

Price Knowledge in Household Demand for Utility Services

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ABSTRACT.

A household's decision to acquire price knowledge is endogenous in the demand for utility services and may affect elasticities and consumption levels. A simultaneous equation model with endogenous switching is developed to evaluate the effects of price knowledge and other sources of heterogeneity. Results indicate informed households were more responsive to average and marginal price signals. Informed households also use less water, but this is due to heterogeneity rather than price knowledge. Controlling for heterogeneity, price knowledge actually increases monthly water usage. The implications of accounting for differences in price knowledge in utility demand modeling and demand management policy are discussed.

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I. INTRODUCTION

A central tenet of microeconomic theory is that well-informed, rational households will consider marginal prices when making their budget allocation decisions. Nevertheless, there has been considerable debate concerning the ‘correct’ price to include in empirical models of household demand for public utility services. The controversy stems from the discrete nature of the household budget constraint implied by the block pricing schedules prevalent in utility service billing and household’s perceptions of these prices (e.g., Taylor 1975; Hewitt and Hanemann 1995; Renzetti 2002). Empirical price elasticity estimates play an important role in utility rate design and the choice of price and non-price demand management strategies (e.g., Whirl 1997; Renwick and Archibald 1998; Dalhuisen et al. 2003)

A key assumption in the price specification debate is that households are *well-informed* or behave *as-if* they are. Violations of this assumption introduce the possibility that perceived price signals differ from actual signals. The specification issue is usually described as whether the marginal or average price more accurately reflects the opportunity cost of service perceived by the household. Foster and Beattie (1981), for example, argued that households are more likely to respond to the average price of service because this only requires knowledge of the total bill and consumption. Marginal prices are not worth the trouble to learn the rate schedule and track consumption levels.¹ This rationale is consistent with the economic theory of consumer search, bounded rationality and an ‘absent-minded’ consumer (e.g., Stigler 1961; Conlisk 1996; Mullainathan 2002; Ameriks, Caplin and Leahy 2004).² An implication is that a little ignorance on the part of households is rational. Unfortunately, an analysis of the factors that influence

household acquisition of utility price information and the impact of this information on household responsiveness to pricing signals has been neglected in the price specification debate.

The acquisition of price knowledge can be considered an act of human capital formation by the household. Stigler and Becker (1977), Becker and Murphy (1988), and Becker (1996) have described the theoretical basis to explain how differences in tastes, perceptions and experience build human capital that influences consumption. And, knowledge as a form of human capital has been evaluated for some types of household purchasing decisions (e.g., Sexton and Sexton 1987; Ratchford 2001). A similar perspective on price knowledge for utility services invites an investigation into the sources of household price perceptions as an approach to understand the underlying behavioral mechanisms that determine consumption decisions (McFadden 2001). These sources of price perceptions may go beyond the substitution and budget share factors often cited as the cause of relatively low price elasticities for utility services (e.g., Espey, Espey and Shaw 1997; Espey and Espey 2004). This information can be used to evaluate how household consumption might respond to demand management policies and programs designed to change public knowledge of prices for utility services.

The household decision to acquire price knowledge is one of many potential sources of endogeneity in household demand for utility services. The purpose of this paper is to evaluate the effects of household knowledge of prices for utility services on measures of demand elasticity and consumption levels. We examine three empirical questions that are central to the utility services price specification debate. First, does price knowledge have any effect on price elasticities and other measures of price responsiveness? If it does, then failing to account for differences in price knowledge in demand modeling will lead to biased parameter estimates and misleading information for policy analysis. Second, does monthly water use actually differ

between households with and without knowledge of marginal prices? Third, would consumption change if all households were knowledgeable? While the answer to the second question is directly observable, the last question requires an analysis that accounts for the effects of price knowledge *and* other unobservable factors that may influence household consumption. These unobservable factors may play an important role in anticipating the potential outcomes from policies designed to influence household consumption behavior.

The following section presents a brief review of the empirical evidence on price specification and perceptions in residential demand modeling for utility services. Section three introduces a household water demand model with endogenous price knowledge and switching behavior to explore the determinants of price knowledge and the effects on household consumption. We also describe a ‘treatment effects’ approach (Blundell and Costa Dias 2000; Heckman 2001; Heckman, Tobias and Vytlačil 2001) to evaluate potential consumption responses to price knowledge. The fourth section describes the data and empirical specification followed by estimation results and alternative measures of price responsiveness in section five. We conclude with a summary and observations on the significance of the results for utility service demand modeling and for demand side management policies to influence household consumption of utility services.

II. PRICES AND PRICE PERCEPTIONS IN UTILITY SERVICE DEMAND MODELS

An extensive literature has developed on residential demand estimation for utility services and the effects of specification on measures of household responsiveness to price. Prior literature reviews and meta-analyses indicate that alternative specifications of the price variable have statistically significant effects on estimated price elasticities (e.g., Espey, Espey and Shaw 1997; Hanemann 1998; Renzetti 2002; Arbues, Garcia-Valinas and Martinez-Espineira 2003;

Dalhuisen et al. 2003; Espey and Espey 2004; Kamerschen and Porter 2004). These specification decisions depend, in part, on researchers' understanding of household's price perceptions.

Opaluch (1982; 1984) first proposed a revision of the "fully informed" marginal price specification attributed to Taylor (1975) and Nordin (1976) to test whether marginal or average price better explains variation in utility services consumption. Opaluch's specification, which has appeared in various forms (e.g., Charney and Woodard 1984), can be expressed as:

$$Q_t = \beta_0 + MP_t \beta_1 + (AP_t - MP_t) \beta_2 + (y_t - RSP_t) \beta_3 \quad [1]$$

where MP_t is the marginal price in the last block of consumption in period t , AP is the average price, y is income, RSP is the so-called *rate structure premium* or *bill difference* variable equal to the difference between the actual bill and what the bill would have been if all consumption were charged at the marginal block price, and β_0 through β_3 are parameters. All price and income terms are normalized by a price index for a Hicksian composite of other commodities.

Consumption responses to price schedule changes are defined as a weighted average of MP , AP , and RSP signals. The relative weighting and statistical significance of each price signal then becomes an empirical issue. For example, consumption varies with average price if $\beta_1 = \beta_2$, but varies with marginal price if $\beta_2 = 0$.

Chicoine and Ramamurthy (1986) and Chicoine, Deller, and Ramamurthy (1986) estimated an equivalent form of [1] with an Illinois sample and found that households appear to respond to a combination of marginal and average price information. Bacharach and Vaughn (1994) found a similar result for a sample of Argentine households. Griffin and Chang (1990) used data from Texas to estimate [1] without the RSP because it was highly correlated with the price terms. They reported that "there is strong empirical evidence to prefer the AP specification

over the *MP* specification” (p. 2253). Two recent analyses of the same model with panels of water users in Europe also concluded that households appear to respond more to average price than marginal price signals (Nauges and Thomas 2000; Martinez-Espineira 2002).

An alternative approach to measure price perceptions for utility services was introduced by Shin (1985). Perceived prices, \tilde{P} , were described as a function of the average and marginal price

$$\tilde{P} = MP \left(\frac{AP}{MP} \right)^k \quad [2]$$

where k is a price perception parameter such that a household perceives marginal price when $k=0$ and average price when $k=1$. This perceived price variable was used in a double-log demand model as:

$$\begin{aligned} \ln(Q_t) &= \alpha + \ln(Q_{t-1})(1 - \theta) + \ln(\tilde{P}_t)\theta\eta + \ln(y_t)\theta\gamma \\ &= \alpha + \ln(Q_{t-1})(1 - \theta) + \ln(MP_t)\theta\eta + \ln(AP_{t-1}/MP_t)k\theta\eta + \ln(y_t)\theta\gamma \end{aligned} \quad [3]$$

where the lagged dependent variable was assumed to follow a Koyck adjustment process,³ α is the intercept, θ is the partial adjustment parameter, η is the constant perceived price elasticity, and γ is the constant income elasticity. Nieswiadomy and Molina (1991) recommended a lagged value for average price rather than the current period average price for water demand estimation. Long run effects in this specification can be recovered by manipulating the partial adjustment parameter. Full adjustment ($\theta = 1$) occurs subject to the household’s price perception. If the household maintains a perceived price other than their marginal price ($k \neq 0$), they cannot adjust Q to an efficient level relative to the consumption of other items. The completely adjusted household ($\theta = 1, k = 0$) will optimally select its knowledge level and capital stock and respond to changes in the marginal price of service. The price perception parameter can be recovered as

the ratio of the parameters on $\ln(MP)$ and $\ln(AP_{t-1}/MP)$, thereby providing a convenient way of testing which price signal exerts the greatest influence on consumption. This specification can also be expanded to show that k is a weight that allocates a (short-run) perceived price response $\theta\nu$ to marginal and average price signals:

$$\ln(Q_t) = \alpha + \ln(Q_{t-1})(1 - \theta) + \ln(MP_t)\theta\eta(1 - k) + \ln(AP_{t-1})k\theta\eta + \ln(y_t)\theta\nu \quad [4]$$

where the coefficients on the price terms are the share of the (short-run) perceived price elasticity attributed to each price signal.

Shin (1985) estimated [3] with electricity time series data for Ohio. He found that demands with decreasing block rate structures were influenced more by variations in average price than marginal price. Nieswiadomy (1992) and Nieswiadomy and Cobb (1993) reported similar results for water demands in a cross-section of U.S. utilities with a variety of rate structures. Michelsen, McGuckin, and Stumpf (1998) found evidence that responses to water prices may vary by season in the western U.S. These three studies, however, were based on aggregate consumption data that may obscure marginal price responses by individual households. Subsequent research by Nieswiadomy and Molina (1991) using household level water consumption data to estimate [3] found that households facing increasing block rates responded to MP while those facing decreasing block schedules responded to AP_{t-1} . The results, however, were inconclusive due to large standard errors for the price perception parameters.

A further concern emphasized by Hewitt and Hanemann (1995) is that households' responses to utility service price signals with block rates are complicated by the co-determination of marginal prices and consumption. The discrete-continuous choice models employed by Hewitt and Hanemann and others provide a framework to identify some of the sources of preference heterogeneity (e.g., Terza and Welch 1982; Herriges and King 1994; Rietveld,

Rouwendaal and Zwart 1997; Pint 1999; Olmstead, Hanemann and Stavins 2003). For example, sociodemographics and tastes for water consuming features of the housing unit may be sources of information to explain household's behavior around rate block boundaries. These models, however, cannot be used to measure price perceptions because it is assumed that households know the price schedule with certainty or act as-if they do (Hewitt and Hanemann 1995, pp. 182 – 183).⁴ Variation in price knowledge is captured in the error components, but the determinants and effects of household's price knowledge are unobservable. Thus, an alternative approach that explicitly models differences in household's knowledge of utility service price schedules is necessary to evaluate the effects on consumption decisions.

III. WATER DEMAND WITH ENDOGENOUS PRICE KNOWLEDGE

Previous empirical evidence indicates that the average household may not be fully informed of the marginal cost of service or, at best, they adjust their consumption based on other billing signals. A consumer will choose to learn the price schedule if she anticipates that the decision will be worthwhile.⁵ Let the expected net benefit of knowing the price be summarized by a reduced form index function

$$D^* = \mathbf{GZ} + \varepsilon \quad [5]$$

where \mathbf{G} is a vector of observable factors affecting the expected net benefit of price knowledge, \mathbf{Z} is a conformable vector of parameters, and ε represents unobservable factors influencing the expected net benefit of price knowledge. Individual and time subscripts are suppressed for clarity. A household will choose to know the price of service if the expected net benefit of doing so is non-negative or $D^* \geq 0 \Leftrightarrow \varepsilon \geq -\mathbf{GZ}$. Note that D^* can be interpreted as indexing the expected net benefit of knowing the price or the expected net benefit of being in the group that knows the price.⁶

Observed consumption, Q , conditional on price knowledge, can be written as an endogenous switching regime model:

$$Q = \begin{cases} \mathbf{XB}^1 + MP\pi^1 + \omega^1 & \text{if } \varepsilon \geq -\mathbf{GZ} \\ \mathbf{XB}^0 + MP\pi^0 + \omega^0 & \text{otherwise} \end{cases} \quad [6]$$

where the 1 and 0 superscripts denote demand parameters with and without price knowledge, respectively, MP is the marginal price of service, \mathbf{X} is a vector of other observed factors, \mathbf{B}^1 , \mathbf{B}^0 , π^1 , and π^0 are parameters, and ω^1 and ω^0 are regime specific unobservables. With this discrete-continuous demand model, we assume knowledge of utility service price is not completely random so there can be endogenous switching between regimes. Assuming a joint distribution for the ω terms and ε , this demand model can account for endogenous sample selection to yield unbiased parameter estimates (Maddala 1983). Thus, separate measures of conditional price responsiveness can be recovered for households who know the price of service and those who do not.

This model, however, does not account for the simultaneity of consumption and price that occurs with block rate pricing. It is necessary to model this simultaneous process to isolate the price elasticities conditional on price knowledge. This is especially important if, in fact, some households are aware of marginal prices and the effects of consumption decisions on block rates while others are not. The complete system of simultaneous equations for marginal price and quantity, conditional on price knowledge, can be specified as:

$$\left. \begin{aligned} MP &= \mathbf{KJ}^1 && + v^1 \\ Q &= \mathbf{XB}^1 + MP\pi^1 + \omega^1 \end{aligned} \right\} \text{if } \varepsilon \geq -\mathbf{GZ}$$

$$\left. \begin{aligned} MP &= \mathbf{KJ}^0 && + v^0 \\ Q &= \mathbf{XB}^0 + MP\pi^0 + \omega^0 \end{aligned} \right\} \text{otherwise} \quad [7]$$

where \mathbf{K} is a vector of observed influences on marginal price with conformable regime specific parameter vectors \mathbf{J}^1 and \mathbf{J}^0 , and the unobservable influences in the price equations are given by v^1 and v^0 . This simultaneous equation model assumes that price knowledge affects both the price level and consumption across households. The lack of price knowledge may therefore lead to errors in both perceptions of the price level and in decisions about the level of utility services to consume.⁷ This instrumental variables approach is consistent with earlier work by Rosen (1976) for labor supply and extended to utility price/quantity estimation by Agthe et al. (1986), Chicoine, Deller and Ramamurthy (1986), and others.

The endogenous switching, simultaneous demand model in [7] can be used to isolate the effects of price knowledge because it explicitly models the structural differences (observable and unobservable) between those who know and don't know the price of service. Furthermore, if we consider price knowledge a voluntary *treatment* then the structural differences between groups can be analyzed with program evaluation methods to identify counterfactuals and the *effects* of price knowledge on consumption. Note that we focus on the consumption effects of price knowledge rather than money metric welfare measures because the latter cannot be clearly defined given the ambiguous nature of the pricing signal.

Program evaluation methods focus on ways to isolate the effect of a program treatment on an outcome of interest.⁸ A common application considers the effect of job-training programs on earnings. In most cases, treatment effects cannot be calculated for each program participant (or non-participant) because outcomes without (with) treatment are not observed. For example, the wage level of participants had they not entered the training program are typically not available. Thus, analysts aim to recover *expected* outcomes based on unobserved distributions of outcomes. The expected outcomes *with* and *without* treatment can be used to calculate the

expected treatment effects for different groups. Calculations become complicated, however, when participants choose (self-select) to enter a program based on anticipated gains, rather than entering by random assignment. In this case, the effect of treatment will vary across the population and simple evaluation methods such as dummy variables break down (Heckman 1997). This is precisely the case we have in evaluating the effect of price knowledge on consumption levels: households choose whether or not to know the price.

Table 1 shows the expected values for consumption and the *treatment effect* relationships that can be identified in a split sample of households who *know* and *don't know* prices for a specific utility service. The shaded cells down the diagonal are the expectations that are actually observed in a sample. For example, the expected consumption with price knowledge for a sample group that reported knowing the price can be estimated from data on the households in this group. The expected consumption without price knowledge for this group is a *counterfactual* outcome. The same logic would describe the actual and counterfactual outcomes for the group without price knowledge.

The expectations in Table 1 can be used to estimate expected differences in consumption between those who know and don't know utility service prices. These differences could reflect the actual effect of price knowledge or simply differences in unobserved heterogeneity (Winship and Morgan 1999). Failure to distinguish between the causal effect of price knowledge and the artifacts of heterogeneity in the sample could contribute to misleading policy prescriptions. Program evaluation techniques for observational data can be used to identify the actual (causal) effects of price knowledge for each group in the sample. The effect of price knowledge for those who *know* the price is the “effect of the treatment on the treated” (*TT*)

$$TT = E[Q^1 | \mathbf{X}, MP, D = 1] - E[Q^0 | \mathbf{X}, MP, D = 1] \quad [8]$$

where Q^1 and Q^0 are defined in Table 1 as the consumption levels with and without price knowledge, respectively, and $D = 1$ denotes those in the sample who know the price (i.e., $D = 1$ if $\varepsilon \geq -\mathbf{GZ}$ and zero otherwise). The “effect of the treatment on the untreated” (TU) can be similarly defined for those who do not know the price, but could be informed:

$$TU = E[Q^1 | \mathbf{X}, MP, D = 0] - E[Q^0 | \mathbf{X}, MP, D = 0]. \quad [9]$$

The TT and TU parameters give the expected consumption effect of price knowledge on a randomly chosen household from the groups who *know* and *don't know*, respectively. These are policy relevant treatment effects (Heckman and Vytlačil 2001) and provide an alternative to standard welfare measures of policy impacts when the conditions for utility maximization may not be satisfied.

The policy relevant treatment effects can also be distinguished from heterogeneity effects in Table 1. First, those who know the price may inherently consume more (or less) regardless of price knowledge due to other endogenous determinants of household demand. This “base heterogeneity effect” (BH) is given for two states of nature:

$$BH^1 = E[Q^1 | \mathbf{X}, MP, D = 1] - E[Q^1 | \mathbf{X}, MP, D = 0] \quad [10]$$

$$BH^0 = E[Q^0 | \mathbf{X}, MP, D = 1] - E[Q^0 | \mathbf{X}, MP, D = 0] \quad [11]$$

where BH^1 and BH^0 are the differences in consumption between the *know* and *don't know* groups, respectively. Second, the consumption of those who know the price may change more (or less) because of the price knowledge than those who don't know the price, if they did. This “transitional heterogeneity effect” (TH) is the difference between the effect of price knowledge for the *know* and *don't know* groups ($TT - TU$) and is due, in part, to variations in the expected net benefits of price knowledge. The BH and TH measures can be estimated from the complete endogenous switching regression model in [7]. These measures are necessary to understand

inherent differences in consumption behavior between the two groups and to properly anticipate potential responses to changes in pricing policy.

IV. DATA AND MODEL SPECIFICATION

Data for this analysis includes household responses from a 1997 survey of customers of three North-Central Florida water utilities (Bureau of Business and Economic Research 1997) and the corresponding 1997-99 monthly billing records for these households. Monthly precipitation and temperature records from the nearest regional airport for each utility were also added. The sample consisted of 742 households divided almost evenly among the three utility areas. Two of the utilities had an increasing block rate structure and the third had a uniform structure. Both block and uniform rates were included in the analysis to examine the effect of rate structure on price knowledge and demand. Note that all utilities use a fixed base charge for service so that average and marginal prices differ, even for the utility with the uniform marginal charge. Adjusting for months with no consumption data over the study period, there were a total of 24,695 monthly household observations.⁹

As part of the survey, households were asked whether they knew the marginal price for water service (“Can you tell me approximately what you pay for each 1,000 gallons or cubic feet of water over the base rate?”). Table 2 lists the summary statistics for all households and months for the relevant study data according to whether the household responded affirmatively or not to this question. Only 6 percent of the households in the sample reported that they knew the marginal price for water service. This percentage is very similar to the results of a customer survey for three water utilities in Texas in which only seven percent of respondents indicated they used marginal or average prices in making water consumption decisions (Stratus Consulting 1999, pp. 3-7).¹⁰ Households with knowledge of marginal prices consumed, on average, about a

thousand gallons less water each month than those who did not know the marginal price indicating that price knowledge may influence consumption. The average and marginal prices in the sample are similar to those for utilities in the U.S. with service areas of 250,000 or less in population (Raftelis Consulting 2003). Average prices were higher than marginal prices due to fixed base charges. Due to data limitations, we assume that all household variables, except water use and prices, are constant over the study period.¹¹

With the available household survey and utility data in Table 2, the equations of the endogenous switching model in [7] can now be specified as:

$$D = \mathbf{S}\mathbf{z}_1 + \mathbf{U}\mathbf{z}_2 + \mathbf{R}\mathbf{z}_3 + \varepsilon \quad [12a]$$

$$MP^1 = \mathbf{S}\mathbf{j}_1^1 + \mathbf{C}\mathbf{j}_2^1 + \mathbf{U}\mathbf{j}_3^1 + \lambda\varphi^1 + \nu^1 \quad [12b]$$

$$Q^1 = \mathbf{S}\mathbf{b}_1^1 + \mathbf{C}\mathbf{b}_2^1 + \widehat{MP}^1 \pi^1 + \lambda\rho^1 + \omega^1 \quad [12c]$$

$$MP^0 = \mathbf{S}\mathbf{j}_1^0 + \mathbf{C}\mathbf{j}_2^0 + \mathbf{U}\mathbf{j}_3^0 + \lambda\varphi^0 + \nu^0 \quad [12d]$$

$$Q^0 = \mathbf{S}\mathbf{B}_1^0 + \mathbf{C}\mathbf{B}_2^0 + \widehat{MP}^0 \pi^0 + \lambda\rho^0 + \omega^0. \quad [12e]$$

Expression [12a] models the binary price knowledge indicator variable, D , as a function of a vector of household property and socioeconomic characteristics, \mathbf{S} , a vector of utility dummy variables, \mathbf{U} , that indicate utilities with increasing block rates, and a vector of exclusion restrictions, \mathbf{R} . Property and household characteristics in \mathbf{S} include income, property age, household size, lawn size, and dummy variables for ownership of an irrigation well, or a dishwasher. The exclusion restrictions in \mathbf{R} consist of dummy variables for consumption of bottled water, awareness of low flow fixtures, awareness of xeriscaping, nonlinear terms for income, lawn size, house age, and household size, and utility company interactions with income and household size. Polynomial and interaction terms were included in the empirical

specification to improve the fit and enhance the performance of the control functions in the price and demand equations.¹²

Equations [12b] and [12d] model the marginal price levels with and without price knowledge, MP^1 and MP^0 , as a function of \mathbf{S} , \mathbf{U} , a vector \mathbf{C} with water use, average price, precipitation, and the selectivity control function, λ . The utility company dummies, \mathbf{U} , are simple and effective price instruments because they are correlated with the price schedules, but uncorrelated with the quantity decision, after controlling for weather and socioeconomic differences.

Monthly consumption levels with and without price knowledge, Q^1 and Q^0 , in equations [12c] and [12e] are a function of \mathbf{S} , \mathbf{C} , λ , and the predicted values, \widehat{MP}^1 or \widehat{MP}^0 , from the relevant instrumental price equation. With logarithmic transformations of the continuous variables in the system, this demand specification is comparable to the Shin model described in [4]. This specification is used so that our estimated parameters can be compared with prior results in the utility services pricing literature.

The control function, λ , and the related parameters in the price and demand equations proxy the expected value of unobservables in these equations conditional on the price knowledge decision (Heckman 1978). The control function models the potential selection into a price knowledge group based on unobserved factors. Specifically, λ models $E[\varepsilon|D=1]$ and $E[\varepsilon|D=0]$ for the sample group that knows and doesn't know the price, respectively. The parameters φ^1 and φ^0 represent the correlations between the decision to know the price and the price level for each group. Similarly, the parameters ρ^1 and ρ^0 measure the correlation between the decision to know the price and consumption levels for each group. Note that the influence of

price knowledge on the expected value of the price and consumption levels is given by the product of λ and the related correlation parameters. Thus, the direction of the price knowledge influence on the expected value of conditional prices and demands depends on the relative signs of λ and the correlation coefficients (Maddala 1983).

Assuming that ε is joint normally distributed with the v and ω terms, the parameters of [12] can be estimated with two-stage procedures for simultaneous equation systems with endogenous switching (Lee, Maddala and Trost 1980). In this estimation, the control function λ is defined as $\phi(\mathbf{G}\hat{\mathbf{Z}})/\Phi(\mathbf{G}\hat{\mathbf{Z}})$ if the price is known and $-\phi(\mathbf{G}\hat{\mathbf{Z}})/1-\Phi(\mathbf{G}\hat{\mathbf{Z}})$ otherwise, where $\hat{\mathbf{Z}} = \{\hat{\mathbf{z}}_1, \hat{\mathbf{z}}_2, \hat{\mathbf{z}}_3\}$ are the estimated coefficients from [12a] with $\mathbf{G} = \{\mathbf{SUR}\}$, $\phi()$ is the normal density function and $\Phi()$ is the cumulative normal distribution function. Note the negative sign on the control function for those who don't know the price. This implies that the direction of price knowledge influence on the price level and water use for this group is the opposite of the signs on φ^0 and ρ^0 , respectively. Formulas to calculate the conditional expectations in Table 1 using the parameters from the endogenous switching model in [12] are provided in the Appendix.

V. RESULTS

Estimated parameters for the water demand model with endogenous switching due to price knowledge are presented in Table 3. For comparison, a single equation demand model with no switching was estimated with the price knowledge indicator (D) as an explanatory variable. Coefficient estimates from this model are biased and inconsistent but are included here to compare with the switching behavior model.¹³ Results using OLS are listed in the first column of Table 3. The coefficient on D is significant and negative implying that price

information contributes to lower water usage. This is consistent with the differences in average consumption reported in Table 2 and provides a preliminary answer to the second policy question discussed in the Introduction. This may be a misleading conclusion, however, because additional endogenous effects on consumption due to price knowledge have not been properly accounted for in this simple model. Also, the coefficient on the marginal price variable (*MP*) in the single equation model (column one) is positive and significant while the average price variable (*AP*) is negative and significant. These results suggest that the OLS specification fails to account for the endogeneity of price and price knowledge.

The price knowledge indicator Probit coefficients for the switching model are listed in the second column labeled 'Know Decision' in Table 3. These coefficients can be interpreted as measures of the influence of observable household characteristics on the probability of knowing the marginal price or the probability of being in the group with knowledge of the marginal price. House age (*HAGE*), ownership status (*OWNPL*) and presence of an irrigation well (*WELL*) or dishwasher (*DISH*) were negatively related to the probability of knowing the marginal price. On the other hand, higher income (*y*), household size (*HHSZ*), and lawn area (*LAWN*) increased the probability of knowing the marginal price but with diminishing marginal effects. The coefficients for low flow fixtures (*LFLOW*), xeriscaping (*XERI*), and bottled water usage (*BWATER*) indicate a significant and positive relationship between awareness of non-price demand management practices and marginal price knowledge. The negative, significant coefficients for the two utilities with increasing rate schedules (*COCD* and *GRUD*) indicate that households with increasing block rates were less likely to know the marginal price of service than those facing a uniform charge. This result suggests that the expected net benefits of price knowledge are lower under block rates than under a uniform rate. This is consistent with a

'rational ignorance' hypothesis, but it does not rule out the possibility that other unobserved differences such as billing formats or prior water education programs across utilities may also be important. A likelihood ratio test strongly rejected a restricted specification with a single dummy variable for utilities with increasing block rates. The positive and statistically significant interaction terms for the utility dummy variables with income and household size also suggest other endogenous characteristics of each utility service area may contribute to the decision to know the price of service (e.g., Nauges and Thomas 2000; Olmstead, Hanemann and Stavins 2003).

Coefficients for the marginal price instrument equations are reported in the third and fifth columns of Table 3. The coefficients for the property and sociodemographic variables are similar in sign and statistical significance for the two groups. This implies that observed influences explain a similar amount of variation in the price level for each group. As expected, the utility dummy variables (*COCD* and *GRUD*) are highly significant reflecting differences in rate structure and levels. The coefficient for the control function term (λ) is negative and highly significant for households in the uninformed group. An increase in the probability of knowing the marginal price increases the expected value of the *MP* instrument. For these households, however, the response was very slight because the marginal price elasticity with respect to a change in the probability of price knowledge was small (0.0068).¹⁴ Similarly, the control function term was not significant for the informed group indicating that the expected value of the *MP* instrument was independent from the factors that predicted price knowledge.

The differences between the demand equation coefficients in columns 4 and 6 of Table 3 illustrate the heterogeneity in the sample with respect to water use. Many of the quantity equation coefficients for the two groups are similar in sign, but smaller in magnitude for the

uninformed group. In contrast to the OLS results, the marginal price (*MP*) coefficient is negative and significant in the simultaneous equation specification for both groups indicating that the instruments help to control for price endogeneity. On the other hand, the average price (*AP*) coefficient is positive and significant which may reflect habit-persistence in monthly water use rather than responses to price signals.

The parameter on the control function variable (λ) in the conditional demand equation for the informed group is negative and significant at the five percent level while the same parameter for the uninformed group is not significant. Thus, demand for the uninformed group was independent from the factors that determined the probability of knowing the price. On the other hand, consumption by the informed group was directly related to the probability of knowing the price. For this group, the demand elasticity with respect to a change in the probability of knowing the price was a relatively modest 0.1293. Thus, the directly observable effects of price knowledge occurred primarily through the demand equation.

The responsiveness parameters for the complete water demand model are summarized in Table 4.¹⁵ These results indicate that water demand responses are indeed sensitive to price knowledge. The short-run marginal price elasticity for the informed group was over two times larger than for the uninformed group. Note that the mean price elasticity estimate of -0.43 reported in Dalhuisen et al. (2003) falls between estimates for the two groups. The average price elasticity for the informed group was more than five times the average price responsiveness for the uninformed group. The differences in elasticities between the two groups are somewhat less pronounced in the long-run because the partial adjustment parameter is smaller for the informed group. The response to marginal price changes is highly elastic in the long run for the informed group and near unitary elasticity for the uninformed group. While these results indicate greater

responsiveness to price than many water demand studies, they are not unusual for a partial adjustment model. For example, Lyman (1992) reports several long-run marginal price elasticity estimates larger than -2.0 for peak season water usage in Idaho. The partial adjustment parameters and the long-run results could be misleading if households adjust consumption over a longer period of time than prescribed in the simple Koyck process used in this model.

The price perception parameters for both groups were statistically different from zero (and one) at a five percent level indicating that all households responded to some combination of marginal and average price signals.¹⁶ The informed group, however, assigned relatively more weight to marginal price.¹⁷ Furthermore, a 99 percent confidence interval around k contained zero for the informed group (-2.76, 0.14), but not for the uninformed group (-0.75, -0.06).

The complete demand model was also used to estimate conditional water use expectations and to evaluate the treatment effects of price knowledge. These results are presented in Table 5. Considering first the observed differences in water use between the two groups of households in the shaded cells along the diagonal, the group with price knowledge consumed 0.92 thousand gallons less water per month, on average, than the group without price knowledge. This simple comparison is misleading because it does not account for other unobserved factors that may have influenced consumption. The last row adjusts for this base heterogeneity and shows the differences in expected consumption. With the counterfactual condition that the uninformed group knew the price (BH^1 in Table 1 and equation [10]), the group who *actually* knew the price would be expected to use 2.39 thousand gallons *less* a month on average. Similarly, with the counterfactual condition that the informed group did not know the price (BH^0 in Table 1 and equation [11]), the informed group would still consume 1.41 thousand gallons less per month. Under both counterfactual conditions, the group that actually

knew the price would consume less. These differences reflect systematic sources of variation between the two groups that could not be fully accounted for in the observable determinants of the demand model. Knowledge of marginal prices alone does not explain why uninformed households use more water.

The last column in Table 5 presents the treatment effects of price knowledge as the expected change in consumption for a randomly selected household in each group. For the group with price knowledge, the first entry in the last column indicates that the mean effect of price knowledge (TT in Table 1 and equation [8]) was an *increase* of 0.49 thousand gallons per month in consumption. Similarly, if the group without price knowledge were informed (TU in Table 1 and equation [9]), the mean effect would also be an *increase* in consumption of 1.47 thousand gallons. The price knowledge effect is larger for the group that did not know marginal prices resulting in a negative value for the transitional heterogeneity effect (TH in Table 1). The estimated treatment effects indicate that both groups, if uninformed, would *overestimate* the price of service. Knowing the marginal price (which was lower than average price for the sample (Table 2)) increases consumption and this effect is greater for the uninformed group. These results are consistent with the responsiveness parameters that indicated uninformed households responded primarily to some form of average price signals.

VI. DISCUSSION

Prior research on household perceptions of prices for utility services has not directly evaluated the effects of price knowledge on responsiveness to price signals and consumption. Price knowledge is endogenous to the household and a potential source of variation in demand. Assumptions about household's perceptions of average and marginal prices can lead to different

econometric specifications of the residential demand function for utility services and possibly conflicting expectations of the effects of pricing policy changes on consumption.

In this paper we developed a simultaneous equations model with endogenous switching to estimate water demand conditional on the household's decision to know the marginal price of service. The model corrects for simultaneity in marginal prices and quantities with block rates using an instrumental variables approach. Coefficients from the model were used to derive price responsiveness parameters conditional on price knowledge. The estimated coefficients were also used in conjunction with methods derived from the program evaluation literature to identify how consumption responds to price knowledge.

Coefficient estimates for the price knowledge indicator equation revealed that observable characteristics such as higher monthly income, larger household size, home ownership, larger lawn area, and awareness of non-price demand management practices increased the likelihood of knowing marginal price. Households facing block rate structures, however, were less likely to know the marginal price. These results support a rational ignorance explanation of the decision to know marginal price based on expected net benefits. Unfortunately this is not the whole story because other unobservable differences across utilities and households included in the sample also influenced the decision.

The price responsiveness parameters also provided evidence of significant differences in behavior for households with and without price knowledge. Both groups responded to a combination of average *and* marginal price signals, but informed households were significantly more responsive to *both* prices. This confirms the importance of price knowledge as a determinant of consumption behavior and supports the argument that the lack of observed responsiveness to marginal price signals for public utility services is due to imperfect

information about prices. Residential demand models that do not recognize this endogeneity may yield biased estimates of consumption responses to price changes. The efficacy of marginal price, as well as average price, demand specifications is questionable without a better understanding of how households acquire and use utility price information.

Turning to the second and third questions we posed in the Introduction, the analysis demonstrated that differences in price knowledge alone did not fully account for variations in household consumption. The estimated heterogeneity effects revealed that, independent of price knowledge, informed households would use less water on average than uninformed households. This systematic difference in consumption between the two groups could not be explained with the observable determinants of the demand model and indicates a more complex relationship between price knowledge and utility service consumption behavior. In addition, the simple conclusion that all households would have lower consumption if fully informed is incorrect. The treatment effect analysis revealed the counterintuitive result that price knowledge *increased* consumption for each group, possibly because they *overestimated* the price of service. While this result is surprising, it is consistent with electricity use experiments in which information and self-monitoring programs resulted in a downward revision of the estimated costs thereby increasing consumption (Battalio et al. 1979; Sexton and Sexton 1987).

The results from this analysis raise several issues for utility services demand research and demand management policies. First, the vast majority of households apparently did not expect a net benefit from knowledge of the price schedule. To the extent the results from this sample are representative of other areas and utility services, further inquiries are needed to determine why households choose to be uninformed and the consequences for predicting household responses to changes in utility prices. In this regard, it may be useful to consider how households respond to

pricing and consumption information provided in utility billing statements, the bundling of services in billing statements, the frequency of billing, and other information provided by the utility about rate structures and service charges. Also, given that price and non-price demand management policies (i.e., subsidies for efficient technologies and usage restrictions) are often implemented jointly (e.g., Renwick and Archibald 1998), further studies are needed to measure the influence of non-price policies on price knowledge.

Second, the speed of adjustment of household consumption to changes in utility prices and/or rate structures will vary with price knowledge. Predictions based on an assumption of fully informed households may overestimate changes in consumption and incorrectly forecast changes in utility revenues. More research on the relationship between household knowledge and the lag structure of consumption responses to pricing changes would provide useful information for demand forecasting and revenue estimation.

Further research is also needed to evaluate the effects of policies to promote greater awareness of the price of utility services. For the households and utilities included in this analysis, the counterintuitive result that consumption would increase if households were fully informed may be due to the pricing used by these utilities. Whether households in other service areas also overestimate the cost of service is an empirical question that has important implications for utilities that wish to encourage households to be better informed.

Finally, this research suggests that policymakers should explicitly consider household's awareness of utility prices when they establish and review demand side management policies for utility services. The common perspective that pricing policies are ineffective due to a lack of responsiveness by households may be a by-product of the way utility services are billed and households receive information about their consumption decisions. The relative efficacy of price

and non-price instruments cannot be fully evaluated if household responses to price signals are tempered by incomplete knowledge.

APPENDIX

The expectations in Table 1 and Table 5 are calculated as follows using the normal endogenous switching model specified in [12]:

$$E[Q^1 | \mathbf{X}, D = 1] \approx \frac{1}{\sum_{n=1}^N D_n} \sum_{n=1}^N D_n \exp\left(\mathbf{X}_n \hat{\mathbf{B}}^1 + MP_n \pi^1 + \lambda_n \hat{\rho}^1 + (\hat{\sigma}^1)^2 / 2\right) \quad [\text{A1}]$$

$$E[Q^0 | \mathbf{X}, D = 1] \approx \frac{1}{\sum_{n=1}^N D_n} \sum_{n=1}^N D_n \exp\left(\mathbf{X}_n \hat{\mathbf{B}}^0 + MP_n \pi^0 + \lambda_n \hat{\rho}^0 + (\hat{\sigma}^0)^2 / 2\right) \quad [\text{A2}]$$

$$E[Q^1 | \mathbf{X}, D = 0] \approx \frac{1}{\sum_{n=1}^N (1 - D_n)} \sum_{n=1}^N (1 - D_n) \exp\left(\mathbf{X}_n \hat{\mathbf{B}}^1 + MP_n \pi^1 + \lambda_n \hat{\rho}^1 + (\hat{\sigma}^1)^2 / 2\right) \quad [\text{A3}]$$

$$E[Q^0 | \mathbf{X}, D = 0] \approx \frac{1}{\sum_{n=1}^N (1 - D_n)} \sum_{n=1}^N (1 - D_n) \exp\left(\mathbf{X}_n \hat{\mathbf{B}}^0 + MP_n \pi^0 + \lambda_n \hat{\rho}^0 + (\hat{\sigma}^0)^2 / 2\right) \quad [\text{A4}]$$

where N is the total number of observations and $\lambda_n = \phi(\mathbf{G}_n \hat{\mathbf{Z}}) / \Phi(\mathbf{G}_n \hat{\mathbf{Z}})$ if $D=1$ and

$\lambda_n = -\phi(\mathbf{G}_n \hat{\mathbf{Z}}) / [1 - \Phi(\mathbf{G}_n \hat{\mathbf{Z}})]$ otherwise with $\hat{\mathbf{Z}}$ and \mathbf{G} defined in Section IV. The estimates in

logarithms are adjusted back to the original units (thousand gallons) using the expectation of the lognormal distribution and the standard errors σ^1 and σ^0 for each regime. Various forms of these expectations appear in Dolton and Makepeace (1987), Vella (1988), and Lee (1995). We calculate the expectations in original units first and then perform the necessary subtractions to recover the treatment effect parameters. These calculations can be done in one step (in logarithms) using the formulas presented in Heckman, Tobias and Vytlačil (2001).

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¹ Foster and Beattie (1981 p. 259) state: “Given (1) consumers’ general lack of knowledge concerning marginal prices, (2) the complicated nature of the typical price schedule, and (3) the infrequent and complex billing statements provided consumers, the possible gains to the typical water consumer from applying such a complex maximization rule likely are less than the opportunity cost of the time and mental gymnastics required for ‘rational behavior’ under such a rule.”

² For example, Conlisk (1996 p. 685) summarizes the bounded rationality perspective on rational expectations by suggesting that “deliberation cost may make rational expectations cost more than they are worth.” Conlisk (1996 p. 686) also quotes Frank Knight: “It is evident that the rational thing to do is to be irrational, where deliberation and estimation cost more than they are worth.”

³ The partial adjustment model was used because households are unable to fully adjust their water use in the short run (billing cycle) given a fixed stock of water-using capital and household capital such as price knowledge.

⁴ These models are based on a two-error maximum likelihood approach first developed in Burtless and Hausman (1978) and Hausman (1985) to evaluate labor supply decisions. Subsequent literature has raised concerns about the strong convexity assumptions and functional form restrictions with this approach (e.g., MaCurdy 1992; Heim and Meyer 2003). Hewitt (2000) reports that restrictions alone are not sufficient to assure theoretically consistent estimates of water demand equation parameters.

⁵ We thank an anonymous reviewer for suggesting this characterization of the price knowledge decision.

⁶ The indicator of price knowledge is a household's own perception of their knowledge of price (Kujala and Johnson 1993). Research in marketing (e.g., Monroe and Lee 1999; Estelami and Lehmann 2001) has focused on the distinction between knowing and remembering prices and the use of memory tests to assess how buyers process and use price information. Our approach focuses on the behavioral implications of deciding whether or not price knowledge is expected to be beneficial.

⁷ This specification of the error terms differs from that of Herriges and King (1994) and Hewitt and Hanemann (1995) who assume that perception errors only influence the consumption decision. Their error structure follows from the assumption that households know marginal prices so that differences between planned and observed consumption cannot be attributed to factors related to price.

⁸ More complete information about the program evaluation literature and different types of measurable treatment effects is available in Heckman (2001) and Wooldridge (2002 pp. 603 – 42).

⁹ All monthly observations with no reported water use for two consecutive months were dropped from the sample. It was assumed that zero water usage is caused by factors exogenous to water use decisions (e.g., vacations or billing errors). Households who moved during the study period were also dropped from the sample.

¹⁰ The only other comparable reported survey for utility services is Hoffman (1975) who found that 4.4 percent of households knew the price of electric service. Other research for conventional market products also indicates that consumers' knowledge of prices is generally very limited (e.g., Dickson and Sawyer 1990; Wakefield and Inman 1993; Monroe and Lee 1999).

¹¹ This assumption is plausible for basic socioeconomic variables, such as household size and lawn size, but is somewhat tenuous for other variables that may be related to water consumption decisions. For example, a household that did not initially consume bottled water may have started to consume this product in subsequent years. More critically for present purposes, though, is the possibility that a household who did not know the marginal price of water service at the time of the survey may have actually learned the price at a later time. In this case the results will be conservative approximations of the actual difference in water use behavior attributable to price knowledge.

¹² A variable defining the amount of time spent on the line during the phone interview was also included in **R**. This interview time variable may be a proxy for unobserved attitudes about water use practices and conservation that distinguishes those with price knowledge (Branden, Gritz and Pergamit 1995; Bogen 1996).

¹³ Specification tests reject the null of exogeneity for both the price knowledge indicator (D) and the marginal price ($\ln(MP)$) are endogenous with respect to monthly consumption ($\ln(Q)$).

¹⁴ The elasticity of the conditional expected price level with respect to a change in the probability of knowing the price, $\Phi(\mathbf{G}\hat{\mathbf{Z}})$, for those who don't know the price is given by:

$$\frac{\partial E[MP^0 | \mathbf{S}, \mathbf{C}, \mathbf{U}, D = 0]}{\partial \Phi(\mathbf{G}\hat{\mathbf{Z}})} \frac{\Phi(\mathbf{G}\hat{\mathbf{Z}})}{E[MP^0 | \mathbf{S}, \mathbf{C}, \mathbf{U}, D = 0]} = \frac{\Phi(\mathbf{G}\hat{\mathbf{Z}})}{1 - \Phi(\mathbf{G}\hat{\mathbf{Z}})} \lambda \varphi^0 \text{ with } \lambda = -\frac{\phi(\mathbf{G}\hat{\mathbf{Z}})}{1 - \Phi(\mathbf{G}\hat{\mathbf{Z}})}.$$

¹⁵ The income, marginal price, and average price elasticities in Table 4 are calculated from the coefficients for these variables. The price perception parameter, k , is the coefficient on the average price variable divided by the sum of the coefficients on the average and marginal price variables. The partial adjustment parameter, θ , is one minus the coefficient on the lagged water

use. Long run values are found by dividing the estimates by the partial adjustment parameter.

The asymptotic standard errors of the estimates are calculated using the delta method.

¹⁶ Existing estimates of the price perception parameter k with aggregate water company data range from 0.01 to 3.28 depending on the season and the location of the utility (Nieswiadomy 1992; Nieswiadomy and Cobb 1993 ; Michelsen, McGuckin and Stumpf 1998). Nieswiadomy and Molina's (1991) point estimates of k with household level data were -0.43 and 1.55 with decreasing and increasing block rate structures, respectively.

¹⁷ From equation [4], k is a weight that allocates price response among average and marginal price signals. The value of -1.311 for those who know the price suggests a weight of -1.311 (k) on average price and a weight of 2.311 ($1 - k$) on marginal price. By comparison, a k of -0.43 for those without price knowledge implies a weight of -0.43 on average price and a weight of 0.57 on marginal price.

Table 1. Definition of Expected Water Use and Treatment Effect Parameters

Sample	Price Knowledge		Treatment Effects
	Know	Don't Know	
Know	$E[Q^1 \mathbf{X},D=1]$	$E[Q^0 \mathbf{X},D=1]$	TT
Don't Know	$E[Q^1 \mathbf{X},D=0]$	$E[Q^0 \mathbf{X},D=0]$	TU
Heterogeneity Effects	BH^1	BH^0	TH

Notes: Shaded and un-shaded cells contain, respectively, observed and counterfactual information.

Q^1 = Water use if price is known

Q^0 = Water use if price is not known

\mathbf{X} = observed control variables

D = (1 if price is known, i.e., $\varepsilon \geq -\mathbf{GZ}$, and 0 otherwise)

Table 2. Summary Statistics for Water Demand Data

Variable Description	Variable	Know Price	Don't Know Price	All
Know the price of a 1000 gal. of water? ^b	<i>D</i>	1.00 (0.00)	0.00 (0.00)	0.06 (0.25)
Monthly Consumption (1000 Gal.) ^a	<i>Q</i>	8.31 (8.54)	9.34 (9.84)	9.27 (9.76)
Marginal Price (\$1996/1000 Gal.) ^{a, c}	<i>MP</i>	1.53 (0.43)	1.48 (0.42)	1.49 (0.42)
Average Price (\$1996/Month) ^{a, c}	<i>AP</i>	2.73 (1.27)	2.60 (1.34)	2.61 (1.34)
Monthly Income (\$1996) ^{b, c}	<i>Y</i>	4,567 (2,846)	4,460 (3,344)	4,467 (3,314)
Own Residence? ^b	<i>OWNPL</i>	0.87 (0.34)	0.90 (0.30)	0.90 (0.30)
House Age (years) ^b	<i>HAGE</i>	7.48 (9.27)	8.16 (9.00)	8.11 (9.02)
Household Size ^b	<i>HHSZ</i>	2.66 (1.13)	2.81 (1.44)	2.80 (1.42)
Lawn Size (Acres) ^b	<i>LAWN</i>	0.53 (0.54)	0.49 (0.60)	0.49 (0.60)
Irrigation Well? ^b	<i>WELL</i>	0.21 (0.41)	0.30 (0.46)	0.29 (0.46)
Dishwasher? ^b	<i>DISH</i>	0.67 (0.47)	0.80 (0.40)	0.79 (0.41)

(continued)

Table (concluded)

Description	Variable	Know Price	Don't Know Price	All
Cocoa Beach?	<i>COCD</i>	0.31 (0.46)	0.33 (0.47)	0.33 (0.47)
Gainesville?	<i>GRUD</i>	0.32 (0.47)	0.35 (0.48)	0.35 (0.48)
Monthly Mean Temp (Degrees F) ^d	<i>MNTM</i>	69.61 (10.34)	69.59 (10.34)	69.59 (10.34)
Monthly Precipitation (Inches) ^d	<i>TPCP</i>	4.35 (3.22)	4.36 (3.21)	4.36 (3.21)
Drink Bottled Water? ^b	<i>BWATER</i>	0.45 (0.50)	0.39 (0.49)	0.39 (0.49)
Know About Low Flow Fixtures? ^b	<i>LFLOW</i>	0.77 (0.42)	0.62 (0.48)	0.63 (0.48)
Know About Xeriscaping? ^b	<i>XERI</i>	0.43 (0.49)	0.36 (0.48)	0.37 (0.48)
Interview Duration (minutes) ^b	<i>INTD</i>	8.34 (2.77)	6.69 (1.78)	6.80 (1.90)

Notes: Standard deviations in parentheses.

^aFrom utility billing records.

^bReported in the water customer survey (Bureau of Business and Economic Research 1997).

^cAdjusted by the U.S. Bureau of Labor estimates of the 1997-99 monthly CPI (1996 = 100) for all items in southern U.S. cities with populations less than 1.5 million (size B/C).

^dMeasurements from the nearest regional airport stations as reported by the U.S National Oceanic & Atmospheric Administration.

Table 3. Water Demand Model Estimates

Variable	All-OLS Demand	Know Decision	Don't Know Price		Know Price	
			Price	Demand	Price	Demand
<i>ONE</i>	-0.182* (0.093)	-6.616** (1.180)	-0.255** (0.022)	-0.728** (0.101)	-0.180** (0.082)	-0.953** (0.421)
<i>D</i>	-0.047** (0.013)					
<i>Ln(Q_{t-1})</i>	0.642** (0.007)		0.102** (0.002)	0.784** (0.008)	0.129** (0.008)	0.811** (0.034)
<i>Ln(MP)</i>	0.375** (0.016)			-0.211** (0.020)		-0.578** (0.089)
<i>Ln(AP_{t-1})</i>	-0.310** (0.016)		0.105** (0.005)	0.061** (0.018)	0.201** (0.020)	0.328** (0.082)
<i>Ln(y)</i>	0.048** (0.005)	0.900** (0.298)	0.002* (0.001)	0.055** (0.005)	0.000 (0.005)	-0.009 (0.026)
<i>OWNPL</i>	0.031** (0.011)	-0.256** (0.048)	0.016** (0.002)	0.007 (0.012)	0.019** (0.009)	0.159** (0.049)
<i>Ln(HAGE)</i>	0.009** (0.003)	-0.094** (0.026)	0.005** (0.001)	0.009** (0.003)	0.000 (0.002)	0.014 (0.013)
<i>Ln(HHSZ)</i>	0.141** (0.007)	0.474** (0.100)	-0.010** (0.002)	0.145** (0.007)	0.009 (0.007)	0.231** (0.037)
<i>Ln(LAWN)</i>	0.019** (0.006)	0.076** (0.036)	0.007** (0.001)	0.013** (0.006)	0.021** (0.005)	0.091** (0.025)
<i>WELL</i>	-0.128** (0.008)	-0.384** (0.035)	-0.015** (0.002)	-0.045** (0.009)	-0.050** (0.007)	-0.123** (0.038)
<i>DISH</i>	0.040** (0.009)	-0.492** (0.036)	0.007** (0.002)	0.055** (0.010)	-0.006 (0.008)	0.180** (0.042)
<i>COCD</i>		-2.914** (0.407)	-0.333** (0.002)		-0.348** (0.007)	
<i>GRUD</i>		-3.738** (0.436)	-0.621** (0.003)		-0.599** (0.013)	
<i>Ln(MNTM)</i>	0.114** (0.021)		0.149** (0.005)	0.136** (0.022)	0.110** (0.017)	0.257** (0.091)
<i>Ln(TPCP)</i>	-0.038** (0.003)		-0.004** (0.001)	-0.042** (0.003)	-0.004* (0.002)	-0.050** (0.013)

(continued)

Table (concluded)

Variable	All-OLS Demand	Know Decision	Don't Know Price		Know Price	
			Price	Demand	Price	Demand
<i>BWATER</i>		0.063** (0.028)				
<i>LFLOW</i>		0.317** (0.033)				
<i>XERI</i>		0.174** (0.031)				
<i>Ln(INTD)</i>		1.530** (0.052)				
<i>Ln(y)²</i>		-0.064** (0.019)				
<i>Ln(LAWN)²</i>		-0.205** (0.027)				
<i>Ln(HHSZ)²</i>		-0.416** (0.054)				
<i>Ln(HAGE)²</i>		-0.006 (0.009)				
<i>Ln(y)*COCD</i>		0.298** (0.050)				
<i>Ln(y)*GRUD</i>		0.428** (0.054)				
<i>Ln(HHSZ)*COCD</i>		0.380** (0.078)				
<i>Ln(HHSZ)*GRUD</i>		-0.059 (0.073)				
λ			-0.034** (0.007)	-0.036 (0.033)	0.002 (0.007)	-0.077** (0.037)
(pseudo) r^2	0.70	0.35	0.87	0.67	0.88	0.65

Notes: Asymptotic standard errors are shown in the parentheses below each estimate.

* and ** indicates parameter estimate significance at the 10 and 5 percent level, respectively.

Table 4. Responsiveness Parameter Estimates

Parameter [Short-run, Long-run]	Short-Run		Long-Run	
	Know	Don't Know	Know	Don't Know
Income elasticity [$\theta\gamma, \gamma$]	-0.009 (0.026)	0.055** (0.005)	-0.047 (0.139)	0.255** (0.026)
Marginal price elasticity [$\theta\eta(1-k), \eta(1-k)$]	-0.578** (0.089)	-0.211** (0.02)	-3.054** (0.893)	-0.979** (0.12)
Average price elasticity [$\theta\eta k, \eta k$]	0.328** (0.082)	0.061** (0.018)	1.732** (0.717)	0.281** (0.092)
Price perception [k, k]	-1.311** (0.562)	-0.403** (0.135)	-1.311** (0.562)	-0.403** (0.135)
Partial adjustment [θ]	0.189** (0.034)	0.216** (0.008)	1.000 -	1.000 -

Notes: Asymptotic standard errors are shown in the parentheses below each estimate.

* and ** indicates parameter estimate significance at the 10 and 5 percent level, respectively.

The short-run and long-run symbols are based on equations [3] and [4] in the text.

Table 5. Expected Water Use and Treatment Effect Parameters (1000 gallons)

Sample	Price Knowledge		Treatment Effects
	Know	Don't Know	
Know	8.46	7.97	0.49
Don't Know	10.86	9.38	1.47
Heterogeneity Effects	-2.39	-1.41	-0.98

See Table 1 for a description of the information in this Table.