.)
1400
1200
1000
800
600
400
200
0
0
10
20
30
40
50
marginal price ($) per 1,000 cubic ft
U.S. Average Apartment Household

Chart 2


Price of Water and Projected Usage
for the Typical Apartment Household
monthly water usage (c.f.)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0
10
20
30
40
50
marginal price ($) per 1,000 cubic ft
Texas
California
Florida

Appendix Table 1
Cities Included in the Analysis

Akron
Albuquerque
Allentown
Atlanta
Austin
Baltimore
Baton Rouge
Birmingham
Boston
Canton
Chattanooga
Cincinnati
Corpus Christi
Dallas
Denver
Detroit
Evansville
Forth Worth
Greensboro
Hartford
Honolulu
Indianapolis
Knoxville
Las Vegas
Lexington-Fayette
Little Rock
Los Angeles
Madison
Memphis
Miami
Milwaukee
Mobile
Nashville
New Orleans
New York City
Norfolk
Oakland
Omaha
Orlando
Phoenix
Pittsburgh
Riverside
Rochester
Sacramento
St. Louis
Salt Lake City
San Antonio
San Diego
Scranton
Seattle
Shreveport
Stockton
Tacoma
Tampa
Toledo
Tulsa
Wichita

Appendix Table 2
Model Results: Linear Specification
(dependent variable: monthly water usage)

Independent Variable	Without City Effects		With City Effects	
	Coefficient	t-ratio	Coefficient	t- ratio
marginal price	-.0584	-15.57	-.0549	-4.28
fixed monthly charge	-.0180	-1.84	-.0113	-0.40
household monthly income ($'000)	.0558	4.78	.0418	4.09
persons in household	.0997	3.93	.1219	5.53
townhouse (1=yes, 0=no)	-.2987	-2.04	-.2315	-1.66
Northeast (1=yes, 0=no)	.6332	4.48	-1.3208	-0.90
South (1=yes, 0=no)	.3455	2.80	.5049	0.71
West (1=yes, 0=no)	2.477	17.72	.5458	0.86
Texas (1=yes, 0=no)	.1606	0.99	-.1903	-0.34
California (1=yes, 0=no)	-1.8678	-12.83	-.8265	-2.15
Florida (1=yes, 0=no)	.2027	0.92	-.2643	-0.35
City Identifiers Included? (1=yes, 0=no)	no		yes	
constant term	1.826	13.17	2.1704	2.66
regression statistics	N = 1766 F(11,1754) = 73.21 adj R-squared = .310		N = 1766 F(58,1707) = 31.19 adj R-squared = .498	
note: water usage in 1,000 CF; marginal price is for first 1,000 CF; Midwest is omitted regional category				

.

Appendix Table 3
Model Results: Full Logarithmic Specification
(dependent variable: natural log of monthly water usage)

Independent Variable	Coefficient	t-ratio
ln(marginal price)	-.772	-17.08
ln(fixed charge)	-.111	-1.89
ln(household monthly income)	.098	3.78
ln(persons in household)	.314	6.25
constant term	1.290	4.59
regression statistics: N=1513; F(4,1508)=90.21; adj R-squared = .191		
note: water usage in 1,000 CF; marginal price is for first 1,000 CF		