CAN DESERT DWELLERS CONTINUE TO AFFORD LUSH LAWNS: ANALYZING CONSUMER RESPONSE TO RATE CHANGES IN FOUR PHOENIX SUBURBS

by

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TABLE OF CONTENTS

TABLE OF CONTENTS – *Continued*

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

It is important for the state of Arizona and its neighbors to understand residential water demand as populations continue to grow. Part of this challenge is understanding how consumers respond to complex increasing block rate tariffs with fixed charges, and whether price increases can be an efficacious conservation strategy. Statistical tests are performed to determine to which price (marginal or average) consumers tend to respond, and to measure the magnitude of response. Previous studies assume that weather has the same effect on all households, but given the diversity of lot sizes this assumption is likely to be false. New variables are introduced to account for increased summer watering needs of larger lots and compared to the standard variables. Various demographic variables are tested for their relationship to water usage. Finally, the policy implications of the various results are discussed.

CHAPTER 1

Introduction

In the hot, dry desert of Phoenix, residential water prices are a hot-button issue. Residents are quite vocal in their response to increases in water rates in spite of the relatively low prices they face, but the question remains as to how their usage changes in response to the price increases. A number of factors determine consumer price response, including the magnitude of the price changes, how publicized the change is, and, of course, the price elasticity. Consumer response is critical to the water provider because, as a regulated monopoly, all price changes must be approved by the Arizona Corporation Commission (ACC), which typically assumes water demand is perfectly inelastic when considering rate changes. If water demand is not perfectly inelastic, then the rate increases approved by the ACC may be insufficient to meet operating costs and the water company will be forced to request additional rate increases.

Water is a scarce resource in the desert Southwest. With the populations of southern California, Las Vegas, and Arizona all competing for Colorado River water, it is important for communities to develop sustainable usage habits. Although agriculture is the largest sector for water use, municipal usage, which is primarily residential, accounts for about 25% of usage[1], and population growth is expected to increase this share. As many new residents move from cooler and rainier climates, they want landscaping to remind them of home, and pools to keep them cool. To discourage these behaviors and encourage conservation, some argue for price in-

[1] http://www.azwater.gov/

creases. The efficacy of price increases in promoting conservation depends on the price elasticity. Low price elasticities could prevent conservation goals from being met, while the price increases would decrease consumer well-being.

With the looming possibility of global climate change, it is also important to understand how weather affects water usage. Previous studies have assumed that weather affects every house the same, regardless of lot size, landscaping, or the presence of a pool. This is not an intuitively appealing assumption, so new methods need to be developed for incorporating weather into water demand models. This thesis interacts the lot size and pool size with potential evapotranspiration, as well as interacting lot size with the number of rainy days. These new interaction terms provide a marked improvement in the explanatory power of the model.

The data used in this thesis was provided by a private water utility, exclusively for this research group. Combined with the other data sources, it contains a very detailed panel of over 39,000 households and 72 months. The rate changes represented in the data range from marginal to substantial changes (from less than 1% increase to nearly doubling). Some of the changes in the increasing block rates even changed the underlying structure of the block pricing, changing block sizes and in one case, adding two additional blocks.

The rate schedules differ by water districts, as do many demographic characteristics of consumers. It is therefore unlikely that all water districts have the same price elasticity, since demographic characteristics such as income, age, and education are likely to play a role in a household's water consumption. Consequently, each community is examined independently with cross-community comparisons following thereafter.

The four communities in the sample represent three very different slices of the population. Sun City and Sun City West are retirement communities, where landscaping and pool ownership are minimal, and the preferences and fixed incomes tend to lead to simple living. Furthermore, some residents are "snow-birds", who spend winters in Arizona and summers in cooler climates. Paradise Valley is the most upscale community in all of Phoenix, with many homes valued over one million dollars. No other water demand studies have specifically examined retirement communities or exceedingly wealthy enclaves. Anthem, on the other hand, is a more stereotypical suburb filled with middle-class families. Analyzing these different communities independently can provide new insights into how different classes of consumers choose how much water to use.

The thesis is structured as follows: economic theory regarding demand for water is explained in Chapter 2; an overview of the literature regarding block rate pricing and water demand is given in Chapter 3; data sources and descriptive statistics are presented in Chapter 4; univariate and regression analysis follow in Chapter 5; and the policy implications of the results are discussed in Chapter 6.

CHAPTER 2

Economic Theory

Consumer theory holds that a consumer's demand for a good is a function of the budget constraint (be it wealth or income), the price of the good, the price of complements and substitutes, and preferences. However, piped water has very few true substitutes. Rainwater and its harvesting offer a substitute, but one that is very unreliable in the Phoenix desert. A house could also have its own well, but for the urban and suburban settings of this study wells are not common, and a household with a well would not also pay for piped water, thus rendering it moot in estimating the demand function with this data set. Water does have many complementary goods, but these generally fall under two broad categories: cheap and consumable, or expensive and durable. The price of goods such as laundry detergent, soap, coffee beans, and small plants have little effect on water demand because they represent a very small portion of the household budget and do not significantly change water consumption. On the other hand, washing machines, toilets, landscaping, and swimming pools make up a large portion of household water consumption. However, as durable goods with high switching costs, consumers are likely to use what they have until the durables absolutely must be replaced. Low flow toilets, shower-heads, drip irrigation, and water conserving landscaping can also function as substitutes for water by reducing the amount of water used for the complementary activities (Agthe and Billings, 1996). Nevertheless, the prices of these goods are not likely to influence water demand; indeed prices of other goods have not been included in other water demand studies.

Because of the infrastructure involved in supplying water, it is a natural monopoly. Therefore the water utility is usually owned and operated by the municipal government, or is a regulated monopoly with all price changes requiring regulatory approval. Facing a distinct set of fixed and variable costs, the water utility must recoup these costs through its billing. As a result of this structure, water bills frequently have two parts, a fixed "service" or "meter" fee designed to distribute fixed costs fairly across constituents, and a variable or "volumetric" charge designed to cover the utility's variable costs. However, this volumetric charge is frequently a block rate pricing schedule rather than a constant marginal rate. Decreasing block rates were once more common, reflecting a perceived economy of scale in water provision, but increasing block rates have become increasingly popular due to their appearance of "fairness" in rewarding conservation and redistributing costs onto users who consume large quantities.

Naturally the price of water is expected to influence the demand. Unfortunately, the complicated nature of water rate schedules leaves a great deal of ambiguity as to how consumers perceive the price of water. Traditional consumer theory would have the consumer respond to the marginal price with an income effect caused by service charges and the structure of the multi-tiered block rates (Taylor, 1975; Nordin, 1976). However, this assumes that the consumer has perfect information about the price schedule, the beginning and ending of the billing period, and how much water the household has consumed and will consume thereafter at any point in the billing cycle. Even accepting the notion that the consumer knows the start and end date of the billing period, the consumer does not know *a priori* what sort of unanticipated shocks to water usage may occur in the coming month. For instance, the temperature, as well as amount and timing of rainfall are unknown at the start of the billing cycle. Also, obtaining information about the price schedule involves significant search cost. Gaudin (2006) reports that in 1995, only 17.2% of water companies reported the household's marginal rate next to the consumption on the bill, and a minuscule 2.9% included the full rate schedule on the bill. Therefore, 97.1% of consumers would be required to contact their utility or search the website in order to determine the marginal rates in blocks exceeding their current usage. As a result, Carter and Milon (2005) find in a survey of residential customers that only 6% know the marginal price they pay for water. Furthermore, most households can expect to spend less than 3% of their income on the water bill, and by virtue of "the importance of being unimportant" most consumers choose not to expend the time and energy to understand their rate schedule or give any other careful thought to their water usage. It then should come as little surprise that those studies which have empirically tested consumer behavior tend to find that the consumer is more responsive to average price than to the marginal price with income effect (Foster and Beattie, 1981a; Griffin and Chang, 1990; Ito, 2010). Several others find that neither marginal nor average price can be rejected statistically as a driver in the consumer's decision (Chicoine and Ramamurthy, 1986; Polzin, 1984).

Inflation is of particular importance when analyzing time-series water usage data. Because price changes for water utilities are infrequent for most utilities, increases in *nominal* water price may not be increases in *real* water price. When Beattie and Foster (1980) look at the water prices of 23 utilities across the country over the period of 1960 to 1976, they find that in 13 of the 23 water utilities the real price had actually decreased. Since real prices increase less than nominal prices with inflation, the failure to account for the effects of inflation would then lead to the determination that in spite of the nominal price increases, water usage has not changed. Therefore, the calculated price elasticity would be biased towards zero (or positivity). A related issue comes from changes in income, such as cost-of-living adjustments. The standard Marshallian demand function is homogenous of degree zero in prices and income, so if one has accurate and timely income and price data then one would expect to find quantities demanded remain constant when prices and income change at the same rate. In terms of real prices and real income, this is important if both move only with inflation, or perhaps because of economic growth in a region are able to change at the same rate. However, micro-level water demand studies have not had time varying measures of household income, and at the aggregate level zero degree homogeneity may or may not hold depending on the true functional form of individual demand functions.

In order to understand the pricing of water, it is also important to note the units for which the consumer is billed. In the United States the two most common units for which water customers are billed are kgal (1000 gallons) and ccf (100 ft^3 = 748 gallons). All data in this study are measured in kgal, so that is the focus of this discussion. Economic theory dictates that at the final demand point, marginal price equals marginal utility *with the same units of measure*. It is therefore assumed that a customer recognizes their marginal utility per 1000 gallons[1]. However, most people would be hard pressed to calculate this “marginal” utility because of its size. For instance, 1000 gallons could be used to flush a toilet 200 times, do 25 loads of laundry, or take 33 five-minute showers[2], and the average swimming pool takes 18,000 to 20,000 gallons to fill. Or turning the calculations around, one could look at the cost of each gallon used, but with prices ranging from roughly \$0.75/kgal to \$6.00/kgal, then costs are ¢0.075/gal to ¢0.6/gal, which are such small costs as to

[1] It is likely that many consumers do not even know the billing units for their water usage.

[2] Numbers calculated from averages reported at http://www.cornerstonesmud.com/id46.htm

be almost imperceptible. Combined with the low marginal price, the high volume per unit makes "perfectly rational optimization" a difficult calculation.

Water demand can be separated into two components, domestic and external. Domestic usage comes from any of the various usages of water which are a part of everyday home life, such as dishwashers, showers, drinking water, toilets, etc. External usage occurs with hoses, sprinklers, pools, fountains, etc. The key differences in the type of usage are seasonality and elasticity. Domestic usage is rather stable from month to month for any given household, and the cost of this usage is so low relative to income, and so vital to modern living, that it is highly inelastic. In the long-run, low-flow toilets, more efficient washing machines, and other technologies can be implemented to reduce domestic usage, but given the low price of water, the incentive to switch away from a currently working unit is low in the absence of subsidies. Even with subsidies, the inconvenience of installation, and the paperwork to receive the subsidy/rebate prevent some consumers from switching. External usage is strongly seasonal, due in large part to the effects of weather on sprinkling/watering needs of plants changing with the seasons. Additionally, pool evaporation and pool usage (and therefore water splashing out of the pool) is significantly higher in summer months. External usage makes up the largest proportion of the average water bill, and is far more discretionary in quantity than domestic usage. This discretionary nature makes it much more elastic than domestic usage (Howe and Linaweaver, 1967).

It is also important to note that although water does provide some utility directly to the consumer, there is a large component of water usage which represents a derived demand. For instance, the demand for cleanliness and hygiene uses water in the form of bathing, washing dishes, doing laundry, and washing a car. Water is applied to a lawn to produce beautiful plants. Therefore, part of the utility of water usage is derived from the utility produced through such applications, and in the absence of a lawn or dirty dishes, the use of water provides little to no intrinsic utility.

There is also the question of the functional form of water demand. Due to the ease of calculation and interpretation of coefficients, the two most commonly used functional forms are linear and Cobb-Douglas. However, there is some debate about the assumptions of these models which give pause in the interpretation of results; the linear form assumes that price elasticity is increasing in price, and Cobb-Douglas form assumes constant price elasticity and complementarity of inputs. The Stone-Geary form allows for flexibility in the elasticity and features the intuitively appealing "subsistence level" or "conditional water use threshold" which represents the amount of water usage which is insensitive to price changes in the short-run (Gaudin et al., 2001; Martínez-Espiñeira and Nauges, 2004). This threshold is likely to contain most of the domestic usage and a portion of outdoor usage which the consumer is unwilling to forgo.

In addition to this minimum threshold level of water usage, there is also the possibility of satiation. The existence of satiation would invalidate the "marginal price equals marginal utility" result, and quite probably leave such consumers entirely insensitive to price changes, whether increases or decreases. Studies of water utilities which have included an allowance of water at no additional cost with the service charge found many consumers used less than this free allowance (Danielson, 1977; Dandy et al., 1997). In the Danielson data, 17% of consumers consumed where the marginal price was zero. Relative to this finding, Foster and Beattie (1981b, p. 258) state that

> [Failing to use the entire free allowance] is inconsistent with the pos-

> tulates of consumer preference and/or behavior. Clearly, either these consumers are irrational from an economic point of view, or they have indifference curves that do not conform to the axioms of consumer theory...

Although Foster and Beattie conclude that the failure to use up the allowance is the result of the consumer responding to average price, it could also be that the consumer has no real value for any additional consumption. Indeed, non-satiation is one of the aforementioned axioms of consumer theory. For example, someone temporarily renting a home with no landscaping or pool would have no incentive to add either, and is likely limited by the rental agreement. As such, all of this consumer's water usage is for domestic purposes. In order to use up this allowance, the consumer could shower more or for a longer time, could run the faucets more, or do dishes/laundry without filling the machine. But these activities do not necessarily increase the consumer's utility. Accordingly, failure to use the entire allowance may be indicative of satiation rather than an incorrect price perception. In the case of this hypothetical renter, the consumer reaches a bliss point, but additional water usage likely causes no disutility. Under these circumstances, the utility function would plateau after reaching the bliss point. This issue has not been examined in the water literature. The only concept of satiation present in the literature is of finite demand at zero price, which is mentioned by Foster and Beattie (1979) as a reason for choosing the exponential functional form, and has been discussed in regards to electricity by Choynowski (2008), who argues for the applicability of finite demand at zero price in water as well. But finite demand at zero price is very different than satiation under existing prices. It may simply represent a capacity constraint[3], and in any case, this form of satiation is only of interest for defining the functional form,

[3]Indeed, even if one turned on every faucet and spigot, running water constantly, the total monthly usage would be finite.

since no utility offers unlimited free water. Graphically, satiation as described by Foster and Beattie (1979); Choynowski (2008) would appear as an intercept on the price axis for an otherwise well-behaved demand curve. The plateau satiation would appear as a vertical segment in the demand curve.

If the non-satiation axiom is violated, then satiated customers would exhibit perfect price and income inelasticity because the budget constraint is not binding. Only when prices increase (or income decreases) to the point that the budget constraint becomes binding would such consumers begin to change their consumption in the ways predicted by consumer theory. Price decreases would never lead to a change in consumption. If one defines elasticity as the response to changes *when non-satiation holds*, then for both aggregate and micro-level consumption data, satiation would lead to bias towards zero in the estimation of price and income elasticities. In the short-run the elasticity estimates are useful for making predictions, as real prices and income remain in the neighborhood where the budget constraint is non-binding. But in the long-run, as utility companies adjust prices, elasticity measures would change as the proportion of households whose budget constraint is non-binding changes.

CHAPTER 3

Literature Review

In the economic literature, there is no debate about whether price should be included in the econometric model, but there has been significant debate as to how consumers perceive and respond to water prices. Because the demand for water is so heavily dependent on landscaping, weather is known to influence usage. Weather variables have taken on many different forms, but there has been very little contention as far as what is correct; authors simply choose one and explain the reasoning behind the decision. The non-price, non-climate variables are frequently determined by what data are available at the same level of disaggregation as the water usage (e.g. household, neighborhood, or entire utility coverage areas).

3.1 Multi-Tiered Block Pricing and Econometric Specification of Price

Taylor (1975) and Nordin (1976) revolutionized the way block rate prices are analyzed, suggesting that marginal price and average price are each insufficient on their own, and instead marginal price should be used along with an income effect equal to the difference between the price that was paid and what would have been paid had all units been purchased at the final marginal price and without a fixed charge. This income effect is referred to as the "difference" variable and also as the "Rate Structure Premium." As a strictly income based effect, it is expected to have the opposite sign and same magnitude as the calculated income coefficient.

In estimating demand, Howe and Linaweaver (1967) choose to use marginal price only, since the study predates the innovations of Taylor and Nordin. They separate the data into domestic demands (indoor) and sprinkling demands through extrapolation from hourly usage data. They also suggest that there is a possibility that water prices are set higher where demand is low, and lower where demand is high, in order to effectively recover the utility's costs. However, their empirical test rejects this hypothesis. Under this inverse pricing model, it could lead to the calculation of a spurious demand function[1]. They find that domestic demands are relatively price inelastic, whereas sprinkling demands are price elastic. A weighted average of the two elasticities yields an overall elasticity of -0.4, which matches well with the other findings at the time.

Foster and Beattie (1979) choose the average price to estimate a demand model for water in spite of the innovation of Taylor and Nordin. Their results are rebutted by Griffin et al. (1981), who argue that the average price, as calculated over the entire utility company, is "not closely related to the marginal price faced by consumers" (p. 255), and that Foster and Beattie have, in fact, estimated the supply curve rather than the demand curve. In reply to those criticisms, Foster and Beattie (1981b, p. 258) defend their choice of average over marginal price by pointing to the proviso stated by Anderson and quoted in Taylor (1975), "provided that the consumers are well-informed." Foster and Beattie argue that, although trained economists, they are uncertain of the form of water pricing schedule they face in their own homes, and do not know their marginal rates. They assume that most consumers are no more aware of the pricing schedule than a pair of economists, and thus are highly skeptical of the applicability of estimation with marginal price. However, they conclude by suggesting that, rather than continuing a theoretical debate, this

[1] The data used in this thesis does not show this demand-price relationship. The prices are highest in Paradise Valley, which also has the highest demand.

is a problem suitable for empirical testing.

Foster and Beattie (1981a) implement such an empirical test, concluding that the use of average price confers more explanatory power than marginal price as measured by R^2, while not resulting in any statistically significant differences in non-price parameters.

A means of empirically testing which price consumers respond to under a linear demand model is suggested by Opaluch (1982). This test can be generalized and simplified (e.g. Griffin and Chang, 1990), as estimating

$$Q = \beta_0 + \beta_1 MP + \beta_2(AP - MP) + \cdots + \epsilon$$

and employing hypothesis testing on the coefficients. Ignoring the hypothesis test results which conclude that consumers respond to both prices or do not respond to price at all; if $\beta_2 = 0$ cannot be rejected, then the consumers respond to marginal price, and if $\beta_1 = \beta_2$ cannot be rejected, then the consumers respond to average price.

Charney and Woodard (1984) respond further in the theoretical debate, suggesting that lagged average price is the best choice for uninformed consumers for two reasons. First, uninformed consumers are only going to have the previous month's bill in evaluating their usage and price, since it is difficult to monitor water usage without regularly checking the meter. Second, because price and usage are simultaneously determined in a block pricing schedule, there is a resultant simultaneity bias which they suggest would be alleviated by lagging, because last month's usage does not determine this month's price. Furthermore, they suggest that the uninformed consumer is unaware of the Nordin income effect, and it should be omitted from estimation under the "uninformed consumer" hypothesis. In response to these ideas, Opaluch (1984) argues that the habitual nature of water usage will result in strong correlation between lagged average price and present average price, and, therefore, the error term as well. So although lagging average price solves the simultaneity problem, endogeneity persists, and it should result in "essentially identical results" (p. 418). He also shows that even the uninformed consumer should be modeled with the Nordin income effect in order to separate the income effect and substitution effect of price changes when using the test described in Opaluch (1982)[2]. However, he does agree with Charney and Woodard that simultaneity bias is a significant issue and should be accounted for in future econometric estimations.

Billings and Agthe (1980) demonstrate graphically that the Nordin specification of marginal price and a difference variable is correct for a perfectly optimizing consumer, and then use this specification to estimate residential water demand elasticities for Tucson, AZ over the years of 1974-77. Their estimate for the price elasticity (not including changes in the difference variable) is -0.267 for the log model, and ranges from -0.45 to -0.61 in the linear model. Perhaps the most interesting statement they make is about the sewage billing procedure. Sewer usage was billed at a rate of the lesser of: 85% of winter water consumption, or 85% of current water consumption. A perfectly informed rational optimizing consumer would therefore reduce winter consumption because its role in determining year-long sewage rates gives it a higher implicit marginal rate. However, Billings and Agthe find the variable to be statistically insignificant. In response they write

> We conclude that most water customers in Tucson during the two winters during which these implicit marginal prices were in effect *were unaware of them and did not respond* to the high implicit price. (pp. 81-82,

[2]Note Opaluch asserts that the Rate Structure Premium should be included when employing his test for determining to which price consumers respond. He does not maintain that it should always be included when modeling behavior of uninformed consumers.

emphasis added)

Because the implicit sewage price variable was insignificant, and its removal did not significantly alter other coefficients, they removed the variable from the model. In spite of this evidence that consumers are either poorly informed or irrational, their model remains formulated on the Nordin specification, which assumes perfect information and rational optimization.

Billings (1982) examines the problem of a bias in estimating water demand where the stochastic error term could potentially move a consumer out of the observed price block for which the marginal price and difference are calculated, as suggested in the criticism made by Griffin and Martin (1981). He employs a regression of the curve formed by plotting usage on the X-axis and total bill on the Y-axis to obtain instruments for the marginal price and difference variables, and finds that employing these instruments with the data used in Billings and Agthe (1980) results in a higher price elasticity (-0.66 compared to -0.49 at the mean price) and a lower coefficient on the difference variable, as predicted in Griffin and Martin (1981). It is worth noting that this instrument for marginal price is similar to an "average marginal price" over a selected range of usage.

The simultaneity bias is once again examined in Agthe et al. (1986). A Hausman test rejects the hypothesis of no endogeneity, so they apply a three equation system, estimating marginal price, rate structure premium, and quantity, and find the results to be "very satisfactory" (p. 4). The price elasticity calculated at the mean price is -0.59, as compared to the original -0.49, and the instrumental variables (IV) estimate of -0.66. They also measure the short-run and long-run elasticities given a capital stock of water-using equipment, estimated as a function of the same variables used in the short-run model. The preceding elasticity measures are their long-run results, and the short-run elasticity is estimated to be -0.265. However, they advise that a study with actual measures of capital stock information would produce better results than these estimated capital stocks.

Testing the endogeneity issue once again, Billings (1987) tests the OLS, IV, and a censored model for bias. The censored model attempts to remove the measurement error issue, as explained in Griffin and Martin (1981), by omitting observations clustered around the breakpoints of the price function. Based on his IV results, he concludes that both the OLS and censored model are biased. Most interesting, however, is that the Nordin difference variable is not statistically significant in 7 of 13 IV regressions, and he suggests that either

> consumers frequently ignore income effects arising from changes in [the difference variable]; or consumers are unaware of the true nature of the pricing scheme for water and therefore do not respond as predicted by demand models which assume well-informed consumers. (p. 344)

Although Agthe and Billings are among the most prolific and popular authors to champion the perfectly optimizing consumer when estimating the demand function, even they admit that their empirical results call this assumption into question.

Whereas Opaluch (1982) offers a test for linear demand models, for a Cobb-Douglas model Shin (1985) recommends a "price perception parameter" of the form $P^* = MP(\frac{AP}{MP})^k$ where k is expected to be between 0 and 1. By using a double-log equation, k can be estimated. If $k = 1$, then the consumers are responding to average price, and if $k = 0$ then the consumers are responding to marginal price. One advantage this has over the Opaluch test is that the perception need not be strictly one or the other for the model to make sense. If a consumer has a vague notion of the marginal price, and a clearer knowledge of the average price, then the parameter could lie between 0 and 1 without the interpretation of the results becoming nonsensical. In his analysis of Ohio electricity usage aggregated across seven utilities with decreasing block rates from 1960-1980, he finds $k = 1.007$, and is able to reject $k = 0$ decisively ($t = 6.97$) but is unable to reject $k = 1$, thus concluding that the consumers tend to respond to average price.

Nieswiadomy and Molina (1989) employ new data and new techniques (variants of IV and 2SLS) to shed further light on the price specification and econometric method debates. Using household-level data from Texas under both increasing and decreasing block rates, they find that OLS does produce biased results, with the bias being in different directions for each rate structure as predicted. Their price elasticity estimates are -0.86 for IV and -0.55 for 2SLS. They also calculate the Nordin difference variable and find that it does not have the expected symmetry to the income variable, countering the claim of Schefter and David (1985) who argue that the asymmetry is the result of data aggregation. The asymmetry of the difference effect and the income effect would appear to confirm Billings (1987) suspicion that consumers do not respond to the price schedule like well-informed rational consumers.

Nieswiadomy and Molina (1991) use Shin's model to test their unique data set containing household panel data for a period of increasing block rates and a period of decreasing block rates. The findings agree with Shin (1985), that facing decreasing block rates, the perceived price appears to be the average price. However, under increasing block rates he finds the perceived price appears to be the marginal price. Nieswiadomy and Cobb (1993) use the 1984 AWWA data at the utility level to analyze the questions of how utilities decide upon their pricing structure, and what effect the structure has on conservation and price elasticity. Their results show that more rainfall decreases the likelihood of choosing an increasing block rate, and prior conservation programs increase the likelihood. Employing the Shin model once again, this time they find that both increasing and decreasing block rates appear to be better explained by average price. Furthermore, increasing block rate utilities (-0.64) are more price-elastic than decreasing block rate utilities (-0.46), validating the idea that the increasing block rate pricing structure promotes water conservation.

Using a summer-only subset of data from Nieswiadomy and Molina, Hewitt and Hanemann (1995) employ an entirely different econometric method than any other heretofore applied to water demand. They devise a Discrete/Continuous (D/C) maximum likelihood model with two error terms: one which affects the choice of which block to consume in, and one which only affects consumption within the block. The authors acknowledge the problem of the frequent ignorance with regards to marginal price and rate structures, but argue that their model employing marginal price and difference variable is nevertheless useful for generalizing the results, even if it is not representative of the true decision process. In their words,

> Though many households do not know the rate structure they face, the utility-maximization-based D/C choice model can be used to estimate a water demand relationship *as if* they did. (p. 183, italics in original)

By modeling block choice explicitly, their model should be free from the bias caused by the endogenous price/usage relationship. Comparing the results of the OLS and IV regressions with the D/C model, they note that the non-price coefficients are nearly identical, while the price coefficient is positive for the OLS and IV models but is negative and elastic (-1.59) in the D/C model. They suggest these patterns in elasticity values are similar to the results of other studies which examined the price elasticity of outdoor water usage (e.g. Howe and Linaweaver, 1967). By using data only from the summer months, Hewitt and Hanemann conclude that they have also measured this "outdoor usage price elasticity". The elastic demand, then, should be seen as evidence in favor of their model, since it is the only model used which reports elastic demand as would be predicted based on previous results.

Another measure of elasticities with the Discrete/Continuous model is undertaken in Pint (1999) using panel data for the Bay Area of northern California from 1982-1992. Before estimating the D/C model she runs OLS and fixed effects models employing a parabolic form with MP and MP^2, finding that the estimated demand curves are upward sloping at higher prices, violating economic theory and giving evidence of the endogeneity problem. Using the D/C model as in Hewitt and Hanemann (1995) resulted in higher price elasticities than the OLS and FE models, ranging from -0.20 to -1.24. The elastic value of -1.24 was for winter usage in the highest blocks, where as the comparable summer elasticity was -0.47, conflicting with the higher "outdoor/summer" results described in the preceding paragraph.

Continuing in the Discrete/Continuous or Structural estimation method, Olmstead et al. (2007) put together a dataset of 1082 households in 11 urban areas, including Phoenix and Tempe/Scottsdale, with daily usage data for two weeks during a wet season and two weeks during a dry season. They also conducted surveys to collect information on household size, property characteristics, and age of the home. This time the elasticity estimate of approximately -0.59 for households facing increasing block pricing, significantly lower than the D/C elasticity result in Hewitt and Hanemann (1995) and the winter result in Pint (1999). Of particular interest to this thesis, they also find the Tempe/Scottsdale and Phoenix dummies to have negative coefficients, implying that residents of these urban areas use less water than average.

Taking the estimation problem a step further, Strong and Smith (2010) use aggregate data from Phoenix, AZ to compute the direct utility function. Comparing these results to the DCC model, the elasticity values are similar (-0.4 and -0.48), however bias was not a primary reason for their use of the utility function methodology. They contend that their method is better for understanding the effects of large rate changes as well as for any question of welfare analysis.

Nauges and Thomas (2000) suggest that there is another possible cause of price endogeneity for which it is much more difficult to control econometrically. Their study of French communities finds that the system features, expected water consumption, and policy objectives play a role in determining the negotiated rate structure. Although the process in Arizona is not a negotiation between the community and the provider, the Arizona Corporation Commission is likely to consider the consumption patterns, average income, and other demographics in determining the rate structure. For example, in 2005 the first tier price in the wealthy area of Paradise Valley covered the first 25 kgal, and in the retirement community of Sun City the first tier price covered the first 4 kgal. This endogeneity, however, is only a cause for concern when multiple communities are pooled for estimation of the demand function.

It is the complexity of the rate structure and the consumer's cost of obtaining information which creates the economic irrationality of their behavior. If price information were more readily available to the consumer, would the consumer begin to optimize better? This question is addressed by Gaudin (2006), who analyzes the price elasticity of water demand for a cross-section of utility companies with a variety of bill formats, each displaying different amounts of information. He finds that including the marginal price paid for water consumed directly on the bill does increase price elasticity by about 30%[3], but non-price information, such as usage

[3]Price elasticity is -0.36 for areas that do not include the information and -0.51 for areas that do. (p. 390)

history in a 12-month histogram, conservation messages, and community averages do not influence elasticity.

Using a survey of Tucson water customers, Agthe et al. (1988) analyze the effects of rate structure knowledge on the determinants of demand. They report that only 21% of those surveyed were aware that water was billed on an increasing block rate. Furthermore, informed households used more water in both summer and winter months, although the authors believe that the higher usage led to this knowledge rather than the converse. In fact, they observe more conservation behaviors in the informed group. Since the rate structure is not presented with the bill, only those who consume above the first tier would even be able to discern the rate structure from careful examination of the bill.

Expanding on these ideas, Carter and Milon (2005) use data from a 1997 survey of Florida consumers and corresponding billing records to test the effect of price knowledge at a micro level. Of particular import to the price perception debate, they report that only 6% of consumers surveyed knew their marginal price for water, which is a similar finding to a Texas survey by Stratus Consulting (1999) which found that only 7% used marginal or average prices in making water consumption decisions. Higher income, larger house size, and larger lawn size increase the likelihood of knowing one's marginal rate, while facing any sort of block rate structure decreases the likelihood. The knowledge of one's marginal rate is associated with an increase in price elasticity, particularly with regards to the marginal price. Surprisingly though, knowledge of one's marginal rate is also associated with increased consumption, which they theorize is a result of an overestimation of the price by those who do not know their actual water rate[4].

[4]This author pays an average of $4 per month for volumetric water usage on a bill which, combined with sewer and trash, totals $45. It is understandable how prices could be overestimated.

Borenstein (2009) argues against the traditional "perfectly optimizing consumer" paradigm and even goes so far as to state:

> It seems safe to say that not only do most consumers not know how much power or water they have used since their current billing period began, most consumers don't know when their current billing period began. (p. 3)

Because the discontinuity of the price schedule creates kinks in the budget curve, the standard economic model would predict a pooling equilibrium, also referred to as "bunching", at (or near) the discontinuities (Castro-Rodríguez et al., 2002). Borenstein finds no such observable bunching, nor does his research assistant Ito (2010) with two data sets of Southern California electricity usage. Ito (2010), using an ideal "natural experiment" data set of households within a mile of the border separating two utilities with different prices, finds that consumer responses are even contradictory to the standard model. His results indicate that in instances when the marginal price increases but the average price decreases for a tier, consumers increase their usage. This increased usage implies that the price elasticity is positive, or consumers respond to average price. His model, however, does not include the Nordin (1976) Rate Structure Premium, so it may exhibit omitted variable bias, especially since average price incorporates intra-marginal rates. In circumstances he describes, where there is an increase in marginal price and a decrease in average price, the difference variable would represent a greater subsidy, thus partly explaining the increased usage. Inclusion of the difference variable is nevertheless unlikely to correct the positive price elasticity[5]. Ito (2010) does find that there is a statistically significant increase in price elasticity for lower income groups, but not so across high and low users.

[5]Howe and Linaweaver (1967) had negative price elasticities when using marginal price alone.

3.2 Weather and Climate Specifications

Weather variables included in past studies include temperature, rainfall, evapotranspiration, and numerous different functions of these variables. These variables are important for explaining outdoor water usage, most notably landscape watering and permanent pools, even above-ground. On the other hand, such uses as car washing, inflatable pools, or a Slip 'n Slide®, although more likely to occur in warmer times, are not affected by evaporation.

Howe and Linaweaver (1967) report that "An earlier study has shown that sprinkling demands follow potential evapotranspiration quite closely when antecedent precipitation has been dissipated" (p. 20). Yet not all rainfall is "effective" in nourishing plant life, since some evaporates and some becomes runoff. They estimate that about 60% of rainfall is effective, so their variable is the potential evapotranspiration minus 0.6 times rainfall. They theorize that this variable multiplied by the square footage of irrigable area will determine the watering needs of a given residence's yard. Although it seems logical to interact these two variables, Howe and Linaweaver, and all subsequent authors using both irrigable area and weather, choose to estimate the effects separately. Howe and Linaweaver also conclude that effective rainfall in the arid Western states "is of such small value that it has little effect on the value of the expression" (p. 21).

A similar method of subtracting total rainfall (rather than effective rainfall) from potential evapotranspiration is used in many studies (Billings and Agthe, 1980; Nieswiadomy and Molina, 1989). Because most water utilities read the meters on different days for different houses in their coverage area, the evapotranspiration and rainfall should be compiled as the sum of daily values over each household's actual billing cycle for any household level data set. Nieswiadomy and Molina (1989) is the first work to do so.

Foster and Beattie (1979, 1981a) define a climate variable based on precipitation during the "growing season" of a given region, as defined by the temperature at which the predominant regional variety of turfgrass becomes dormant. In Phoenix there is a significant portion of the population which has a Bermuda grass lawn, but in the winter a rye grass is planted, since the winter temperature can support its growth. An analysis of Tucson winter water usage in Agthe et al. (1988) finds that "humid" landscaping increases usage even in the winter for Tucson. Because of this winter sprinkling demand, such a "growing season" dependent variable would not work well for this thesis.

Billings (1987) uses three variables, the average monthly temperature, degrees by which the mean exceeds 58°F, and rainfall in months where the mean temperature exceeds 58°F. No explanation is given as to why 58°F was the critical point, but it is quite close to the 60°F that Foster and Beattie (1979) cite as the temperature below which turfgrass becomes dormant in the Southern region, of which Billings' Tucson data is a part. Another, less intuitive method, employed by Griffin and Chang (1990) is to use the number of days in the month without significant precipitation (≥ 0.25 in.) multiplied by the average monthly temperature.

Two closely related papers, Maidment and Miaou (1985, 1986), take a closer look at the effect of weather on water use, and report that neither rainfall nor temperature exhibit a linear relationship with water usage. In Maidment and Miaou (1985) they conclude that it is primarily the occurrence of rainfall, rather than the amount of rain, which affects water use in Austin, TX. They theorize that rainfall has a state-dependent and dynamic effect on water use which is ignored by multiple regression models that include simple monthly rainfall totals. It is state-dependent in the sense that the reduction in water usage is dependent on outdoor water usage prior to the rain event, and dynamic in the sense that it has a strong effect immediately after the rain event, and then over the course of days or weeks water usage returns to prior levels. They find that as temperature increases, water use increases at an increasing rate. In their words,

> Above [70°F], seasonal use rises slowly at first, then more rapidly as air temperature rises beyond 85°-90°F where the rate of rise is 3-5 times faster than when temperature is less than this level. (Maidment and Miaou, 1986, p. 851)

These theories about non-linear relationships are supported by the results of their models, which explains 97% of the variability in daily water usage for Austin in the 1985 paper. In the 1986 paper, they get R^2 values of 0.96 for Texas, 0.73 in Florida, and 0.61 in Pennsylvania. Unfortunately these studies do not include evapotranspiration measures, which may linearize the temperature effect. The nonlinearity issue is further examined in Miaou (1990), where the findings are relatively similar, with the added caveat that there is a saturation point beyond which rainfall does not have any further effect. There is one result particularly of interest in regards to aggregation to monthly water use,

> The number of rainy days in a month is consistently a better explanatory variable, in both linear and nonlinear models, than rainfall amount in describing seasonal water use response to rainfall occurrences. This suggests that the observation established at the daily level that people respond more to rainfall occurrence than to rainfall amount is still valid at the aggregated monthly level. (p. 178)

Martinez-Espiñeira (2002) also uses number of rainy days as the climate variable rather than total rainfall. The intuition for such a count measure is that a household is most likely to respond to rainfall by cutting back on their watering in the following days, without particular regard for the intensity of the rainfall.

3.3 Household and Neighborhood Characteristics

In any study of demand, more finely detailed information provides better estimates of individual demand functions. Some water demand studies are fortunate to have household usage data, while others have aggregate utility coverage areas, but all attempt to account for cross-sectional heterogeneity with cross-sectional variables.

Because consumer theory defines income as a factor in all demand functions, regardless of the good, it is the most ubiquitous variable at the cross-sectional level. There has been variability in the application of income with respect to the Nordin difference variable, as some studies include both variables separately (e.g. Agthe and Billings, 1980) whereas others compute the ex post "virtual income" obtained by subtracting the Nordin difference from the income (e.g. Chicoine and Ramamurthy, 1986). Aggregate studies typically use regional per household income, (Foster and Beattie, 1979; Agthe and Billings, 1980) or per capita income (Griffin and Chang, 1990). Studies with actual household level income are rare but there have been some researchers who conducted surveys or gained access to income tax records to obtain the information (Hanke and de Mare, 1982; Chicoine and Ramamurthy, 1986). The assessed value of the home is commonly used to proxy for income (Howe and Linaweaver, 1967; Dandy et al., 1997), and has also been used to generate estimates of household income (Nieswiadomy and Molina, 1989; Hewitt and Hanemann, 1995; Pint, 1999). Unfortunately, there are problems with using the home value for income. One problem is the implicit non-income signal, since the value of the home one purchases is correlated with preferences for opulence. Another issue is the relationship with home square footage and lot size, since in addition to having some explanatory value for water usage, these factors are correlated with home valuation. This multi-collinearity may cause problems in the estimation.

The literature review of Worthington and Hoffman (2008) reports that "estimates of income elasticity are almost universally income inelastic (less than one) and small in magnitude" (p. 862) and cites, among others, Chicoine and Ramamurthy (1986); Dandy et al. (1997); Gaudin et al. (2001). A table of income and Nordin difference elasticities can be found in Arbués et al. (2003), and shows income elasticities typically lie between 0.10 and 0.40, with the notably elastic exceptions of 1.33-7.829 (Agthe and Billings, 1980) and 1.68-2.14 (Billings, 1982) calculated for Tucson, AZ using aggregate usage and statewide income data.

Agthe et al. (1988) evaluate the hypothesis that price elasticities differ across income groups. This is important for determining the equity of rate schedules and the efficacy of price changes in demand management. The authors summarize the logical arguments for different elasticities as follows:

> It is frequently assumed that low income households have the lowest price elasticities of demand because they have fewer uses for water and fewer substitutes for these uses. High income households, however, may have lower price elasticity of demand because water represents a relatively smaller proportion of their total expenditures. Thus, the question of which income group of water consumers has the lower price elasticity must be determined empirically rather than on a-priori grounds. (p.278-279)

Across four income groups, they find that price elasticity steadily *decreases* as income rises, with the lowest income group at -0.565 and the highest income group at -0.397. Two more recent inquiries into this question have corroborated this result (Ito, 2010; Mieno and Braden, 2011).

The number of residents and their demographic characteristics should affect both domestic and outdoor usage. Number of residents should primarily alter domestic usage, since each person bathes, use dishes, wear clothing, etc. Indeed, it is found to have a positive relationship with usage in several studies, including Howe and Linaweaver (1967), Hanke and de Mare (1982), Billings (1987), Nieswiadomy (1992), and Mieno and Braden (2011). However, it is expected to have very little influence on outdoor usage, since the water needs of the lawn and pool are not strongly affected by the number of users. Combined with the fact that most households have higher outdoor than domestic usage, this is the theoretical underpinning for the finding of economies of scale in Höglund (1999), who reports that "if the average number of persons per household increases from 2 to 3 in a community, demand for water per person declines by 27-35%" (p. 3861).

Additional demographic factors are also likely to come into play. The most obvious of these factors is age, since children, teens, working adults, and retirees are all likely to have different water usage patterns due to differing preferences, behaviors, and understanding of water pricing. One would expect young children to increase the water usage for cleaning up spills, soiled laundry, and the combination of loving to watch running water and lacking a concept of cost or scarcity of water. Children may also play a role in adults' decision in whether their home should have a pool or grass lawn. Retirees are likely to be home a greater portion of the day than working adults or school children, and are more likely to actively garden. On the other hand, they may be thriftier due to their preferences or their budget. Nauges and Thomas (2000) find that percentage of residents in a community over 60 years of age has a negative relationship with water usage for their sample of French communities. Lyman (1992) compares the water usage for children (<10), teenagers

(10-20), and adults (>20). He finds that children add more to water usage than adults, whereas teenagers add the least. However, when he combined the children and teenagers into one group, he was able to replicate the finding of Hanke and de Mare (1982); adults add more to water usage than those under 20 years of age. Unsurprisingly, Lyman rejects the hypothesis that the coefficients on children and teenagers are identical. Martínez-Espiñeira (2003) includes the percentage of the population over 64 and the percentage under 19, and finds that retired populations tend to use less water, and the presence of children tends to move a household into a higher block although it is not significant in determining usage within the highest block.

Ethnicity may also be a factor in water consumption patterns. There are very few studies which have included ethnicity in water demand estimation. There is a trailblazing technical report on Texas water use by Murdock et al. (1988), which found that Hispanic descent was associated with lower water usage. As a result of their finding, several subsequent studies of Texas water usage included percent of the population of Hispanic origin. Griffin and Chang (1990) found an unexpectedly positive but insignificant effect of Hispanic population, and attribute this to the hypothesis that "the [percent Hispanic] variable is correlated with omitted climatic/geographic variables because the percentage of population with Spanish descendency declines as latitude increases" (p. 2253). Gaudin et al. (2001) also uses the variable, and in their general models find the expected negative effect, and in their Stone-Geary models find that the threshold is lower and the elasticity is higher where there are more Hispanics.

3.4 Property Characteristics

In addition to the effects of the people living in the household, the characteristics of the property itself are important in determining water demand. Lot size, or the inversely related housing density, are frequently used as a measure of the area a household could choose to landscape. Howe and Linaweaver (1967) used housing density and the size of the region to compute an estimate for lot size, but found it had a surprisingly negative, although insignificant, effect on demand. Although not measuring the size of the lawns, the study by Agthe and Billings (1987) included a dummy variable for whether the front or back yard had landscaping which requires irrigation and find the expected positive relationship to usage. Nieswiadomy and Molina (1989) used lot size and house size to calculate the "lawn size." Stevens et al. (1992) include population density in their model, and find the expected negative relationship to usage. Lyman (1992) includes several measures of watering, with variables for the size of the lawn, flower beds, and vegetable gardens. The coefficient for lawn size is positive and significant, whereas vegetable gardens are positive and insignificant, and flower beds are negative and insignificant. Hewitt and Hanemann (1995) construct lawn size by the formula $lotsize - 2 * housesize$, which is not explained. However, the doubling of the house size is likely to account for driveways, patios, and other non-irrigated outdoor areas. Dandy et al. (1997) and Pint (1999) use lot size independent of other property characteristics. Olmstead et al. (2007) includes lot size as estimated by the homeowner, and estimates a positive and significant relationship to usage. Griffin and Mjelde (2011) includes "outdoor area", defined as the lot size minus the area of the house, garage, porch, and other additions.

The square footage of the house itself does not directly explain usage, since aside from mopping, indoor usage does not directly depend on size. It may yet be a measure of preferences, a proxy for water using capital stock, or a proxy for number of residents. For similar reasons, the number of rooms, number of bathrooms, or number of water-using fixtures are occasionally used. Nieswiadomy and Molina (1989), Hewitt and Hanemann (1995), and Pint (1999) use square footage of the house as an explanatory variable, and find a positive and significant coefficient. Dandy et al. (1997) includes number of rooms, although the results vary in sign and are not highly significant. Chicoine and Ramamurthy (1986) and Hewitt and Hanemann (1995) include number of bathrooms as a measure of household technology, and find the expected increase in water usage with more bathrooms. However, Lyman (1992) estimates a negative and significant coefficient for bathrooms, and suppose that, due to high correlation with property value, number of bathrooms either has no role, or is indicative of behaviors that use less water. Because Hewitt and Hanemann (1995) include both house size and number of bathrooms, they produce the interesting result of negative but insignificant coefficients on house size. They suggest "one possible reason that house size negatively (though insignificantly) affects consumption in the OLS model is that number of bathrooms represents a better proxy for household size than house size." (p. 186) Olmstead et al. (2007) also include both house size and number of bathrooms, but in contrast to Hewitt and Hanemann (1995), both variables are positive and significant.

Indoor water use is a function of the quantity and type of appliances in the household. Newer homes are likely to be built or furnished with more modern appliances, many of which are more efficient. However, homes that are significantly older may have fewer appliances. Thus it is unknown what effect the year of construction has on water usage, but it is a plausible variable. Hanke and de Mare (1982) use a dummy variable to separate newer houses from older houses, and conclude that newer homes have higher water usage. Nieswiadomy and Cobb (1993) include percentage of homes built before 1939, and also conclude that older homes use less water, particularly under decreasing block-rates. On the other hand, Carter and Milon (2005) and Lyman (1992) find age of the house to have a positive and significant effect on usage. Nauges and Thomas (2000) use the percent of homes built before 1949 and the percent of homes built after 1982 in order to allow for different effects. They discover a positive coefficient for the old homes and a negative coefficient for the recent homes, suggesting that water usage is monotonically increasing with age. In contrast, Olmstead et al. (2007) employs a quadratic specification for age, finding that homes aged 20-40 years use the most water, while both newer and older homes use less.

The installation and use of water conserving fixtures is one manner in which households can "substitute" for water consumption. Some of these fixtures come standard, or at least as upgrade options, in newer homes, but require retrofitting for older homes. Because the installation of such fixtures is a major part of the higher long-run price elasticity, understanding the decision making process is useful to economists. Agthe and Billings (1996) use survey data from Tucson, Arizona to model the decision to install low-flow faucets, shower-heads, toilets, and drip irrigation as a function of income, household size, water price, and an environmentally conservative mindset. Their results show that income is negatively correlated with indoor fixture installation, with only faucets being statistically significant. They attribute this negative relationship with income to the higher proportion of income going to water increasing the attractiveness of the low-cost indoor fixtures. However, income is positively correlated with drip irrigation and statistically significant, which they attribute to the higher switching cost. It is also probable that for drip irrigation to be cost effective, there must be significant landscaping which would be more common for wealthier households. But most importantly they conclude that the marginal price is positively correlated with installation of all such fixtures, and is statistically significant for faucets, toilets, and drip irrigation.

The effect of pools on water usage is difficult to predict. Filling a pool requires tremendous amounts of water (18-20 kgal on average), but complete filling is a rare event. Regular topping off may even require less water than irrigating an equivalent area of grass. Furthermore, pools are usually surrounded by a deck and arid landscaping, so more than just the area of the pool is diverted from water intensive landscaping. Using data drawn from a community with free allowances of water, Dandy et al. (1997) find that the pool water is changed more frequently when water is free than when it is not. Having also run seasonal models, he reports that pools increase usage in both summer and winter months, with the summer effect being higher. Agthe and Billings (1987) estimate that pool ownership tends to increase water usage by 310 cubic feet (2,300 gallons) per month, but suggest the possibility that "the pool may replace turf that would otherwise require irrigation" (p. 284), so to the extent that similar households have grass instead of a pool, this coefficient will understate the effect. However, a constant effect for pools as estimated in Agthe and Billings (1987), rather than one that changes with season, is not likely to confer much explanatory power. Strong and Smith (2010) employ aggregate data, so they include percentage of homes with pools, and find the variable did have a positive effect on usage.

CHAPTER 4

Description of Data

4.1 Water Usage Data

Water consumption and prices were provided by EPCOR Water[1] for four water districts in the greater Phoenix metropolitan area (Paradise Valley, Anthem, Sun City, and Sun City West), covering the billing periods from January 2005 through December 2010. Because of the delay between meter readings and billing, this represents the water usage period between late November 2004 and early December 2010. EPCOR Water sent each water bill in a line item format, from which the total bill and usage amounts are calculated. A sample bill and a line item format representation are included in the Appendix.

The sample area does not include smart meters, so all meter readings are performed by utility employees. In order to accommodate the limitations of meter readers, the meters are not all read on the same day, but rather on a rolling cycle throughout the month. This is critical in calculating the effect of climate on water usage, because a billing cycle is far from synonymous with a calendar month. Therefore, weather variables must be measured for the actual billing cycle and not the calendar month of the bill. Furthermore, manual meter reading introduces uncertainty and variability in the meter reading date. Unlike some other utility companies, EPCOR does not calculate the price tiers on a "per day" usage basis, so the length of the billing cycle can move a consumer into another tier even if

[1] Operated under the name Arizona American Water during the study period. The operations were sold to EPCOR Water in January 2012.

their daily habits are unchanged. Many economic demand models are built on the assumption that a household chooses how much water to use in a billing cycle, but to do so they must know when the billing cycle begins and ends. Most consumers are unlikely to observe the exact date the meter reader records their usage, thus ending the current billing cycle. Even if they did observe this, in the case where the meter reader comes later than expected, they are unlikely to completely discontinue water usage which is a part of their everyday life just to avoid moving into a higher price block. Consequently, the manner in which the water is metered for billing is relevant for demand estimation.

According to EPCOR Water, a "full" billing month is considered to be between 25 and 35 days. Accordingly, all data for billing periods not falling within this range are excluded. This removal is necessary because the billing period lengths present in the sample varies from 1 to 306 days[2], and any model attempting to explain monthly water usage would be biased by such large variation in the number of billing days. This also allows billing frequency to be excluded as a variable, since all communities in the sample have monthly billing. There were other billing oddities which were accounted for in the data compiling process, including overlapping billing periods and sequential bills which are each too short to be a full billing month but were combined to become full bills. Where multiple bills combined to make one full billing cycle, the two bills were added together with the starting and ending dates covering the full month. Some of the overlapping billing periods were the result of non-payment of a bill. After a non-payment, the subsequent month's bill actually represented two months of usage. In this case, the bill for the second month was made distinct by subtracting the prior month's bill. One other scenario requiring

[2]Short bills are typically account activations close to the meter reading date for that house. The cause of long bills is unknown.

some data manipulation is bills which span changes in price. EPCOR Water employs a complicated prorating formula, so although the usage and bill amounts are easily recovered, variables such as marginal price and the rate structure premium are not perfectly accurate, since they are calculated *as if* the whole bill were priced according to the new schedule.

There are customers who have multiple meters at a single address, such as separate meters for the lawn and the house, or for a guest house and a main house. All such households were removed, because economic modeling struggles to account for a single household facing multiple prices simultaneously. Additionally, there is no guarantee that the residents of an address were the same individuals across the study period. If a house was sold or leased to different residents, the estimated model would treat all the residents at that address as being identical.

It comes as no surprise that the usage data shows seasonality, as can be observed in Figures 4.1 and 4.2. The Paradise Valley water district uses several times more water on average than the other communities in the sample, the reasons for which are discussed shortly. This higher usage level makes the seasonality significantly more pronounced.

4.2 Water Prices

In each of the four communities studied here, there is at least one significant pricing change during the sample period. Because each pricing change must be approved by the Arizona Corporation Commission, the timing and magnitude of these changes differ greatly. It is also notable that in addition to changes in the stated rates for water, there were additional surcharges, earmarked for various purposes, added to and removed from the rate schedule over the course of the six-year sample period.

Figure 4.1: Average Water Usage by Community

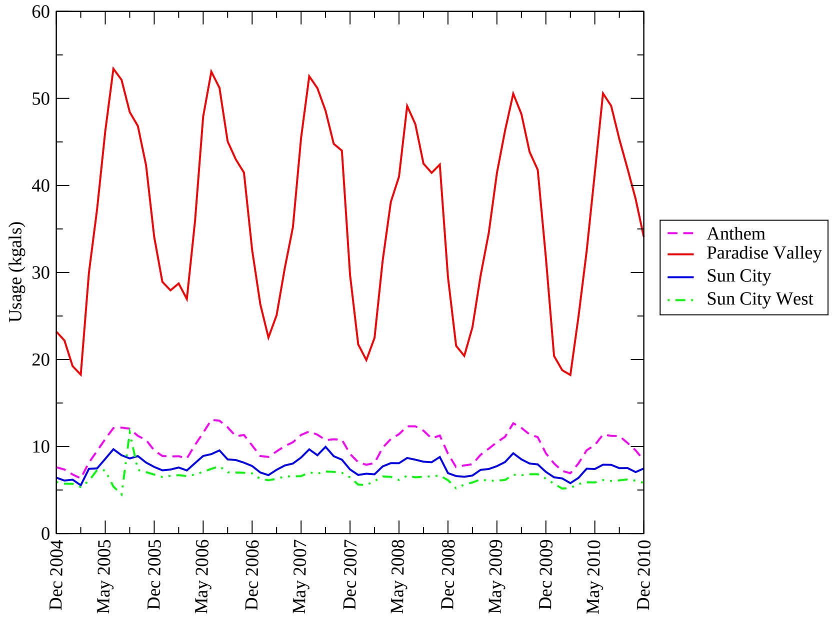
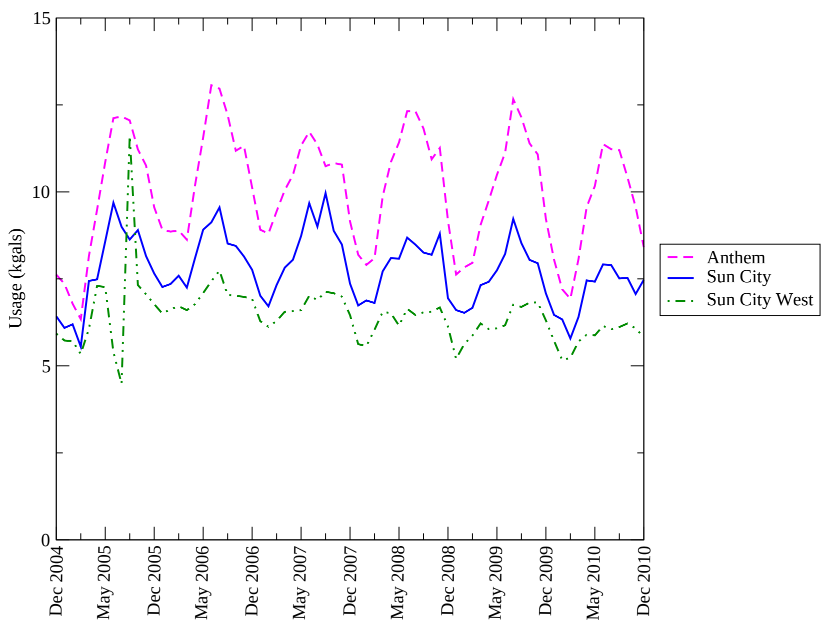


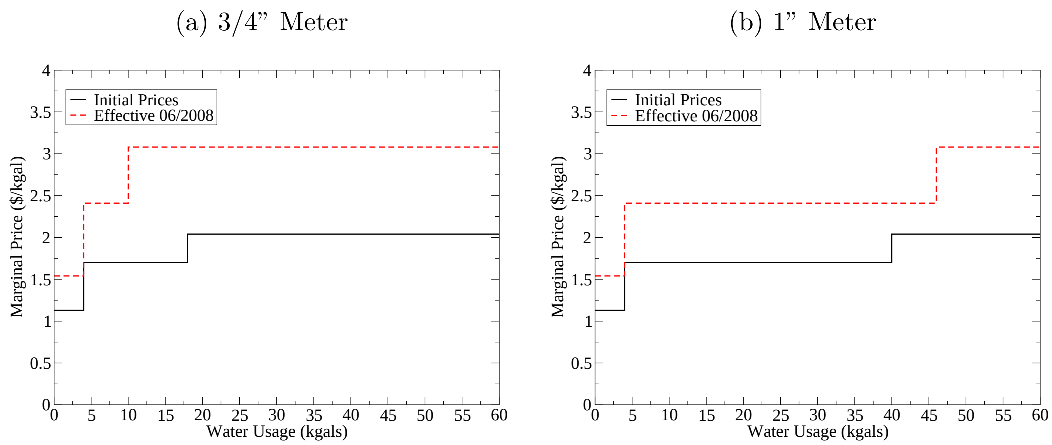
Figure 4.2: Average Water Usage by Community (Excluding Paradise Valley)



For most households the majority of the bill is the usage, billed according to an increasing block rate schedule. There is also a fixed service charge for each meter, which depends on the diameter of the pipe, and ranges from $6 up to $141, plus fixed surcharges in some communities. In addition to the price of the water, there are volumetric surcharges. Some are a constant addition to the marginal price, and others are themselves two-tiered block rates with the first block price being 0. Therefore, the marginal price paid by a household is frequently not the rate indicated on the tariff schedule, but rather the sum of the rate on the tariff schedule and any surcharges which apply at the final usage level. This makes it even more difficult for households to know the true marginal price when making consumption decisions.

Anthem has very simple pricing, with only one change and no surcharges. Thus the stated price of water is also the true marginal price. There are two rate schedules, which differ in fixed charges and breakpoints depending on the meter size. Figure 4.3 shows these rate schedules. It is interesting that the marginal prices are the same, but the breakpoints are extremely different, and move even further apart after the rate change. The change in price is large, particularly in comparison with the other changes studied in the literature, with the marginal prices going up 36% for Tier 1, 42% for Tier 2, and 51% for Tier 3. This change occurs conveniently in the middle of the sample period, May 2008. The most intriguing part of the change in rate schedule for Anthem is that not only do the price levels change, but the breakpoint for the top tier drops from 18 kgals to 10 kgals for the 3/4" meters, while it moves from 40 kgals to 46 kgals for the 1" meters. Such a change, present in other communities of this study as well, has not been examined in the literature. Borenstein (2009) uses data with such a change, but does not explicitly consider the

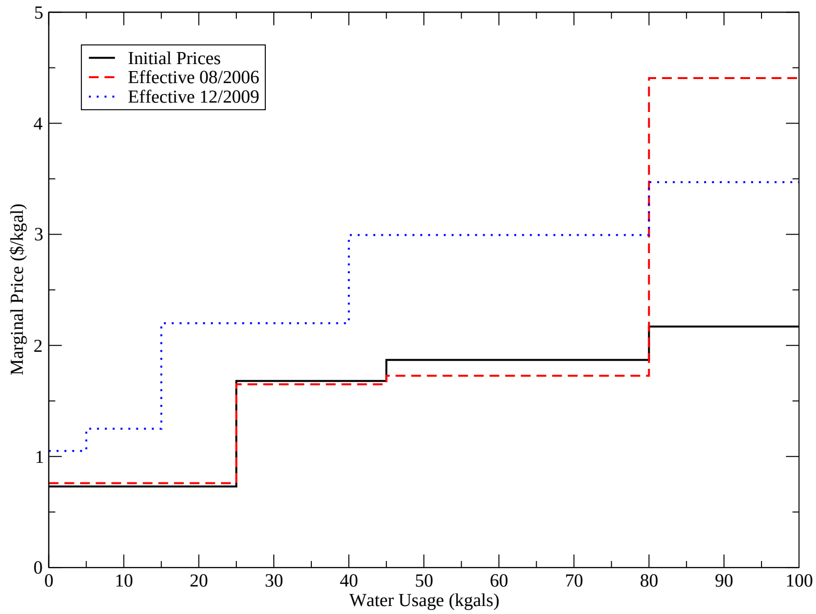
Figure 4.3: Anthem Rate Schedules



effect of the change in the rate structure. If usage is price elastic and consumers respond to the marginal price, one would expect the simultaneous price increase and change in the breakpoint to cause noticeable reductions in water usage for households with 3/4" meters. Referring to Figure 4.2, the annual peaks in Anthem are not as high subsequent to the price change as they were prior, and the troughs also appear slightly lower. However, May 2008 also corresponds to a time when many of the primarily middle class residents of Anthem would begin struggling with unemployment or underemployment, and falling home values. Therefore the reduction in usage is likely to be the result of a combination of the price increase and decreases in income and wealth.

Paradise Valley has the most complicated pricing. There are two changes in the official water rates, with several surcharges that change many times over the sample period for a total of 10 different rate schedules. Figure 4.4 presents the marginal price of water, as calculated by summing the stated rate for water in that tier, and the applicable surcharges at the time of official rate changes. Once again there is a change in the block structure, as it shifts from 3 blocks at the beginning of the

Figure 4.4: Paradise Valley Rate Schedule



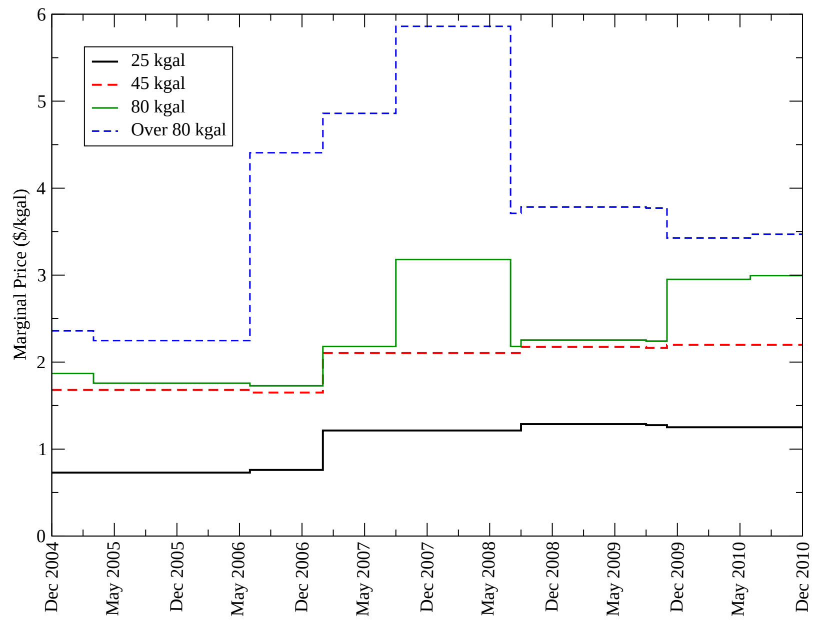
sample to 5 blocks by the end. Unfortunately, there are only 12 months of data for the 5 block schedule. It is also interesting to note that the price for consuming in the highest block both increased and decreased during the study period.

The "CAP Surcharge" is applied to households using more than 45 kgals of water in a billing cycle, and the proceeds are earmarked for the purpose of recovering costs related to the use of Central Arizona Project (CAP) water which is conveyed to the Phoenix Metropolitan area from the Colorado River. Because the stated billing schedule is divided into blocks at 25 and 80 kgals, this surcharge effectively adds an additional block to the rate schedule, and the surcharge ranges from about $0.08 to $0.24 per kgal. There is also a "High Block Usage Surcharge" which applies to the households using more than 80 kgals of water, and is earmarked for construction of fire flow projects. This effectively functions as an increase in the marginal cost of the highest block ($2.15 in 2006-2007, and $1.00 in 2008-2009), but it is not documented as such on the rate schedule, and is in fact billed as a separate line item. Although billed distinctly from the normal water usage, it represents a significant increase in marginal price.

There is also a separate "Public Safety Fire Flow Project Surcharge" which served the same purpose as the "High Block Usage Surcharge", but spread a lower price increase over more households. While the "High Block Usage Surcharge" added $2.15 for users exceeding 80 kgals, this surcharge was $1.00 for users exceeding 25 kgals, and this surcharge was phased out at the same time as the "High Block Usage Surcharge" was reduced to $1.00. The final surcharge faced by Paradise Valley users is the "Arsenic Recovery Surcharge". When the EPA mandated that all water utilities take steps to reduce arsenic levels in the water supply, the Arizona Corporation Commission allowed water companies to pass the cost of construction and operation of new arsenic treatment facilities to consumers through a surcharge until their next rate case when the cost could be bundled into the standard rates. This came in the form of an additional fixed charge each month, and an increase in price at all levels of consumption, ranging from $0.45 to $0.53 per kgal over the sample period.

In order to effectively present all of the rate and surcharge changes in the Paradise Valley water district, fixed levels of water usage were selected and the marginal price at each level is charted over the study period in Figure 4.5. The levels were selected to correspond with the various tiers in 2005, with 25 kgals being the first tier, 45 kgals being the second tier without the CAP surcharge, 80 kgals being the second tier with the CAP surcharge, and over 80 kgals being the third tier. This masks *some* of the effects of the December 2009 change in the breaking points, but the graph does present the complexity of the rate schedule along with the frequency and

Figure 4.5: Paradise Valley Rate Schedule by Levels



magnitude of changes for users at different levels.

The Sun City rate schedule is another simple one, with one change in prices and no surcharges as shown in Figure 4.6. Once again there is a change in the block rate structure, with the breaking point for the second tier moving down from 4 kgals to 3 kgals.

Sun City West, shown in Figure 4.7, faced the introduction of an "Arsenic Recovery Surcharge" which increased prices at all levels of usage by approximately $0.50 per kgal in December of 2006, and then a dramatic increase in prices in December of 2009. The prices more than doubled from their starting levels, and were about 70% higher than the rates after the introduction of the surcharge.

In order to account for inflation, all price variables are adjusted for inflation according to the Bureau of Labor Statistics CPI for Phoenix. Because the Phoenix area CPI is only available on a biannual basis, monthly values are interpolated

Figure 4.6: Sun City Rate Schedule

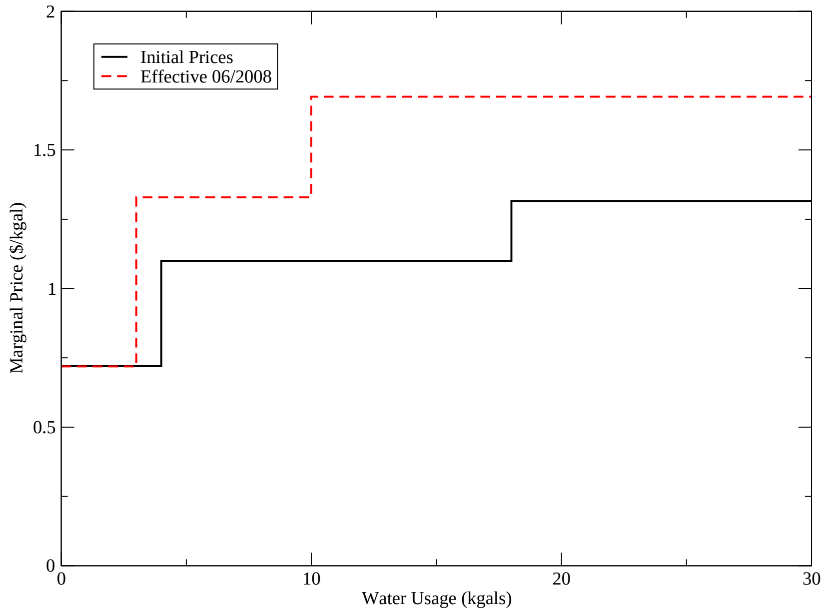
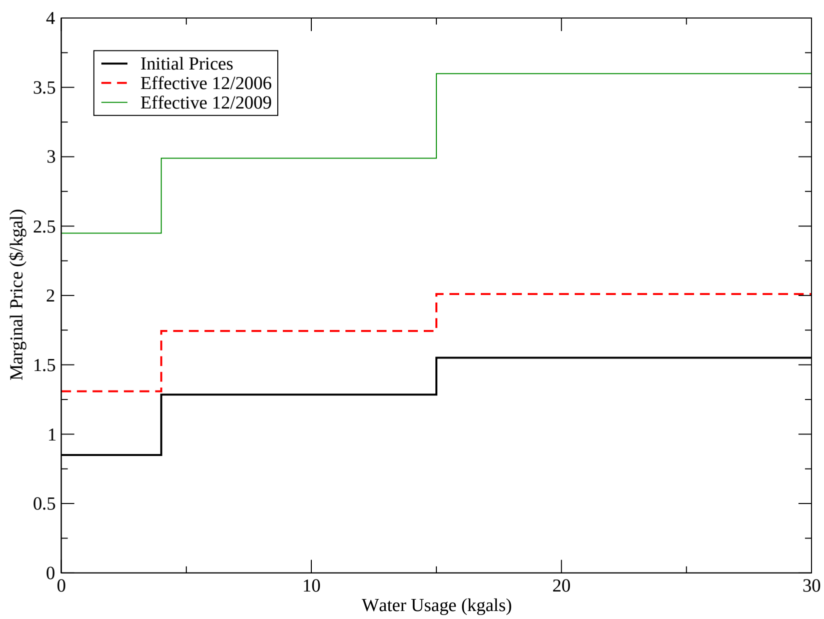


Figure 4.7: Sun City West Rate Schedule



in a linear fashion. The month in which the bill period closed is matched with the interpolated CPI for the calculation or real prices and the real property value. Unsurprisingly, due to the recession the sample period had relatively low inflation, as the CPI[3] increased from 107.3 to 120.8 over the six years, or roughly 2% annually.

4.3 Other Data

Household level data are best for estimating water demand at the household level, so data for residential and vacant properties[4] were collected from the Maricopa County Assessor's Office for the 2011 tax year. In estimating how much water a household will use, characteristics such as the size of the lawn, and the size of the pool are naturally quite strong determinants of water usage. Furthermore, the assessed value of the property was collected for use as a proxy for income/wealth, and adjusted for inflation (but not changes in the housing market) by the Phoenix CPI in the same way as prices. Construction year of the home is included for all communities except Paradise Valley, and the age of the home is calculated as $2010 - ConstructionYear$. Age is held constant over the sample period because the effect is expected to be a result of technology available at the time of construction, rather than an actual effect of aging.

It is worthwhile to note that before computing the total number of addresses and attempting to match, there was trimming, since the set of bills included "addresses" which represented drinking fountains, fire hydrants, clubhouses, and other non-household uses. These non-household water bills were removed. Then the addresses were corrected for minor issues such as misspellings, different abbreviations

[3] The base of 100 is defined as December 2001.

[4] Vacancy as defined by the Assessor's office. A residence recorded as vacant in 2011 may have been in use during the sample period.

(for example: Trail, Trl, Tr), and inconsistent cardinal direction identifiers. Due to discrepancies in the form of addresses between the water bills and Assessor's data, some addresses were not matched uniquely and were therefore removed from the study. Some addresses could not be matched at all, while others produced multiple records. These criteria result in many apartments, condominiums, and townhomes being removed from consideration, since unit numbers created difficulties in matching. For instance, an apartment complex where the management agency was responsible for property taxes but water was metered by individual units would result in no matches. Similarly, a condominium complex with individual owners paying the property tax and a shared water meter paid out of HOA fees would result in many matches, so the one billing address is associated with many different household characteristics. The match rate for each water district is included in Table 4.1.

Once the data is matched, the addresses were removed by an employee of EPCOR Water, and a unique numerical identifier is given in its place to ensure the privacy of the homeowners. Furthermore, to guarantee that each household has enough observations for meaningful panel model estimation, all households with under 62 months of bills are trimmed. Because of how recent the construction in Anthem is, only 78% of matched households reach this criterion. Over 85% of households meet this criterion in the other three communities. All of the following statistics and analyses are based on the matched and trimmed data.

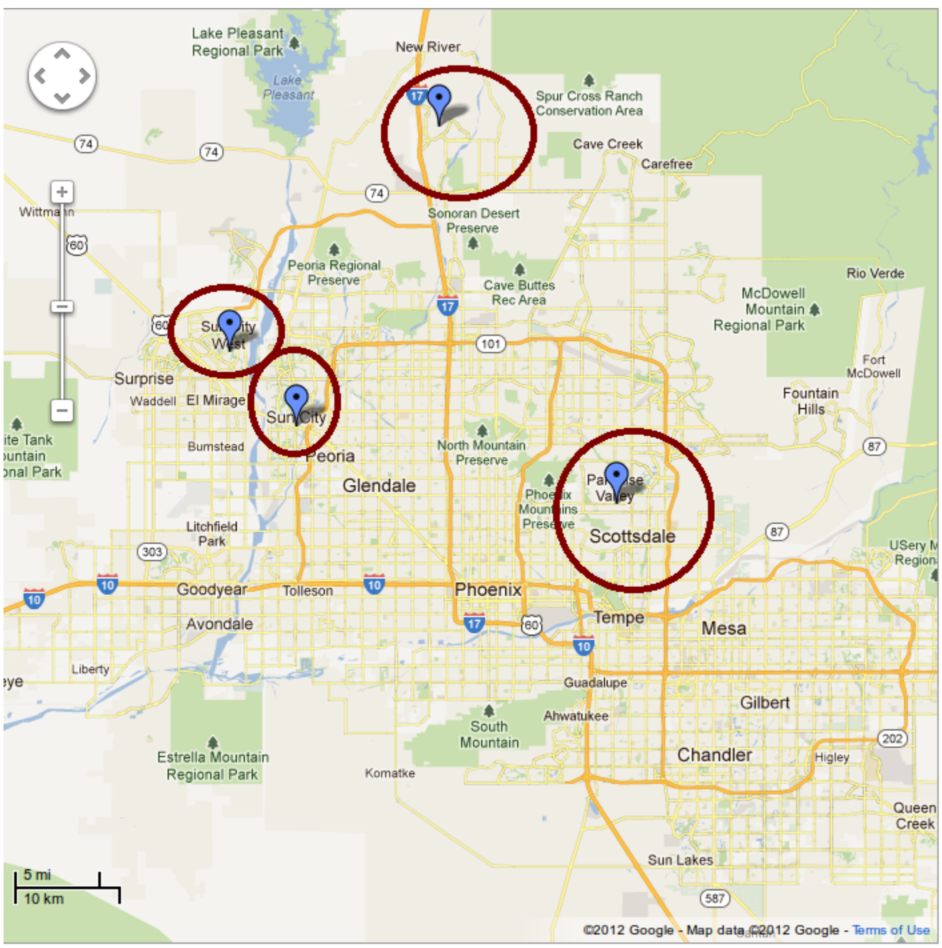
Yard size is the only calculated variable among the property characteristics, and is calculated as $YardSize = LotSize - PoolSize$. Home size was not subtracted from lot size because this caused the estimated yard size to become negative in many cases, most likely because of the popularity of multistory homes in Phoenix.

Anthem is a Del Webb planned community which opened in 1998. Since then,

Table 4.1: Water Bill to County Assessor Address Matching Success Rate

	Total Addresses	Uniquely Matched	Percent
Anthem	8,884	7,999	90.0%
Paradise Valley	4,837	3,346	69.2%
Sun City	23,173	19,329	83.4%
Sun City West	15,124	13,951	92.2%

Figure 4.8: Phoenix Metropolitan Area with Sample Communites Highlighted



home construction continued and the community grew to a population of 21,700 at the time of the 2010 Census. The focus on neighborhood parks and recreation centers made it popular with young families willing to live on the outskirts of the metropolitan area. Of particular import to this study, the HOA requires all landscaping be native or near-native plants in order to conserve water and to preserve the flora and fauna of the neighboring Sonoran desert. The pool ownership rate in the sample homes is 34.9%.

Table 4.2: Anthem Household Statistics
(N = 6268)

	Mean	Min	Q1	Median	Q3	Max
Assessed Value ($)	182,637	95,300	133,500	164,600	208,600	521,100
Living Area (sq ft)	2,373	1,000	1,810	2,168	2,915	5,209
Yard Size (sq ft)	8,250	3,910	5,843	7,434	9,863	34,918
Pool Size (sq ft)	465	11	377	450	541	1,260
Construction Year	2002	1994	2000	2002	2004	2005

Pool Size statistics exclude homes without pools.

The Paradise Valley water district includes the town of Paradise Valley and parts of Scottsdale, both of which are renowned for their luxurious lifestyle. There are numerous country clubs, resorts, and upscale shopping centers. The region is close to downtown Phoenix and is home to some of the world's wealthiest individuals. Many of the homes can best be described as mansions, built onto the rise of hills and mountains, with large lots, lush landscaping, and extravagant pools and fountains. Accordingly, the water prices and water usage in this district far exceed those in the other study districts (see Figure 4.1). Most homes are not as new as in Anthem or Sun City West[5], but many have been renovated. For many residents, money is no

[5] Construction year is not available in the dataset with usage because the variable was not kept

issue. Thus the environmentally-concerned may minimize water usage by upgrading to the latest appliances, installing desert landscaping with drip systems, and even harvesting rainwater. On the other hand, those who are not concerned for the environment may choose to use water indiscriminately. The pool ownership rate in the sample homes is 60.3%.

Table 4.3: Paradise Valley Household Statistics
(N = 2817)

	Mean	Min	Q1	Median	Q3	Max
Assessed Value ($)	759,018	68,000	277,000	656,500	977,300	10,903,500
Living Area (sq. ft)	3,404	899	2,183	2,967	4,214	15,094
Yard Size (sq. ft)	30,887	22	6,954	35,254	45,212	309,350
Pool Size (sq. ft)	555	100	450	512	648	2,500
Construction Year	1977	1931	1967	1977	1984	2005

Pool Size statistics exclude homes without pools.

Sun City is also an unincorporated town, founded in the 1960s as a Del Webb retirement community. This is important to note because households living on a fixed income and choosing to retire in one of these relatively inexpensive and longstanding homes are more likely to be conscious of their expenditures on water. On the other hand, retired individuals are likely to spend more time in their home, and may even garden. The pool ownership rate in the sample homes is 6.2%.

Sun City West was started in the late 1970's by Del Webb to accommodate the demand for retirement housing as the original Sun City was nearing capacity. It is located right next to Sun City, and has similar demographic characteristics. The pool ownership rate in the sample homes is 5.2%.

at the time the data was scrubbed of identifying addresses. However, the construction years were taken from the original datasets matched with the Assessor's data.

Table 4.4: Sun City Household Statistics
(N = 16931)

	Mean	Min	Q1	Median	Q3	Max
Assessed Value ($)	104,887	25,047	85,500	102,100	120,800	602,700
Living Area (sq. ft)	1,544	388	1,236	1,536	1,827	4,382
Yard Size (sq. ft)	9003	268	7500	8720	9773	102446
Pool Size (sq. ft)	424	111	364	418	450	960
Construction Year	1974	1954	1968	1972	1978	2009

Pool Size statistics exclude homes without pools.

Table 4.5: Sun City West Household Statistics
(N = 13282)

Full Panel	Mean	Min	Q1	Median	Q3	Max
Assessed Value ($)	154,616	74,200	123,500	146,500	174,700	393,100
Living Area (sq. ft)	1,787	918	1,497	1,741	2,020	4,301
Yard Size (sq. ft)	9,615	234	8,700	9,300	10,400	28,500
Pool Size (sq. ft)	440	150	390	426	480	800
Construction Year	1988	1911	1983	1989	1994	2003

Pool Size statistics exclude homes without pools.

In order to include demographic data in the demand model, the addresses were run through the geocoding algorithm provided by the University of Southern California GIS website[6] which matched addresses with their Census block, block group, and tract for the year 2000 U.S. Census. The Census Bureau conversion file was used to determine to which 2010 U.S. Census block the household belonged. In some cases, the conversion file indicated that some blocks from the 2000 Census had been further subdivided for the 2010 Census, so the statistics were averaged when joining back to the 2000 Census block designations.

From the 2010 U.S. Census age distribution and household size were collected. Educational attainment was obtained from the U.S. Census American Community Survey at the five year aggregation. Unfortunately due to issues with the geocoding, only Sun City and Paradise Valley could be properly matched to the Census data. The issue in Anthem is obvious; the most of the homes were not even built in 2000, so the geocoding software is unable to match the address to a year 2000 Census block.

Census blocks, roughly equivalent to city blocks in urban areas, provide an approximation of the actual household demographic characteristics. However, because blocks are small, the homogeneity of small neighborhoods does lend some credence to the use of these variables, and there is actually a surprisingly large variance in the demographic variables (see Tables 4.6 and 4.7). Naturally it would be preferable if the data included the exact household size, ages, and educational attainment of the residents at each billing address, but such data are not available. Therefore, in place of residence-specific values, the calculated average for that Census block is used for each house within that block.

[6]Goldberg DW, Wilson JP. 2012. USC WebGIS Services.
Available online at https://webgis.usc.edu.

Table 4.6: Paradise Valley Demographics
(101 blocks)

	Mean	Min	Q1	Median	Q3	Max
% Under 5 Years	2.7	0.0	0.0	1.9	4.5	11.8
% 5–9 Years	4.9	0.0	0.0	4.2	7.7	29.0
% 10–14 Years	6.5	0.0	2.0	6.3	9.2	23.8
% 15–17 Years	4.4	0.0	0.0	4.2	7.0	14.3
% Under 18	18.4	0.0	11.1	18.4	24.8	42.9
% Over 55	48.1	0.0	33.3	45.3	61.5	100.0
Household Size	2.5	1.5	2.2	2.4	2.9	3.9
% Hispanic	4.5	0.0	0.0	1.7	6.3	31.6
% Bachelor's Degree	36.1	28.5	32.7	33.8	39.1	39.1
% Grad/Professional Degree	32.9	21.2	32.3	32.3	36.2	36.2

For Paradise Valley, only the percentage of the population claiming Hispanic ethnicity shows low variability. The individual age brackets for children show about as much variance as one could hope for in such tight ranges of ages. Sun City on the other hand has almost no variance in the age-related variables, which is to be expected based on the minimum age requirement in most areas of the city. Because the individual age brackets for children are so sparse, the regression analysis uses only the "Under 18" category to account for children.

Weather data are collected from the Arizona Meteorological Network (AZMET) and Maricopa County Flood Control District (FCD). Potential evapotranspiration (ETo), which represents the amount of water lost to the atmosphere through soil evaporation and plant transpiration for a cool season grass 3-6" in height (Brown, 2005), is included in the place of temperature and humidity because the theoretical effect of temperature and humidity on water consumption comes from evaporation of standing water (fountains, pools, etc.) and need for increased watering of plants. Both of these effects are more accurately measured through ETo. AZMET measures

Table 4.7: Sun City Demographics
(485 blocks)

	Mean	Min	Q1	Median	Q3	Max
% Under 5 Years	0.2	0.0	0.0	0.0	0.0	22.2
% 5–9 Years	0.1	0.0	0.0	0.0	0.0	16.3
% 10–14 Years	0.1	0.0	0.0	0.0	0.0	9.1
% 15–17 Years	0.1	0.0	0.0	0.0	0.0	4.0
% Under 18	0.6	0.0	0.0	0.0	0.0	30.2
% Over 55	91.7	7.0	90.0	93.4	96.0	100.0
Household Size	1.7	1.1	1.6	1.7	1.8	2.9
% Hispanic	2.7	0.0	0.0	1.4	3.9	50.0
% Bachelor's Degree	13.1	8.6	10.0	10.8	16.9	20.7
% Grad/Professional Degree	7.5	3.0	4.8	8.2	9.6	10.6

of ETo come from two different but closely related methodologies, a comparison of which is included in Figure 4.9. The "Original AZMET ETo" is calculated using a modification of the Penman equation (Brown, 2005), along with the more traditional Penman-Monteith ETo. AZMET also gathers daily rainfall totals; however the AZMET stations are on average less reliable for rainfall totals and more distant from the study residences than the FCD stations. Therefore the daily rainfall totals and number of days with rainfall at or exceeding 0.10 inches were collected from the FCD stations. Maidment and Miaou (1985, 1986) use 0.05 inches as the minimum to constitute a rainy day, and Miaou (1990) uses 0.01 inches of rainfall as the cutoff, however since Arizonans are likely to consider such a "drizzling" to be inconsequential for the lawn, a higher cutoff has been chosen.

FCD data from Anthem were compiled by combining the measurements of three stations by a preference ranking method. The Skunk Tank Wash weather station, which is the closest to the sample residences, was not operational until March 2, 2006, so rainfall data for months prior were collected from Sunup Ranch and New

River Landfill. Furthermore, any missing observations are filled in using the same preference rankings. Sun City, Sun City West, and Paradise Valley each had a single centrally located FCD station.

All weather data are collected on a daily basis, and in order to account for the varying starting dates and lengths of billing cycles, the total ETo, rainfall, and rainy days are calculated for the dates relevant to that bill.

Figure 4.9: Comparison of ETo Calculation Methodologies
(Shared Sun City/Sun City West Station)

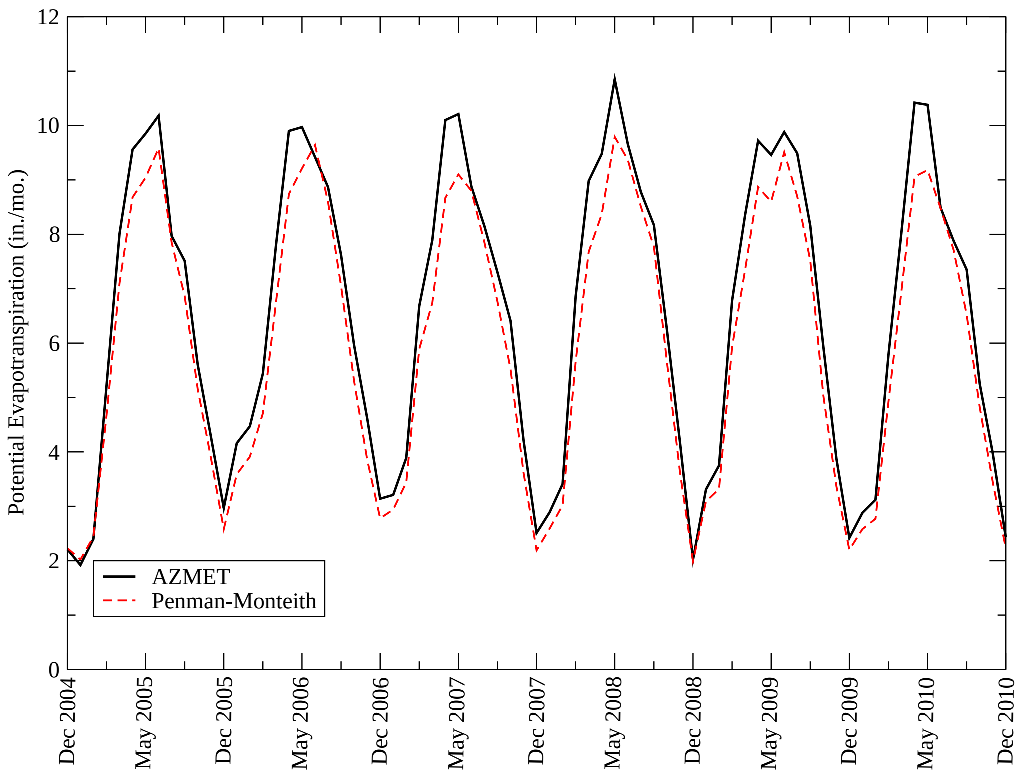


Table 4.8: Summary of Variables

Variable	**Source**	**Time Varying?**	**Cross Section Varying?**	**Expected Sign**
Usage	EPCOR	Y	Y	
Real Price	EPCOR	Y	N	-
Real Home Value	Assessor	Y	Y	+
Yard Size	Assessor	N	Y	+
Pool Size	Assessor	N	Y	+
Evapotranspiration	AZMET	Y	Y*	+
Rainfall	FCD	Y	Y*	-
% Under 18	Census	N	Y	+
% Over 55	Census	N	Y	+/-
% Hispanic	Census	N	Y	-
Household Size	Census	N	Y	+
% Bachelor's Degree	ACS	N	Y	+/-
% Grad/Professional Degree	ACS	N	Y	+/-

* - Weather variables vary over the cross sections because of the asynchronous billing periods.

CHAPTER 5

Estimation and Results

5.1 Univariate Analysis

Although water usage is dependent on a number of variables, a univariate analysis of usage can still be informative. As used in Pint (1999), a table of the percentage of users in each tier demonstrates trends over time. The distribution of households across these tiers is also important for understanding how users will be affected by future rate changes.

Anthem has two distinct rate schedules depending on the diameter of the pipe from the meter to the house (referred to as meter size), with the larger meter having a much broader second tier. Thus the univariate analysis needs to take this distinction into account. Based on the percentages in Tables 5.1 and 5.2, it appears that the rate change and the movement of the breakpoint have not induced consumers to reduce usage. However, the third tier breakpoint for 3/4" meters moved from 18 kgal to 10 kgal, which explains the increase of the percentage of households in the third tier after 2008. Looking more closely at the distribution of usage in Table 5.3, since 2008 the percentages for both the 10-18 and over 18 groups have declined. The percentage

Table 5.1: Anthem Tier Distribution by Price Schedule

	3/4" Meter				1" Meter		
	Tier 1	Tier 2	Tier 3		Tier 1	Tier 2	Tier 3
Prior to 06/04/2008	20.3	69.1	10.6		22.0	75.8	2.2
After 06/04/2008	20.9	44.4	34.7		20.5	78.3	1.2

Table 5.2: Anthem Tier Distribution by Year

	3/4" Meter				1" Meter		
	Tier 1	Tier 2	Tier 3		Tier 1	Tier 2	Tier 3
2005	22.7	67.4	9.9		25.7	72.2	2.1
2006	16.6	71.9	11.6		19.1	78.7	2.3
2007	21.0	66.5	12.5		21.0	76.3	2.7
2008	19.3	54.6	26.1		20.0	78.5	1.5
2009	21.1	45.3	33.6		20.5	78.4	1.1
2010	23.0	45.5	31.5		21.9	77.2	0.9

of households in the 5-10 kgal block seems relatively constant after 2008, but it is evident that some households dropped into the first tier while third tier households moved down to take their place. It is not a strong elastic response, but there is evidence of the expected negative price elasticity. Even though the rates only change once, there seems to be a gradual response over time, the economic explanation for which lies in the difference between short-run and long-run elasticity. As more and more households gain knowledge of the past rate change and impending rate changes[1], residents are more likely to change their stock of water using appliances or to alter their landscaping.

Because the second tier for households with 1" meters covers all usage between 5 and 40 (46 after 2008) kgals, the distribution is not as sensitive to changes. A table similar to Table 5.3 was generated for 1" meters, but provides no additional insight over Table 5.2. With that caveat, it does appear that consumption in the third tier has trended downward since the rate change in 2008. It also bears noting that the first tiers for the two meter sizes are the same, and seem to have the same share of households. This implies that the meter size is not selected by households based on

[1]There was a significant increase in rates on Jan. 1, 2011 just after the sample period ended. This increase was highly publicized and even led to public protests against the water utility, and a lawsuit against Del Webb and Pulte Homes.

Table 5.3: Anthem Usage Distribution (in kgals) by Year for 3/4" Meters

	≤ 4	5-10	10-18	> 18
2005	22.7	43.6	23.8	9.9
2006	16.6	44.5	27.4	11.6
2007	21.0	40.2	26.3	12.5
2008	19.3	44.8	25.4	10.5
2009	21.1	45.3	24.3	9.4
2010	23.0	45.5	22.8	8.7

their usage intentions, so regression results should not be affected by self-selection bias.

For Paradise Valley, the complexity of the rate schedule and the numerous changes made to the schedule during the sample period make univariate analysis tricky. In order to represent the rate schedule with the block rate CAP surcharge, the decimal point was added to Tier 2: Tier 2 is for households in the second tier that do not pay the CAP surcharge, and Tier 2.1 is for households that do pay the surcharge. Also, many of the rate changes in Paradise Valley were just surcharge changes of inconsequential magnitude (less than $0.11 per kgal), so these changes are not considered in dividing the different pricing periods. Looking exclusively at the period with 3 blocks in Table 5.4, the changes in the rate schedule do not appear

Table 5.4: Paradise Valley Tier Distribution - 3 Block Period

	Tier 1	Tier 2	Tier 2.1	Tier 3
Time 1: Before 08/2006	57.6	15.9	13.5	13.0
Time 2: 08/2006 to 02/2007	56.8	15.4	14.0	13.8
Time 3: 03/2007 to 09/2007	53.1	16.5	14.8	15.6
Time 4: 10/2007 to 08/2008	58.0	16.4	13.5	12.1
Time 5: 09/2008 to 11/2009	56.6	15.8	14.3	13.4

Table 5.5: Paradise Valley Usage Distribution (in kgals) by Year

	≤ 5	6-15	16-25	26-45	46-80	> 80
2005	17.6	25.9	14.3	15.5	13.1	13.6
2006	17.9	23.7	13.9	15.9	14.7	14.1
2007	18.0	23.9	13.8	16.3	14.3	13.7
2008	17.7	25.4	14.6	16.5	13.6	12.2
2009	17.9	25.1	14.7	15.7	14.1	12.5
2010	18.9	26.4	13.9	15.5	13.3	12.0

to cause much movement between blocks. The increase in upper block percentages during Time 3 is a result of that period spanning March through September, and the increase in the percentages is likely to be explained by weather effects. Time 4 encompasses the highest rates in this sample, and covering October through the following September, does run the full course of the seasons. During this period there may have been a shift down into lower tiers, but it does not appear significantly different than Time 1. It appears that if demand is elastic at all, it is close to 0.

Examining the changes in usage levels over time in Table 5.5, the rate changes in 2007 do appear to have pushed some users out of the highest usage levels. However, there is something odd about this, as the rates were at their absolute highest during 2007, and decreased thereafter. There has been a general downward trend in usage across all Arizona communities covered by EPCOR Water, so the changes may be unrelated to price. But it may also be a price response, and consumers may have changed landscaping or appliances during the period of high prices and not reverted to prior usage levels after the rate reduction. Another possible explanation is that consumers are responding to the variability of water rates, and fearing future increases, choose to change to more efficient landscape and appliances. Yet this raises the question as to why usage did *not* increase when the rates went back

Table 5.6: Sun City Tier Distribution

	Tier 1	Tier 2	Tier 3
Before 06/2008	28.2	66.6	5.2
After 06/2008	21.5	57.3	21.2

down. The most logical explanation is that, given a set of appliances and landscaping, the households are exhibiting satiation. For instance, a household which has replaced a top-loading washing machine with a side-loading model is not going to respond to the decreased rate by buying a new top-loading model, nor would the household choose to do additional laundry. Because water is a derived demand, when a household changes the amount of water required by its water-using stock, it continues to use that stock in the same manner as before. Whatever the cause, it seems that customers in the top tiers are reducing their usage subsequent to the big rate increase, and persist in using less even after rates return to lower levels.

There also appears to be some movement in the lower tiers. After the change over to a 5 tier rate schedule in December 2009, in which the former first tier of 0-25 kgals was broken into 0-5, 6-16, and 17-40 kgal blocks, households consuming on the edge of these new blocks do give some evidence of scaling down usage to align with the new rate structure, as each of the two lowest blocks have at least 1 percent more households in 2010 than in 2009.

Sun City provides a particularly interesting case because it faced a change in rate schedule which significantly altered the form of the tiers, as shown in Figure 4.6. If consumers respond to marginal price, then one would expect an overall shift into lower tiers as the increase in marginal price happens at a lower usage. However, this shift will lead some households to consume in the same tier, simply at reduced

Table 5.7: Sun City Tier Distribution By Year

	Tier 1	Tier 2	Tier 3
2005	30.2	64.5	5.3
2006	26.1	68.5	5.4
2007	27.5	66.9	5.7
2008	23.7	60.2	16.1
2009	20.5	57.9	21.6
2010	23.8	57.8	18.5

usage, whether by virtue of increasing marginal price, increasing average price, or decreasing the implicit subsidy. If price elasticity is very low, then the percentage in the top tier should increase dramatically, while the percentage in the first and second tiers decrease by virtue of their reduced ranges.

It is evident from Table 5.6 that consumers are not *dramatically* altering their habits in the wake of the change in the rate schedule. A small portion of users in Tier 1 moved into Tier 2, while a sizable number began to consume in Tier 3, as though the movement of the breakpoints resulted in very little change in consumption. A closer look at Table 5.7 seems to support that conclusion[2], but a different story is told by the pattern shown in Table 5.8. This breakdown seems to show households previously consuming over 18 kgals in the third tier reducing consumption after the rate change in 2008, with the biggest change coming in 2010, a year and a half after the price increase. Usage goes down across all the higher levels, with more and more consuming less than 5 kgals. The breakpoint for Tier 2 also changed from 4 kgals to 3 kgals, however analysis at that level has not been performed because the variability in consumption or "household error" would render the percentage consuming exactly 4 kgal a useless or misleading statistic. In con-

[2]Since the rates changed on June 1, 2008, the percentages for that year are a weighted average for usage across the two rate schedules.

Table 5.8: Sun City Usage Distribution (in kgals) by Year

	< 5	5-10	11-18	> 18
2005	30.2	47.5	17.0	5.3
2006	26.1	49.4	19.1	5.4
2007	27.5	48.6	18.3	5.7
2008	28.9	48.4	17.7	5.0
2009	30.4	48.0	17.0	4.6
2010	34.5	47.0	14.7	3.8

clusion, combined with the price change, moving the breakpoints does appear to change consumption patterns, but that change is both small in magnitude and slow in taking effect.

Sun City West strictly had price increases with the breakpoints remaining in the same place. Based on Table 5.9 it appears that the first rate increase did cause some households in the third tier to reduce consumption to second tier levels, while the lower tiers do not appear to have reacted. The second rate change however, appears to have motivated users from the second tier to reduce consumption to first tier levels, as even more households leave the third tier. Looking at year by year changes in Table 5.10, it is apparent that there has been a steady reduction in households in the third tier, while the first and second tier each gain a higher share of households. This is consistent with the evidence in Figure 4.2, where the average usage in Sun City West is steadily decreasing over time. The unexplained anomaly in 2005, evident in that figure, is also the probable cause for the trend-defying percentages in Tiers 1 and 2 for 2005

Table 5.9: Sun City West Tier Distribution By Rate Schedule

	Tier 1	Tier 2	Tier 3
Before 12/01/2006	37.8	56.4	5.8
12/01/2006 to 12/01/2009	38.0	57.7	4.3
After 12/01/2009	43.2	53.5	3.4

Table 5.10: Sun City West Tier Distribution By Year

	Tier 1	Tier 2	Tier 3
2005	42.2	51.6	6.2
2006	32.8	62.0	5.3
2007	36.4	58.8	4.7
2008	38.0	57.9	4.1
2009	40.1	56.0	3.9
2010	43.8	52.9	3.3

5.2 Multivariate Analysis

Although the results in the preceding section are of some use and some interest, the omission of weather effects, inflation and income effects, and property characteristics suggest that drawing conclusions from the univariate analysis may be misleading. Therefore, multivariate analysis is employed to find more robust estimates of the demand function parameters. Because of the panel nature of the data, Ordinary Least Squares estimators are not expected to give the best results. Each household is likely to behave differently, but each household-month observation is not independent, since a household is likely to exhibit similar behavior through time. Econometrically this is represented by a combination of error terms,

$$y_{it} = \beta x_{it} + u_i + \epsilon_{it} \qquad i = 1, \ldots, n; \quad t = 1, \ldots, T$$

where i is the household identifier, t is the billing month, u_i represents a household specific, time-invariant error term, and ϵ_{it} is the observation error term. There are several econometric methods to properly estimate β by taking separate account of such an error term. Random effects, which assumes that u_i is randomly distributed and separates out this effect, is chosen for the primary analysis. Fixed effects is not an appealing choice because it does not allow for prediction out of sample, and it does not allow for the inclusion of time-invariant variables such as demographics and the income proxy. Nevertheless, fixed effects estimates are presented for comparison purposes.

The dependent variable is water usage in kgals, normalized to what that usage would be in 30 day billing period, following Nieswiadomy and Molina (1991) and Nieswiadomy (1992).

$$NormUse = \frac{Usage}{BillingDays} \times 30$$

Hewitt and Hanemann (1995) are correct in arguing that normalization is not employed by the water utility, and therefore the length of the billing period can play a role in determining in which block the consumer ends up. However, Hewitt and Hanemann's assumption that number of billing days can be included as a separate explanatory variable ignores the effect of property characteristics and user preferences. For instance, adding 5 days to the billing period would change usage differently for a two person home with a small yard than for a family of five with a big yard and a pool. Therefore, the models focus on daily effects extrapolated to a 30 day billing period for ease of interpretation.

Various price specifications of average price (AP) and marginal price (MP) were estimated, both in independent models and by means of Opaluch (1982) and Shin (1985). Consistent with Charney and Woodard (1984), all AP values are lagged one month. A Shin test with lagged average price was used in (Nieswiadomy and Molina, 1991), however, no previous use of the Opaluch test has included lagged average price.

For consistency, weather variables are similarly normalized to a 30 day billing period. Potential evapotranspiration is interacted with the surface area of the pool and the yard, because the effect of evapotranspiration an any home's water usage depends on how much water and foliage is present for evaporation and transpiration. A pool is likely to be too small for evaporation to be measured by ETo, but the appropriate measure of evaporation[3] would be $\frac{10}{7}ETo$. Since scaling the ETo would simply change the $\hat{\beta}$ by a factor of $\frac{10}{7}$, the transformation is unnecessary. Furthermore, leaving it unscaled allows for testing the difference between yard and pool effects.

The effect of quantity versus occurrence of rainfall is tested, as this has not previously been done in the economic literature. Only Maidment and Miaou (1985, 1986) and Miaou (1990) test the manner in which rainfall influences water usage, but they were primarily concerned with load forecasting. Furthermore, only Miaou (1990) considered monthly usage, while Maidment and Miaou (1985, 1986) only examined daily water usage.

Demographic effects are explored, but because demographic data could only be matched in two out of the four sample communities, the demographic-inclusive models are compared with models excluding demographics in order to test if omitted variable bias affects estimation results for the other communities.

[3]http://ag.arizona.edu/azmet/etpan.htm

5.2.1 Tests of Price Response

One issue that needs to be resolved when using average price is what to do when a month with zero usage is encountered. Most of the literature uses aggregate data where zeros are not a problem, or use the Taylor-Nordin specification with marginal price. Since nothing was to be found in the literature regarding the average price when usage is zero, a rule is developed for this thesis. Since lagged average price is being used to measure the consumer's perception of price, it seems reasonable to assume that a household using less than 1,000 gallons is not actually be responding to the price of water at all. Zero usage is indicative that the home was vacant for a majority of the month, and without automated irrigation. So, when the household is once again occupied and usage resumes, the lagged average price is assumed to be zero. After the next bill comes for positive usage, the household is assumed to adjust its usage downwards based on price. Models have been run with 0 usage months removed, and with various other defined prices when usage is zero, and unfortunately, the price elasticity estimates are sensitive to these changes. Nevertheless, zero is a valid usage choice for a household, so the observations are retained in the data set with average price assumed to be zero.

It is also important to remember that, with a fixed service charge grater than the marginal price at all levels, the average price is monotonically decreasing, asymptotically approaching the marginal price of the highest block. Therefore consumers with low usage may actually perceive the price of water to be very high, and may choose not to increase usage. If consumers knew the price, they would be more willing to increase usage. This is, no doubt, what Carter and Milon (2005) meant when they determined that the "treatment" of informing a household of its marginal rate increased usage.

Table 5.11: Opaluch Price Perception Test Results

	Anthem	Paradise Valley	Sun City	Sun City West
$MP_{i,t}$	4.35	19.97	9.80	1.65
$AP_{i,t-1} - MP_{i,t}$	-0.37	-0.85	-0.53	-0.49

All variables significant at 99.9% level.

The test of price response in linear demand function estimates as proposed in Opaluch (1982) and rephrased in Griffin and Chang (1990) calls for the estimation of

$$Q = \beta_0 + \beta_1 MP_{i,t} + \beta_2(AP_{i,t-1} - MP_{i,t}) + \cdots + \epsilon_{i,t}$$

with hypothesis testing on the coefficients. Ignoring the hypothesis test results which conclude that consumers respond to both prices or do not respond to price at all; if $\beta_2 = 0$ cannot be rejected, then the consumers respond to marginal price, and if $\beta_1 = \beta_2$ cannot be rejected, then the consumers respond to average price.

The results for the price coefficients are shown in Table 5.11. While property characteristics, weather variables, and demographics were included in the model, these results are not shown here. Since all of the coefficients are significant at the 99.9% level, $\beta_2 = 0$ can be rejected, so consumers are not responding to marginal price alone. However, since the coefficients on $MP_{i,t}$ are all positive and significant, while the coefficients on $AP_{i,t-1} - MP_{i,t}$ are negative and significant, $\beta_1 = \beta_2$ can be rejected, so consumers are not responding to marginal price alone. Therefore the Opaluch test does not help in determining which price to use in subsequent models.

Because the datasets have numerous zeros for both dependent and independent variables, the double log required for Shin's test necessitates either adjustment or dropping many observations. For this reason, 0 values were replaced with 0.001 for

Table 5.12: Shin Price Perception Test Results

	Anthem	Paradise Valley	Sun City	Sun City West
$MP_{i,t}$	2.03	1.60	3.02	0.76
$AP_{i,t-1}/MP_{i,t}$	0.22	0.48	0.33	0.29
k	0.11	0.30	0.11	0.38

All variables significant at 99.9% level.

conversion to the logarithmic scale. Results have been compared to a model which dropped zeros entirely, and the results are quite similar, so this replacement does not appear to bias the results.

The Shin (1985) price perception parameter (k in the term $MP_{i,t}(\frac{AP_{i,t-1}}{MP_{i,t}})^k$) can be estimated by regressing

$$ln(Usage) = \beta_1 ln(MP) + \beta_2 ln\left(\frac{AP}{MP}\right) + \ldots$$

and computing $k = \frac{\beta_2}{\beta_1}$. If $k = 1$, then the consumers respond to average price, and if $k = 0$ then the consumers respond to marginal price.

The results in Table 5.12 appear to indicate that consumers are more responsive to marginal price, although the coefficients are statistically different from 0 as determined by the Delta method. Furthermore, this is deceptive since all the coefficients on $MP_{i,t}$ have an unexpectedly positive and significant sign. Returning to the results in Table 5.11, the marginal price coefficients are positive there as well. This is the result of the simultaneity involved in the usage/price decision for the consumer. Although the literature does suggest that bias will result from this simultaneity, most previous studies did obtain negative coefficients as expected (with the exceptions of Hewitt and Hanemann, 1995; Ito, 2010). Even the IV and 2SLS models estimated in Hewitt and Hanemann (1995) have positive price coefficients, demonstrating the difficulty of removing this simultaneity, and the discrete/continuous choice model used by Hewitt and Hanemann is not feasible with the large datasets used for this thesis. This positive and significant marginal price effect is confirmed in models using the original Taylor-Nordin specification for all communities, and is even present when restricting the analysis to households within a single block.

The Opaluch test does not give any clues as to which price consumers respond to, and the Shin test shows a spurious preference for marginal price. Based on the result of Hewitt and Hanemann (1995), even the application of IV or 2SLS methods may not resolve the issue. Indeed, General Method of Moments models run with instrumental variables applied to the marginal price and rate structure premium model still had positive estimates. Furthermore, as stated in Section 3.1, over 90% of households do not know the marginal price. Since the literature where price specification is tested most frequently finds that consumers respond to average price, and the signs on the average price coefficient are negative for this data, lagged average price is the chosen price specification for the analysis.

5.2.2 Weather Specification

The most common weather specifications in the literature revolve around evapotranspiration and rainfall. Three such variants are tested and compared to similar models with interaction terms combining the weather effects with pool size and yard size.

The results of the test are shown in Table 5.13, and based on R^2, interacting property characteristics with weather variables clearly improves the accuracy of in-sample predictions, in this case by over 50%. The improvement in R^2 is not as

Table 5.13: Weather Variable Comparison for Paradise Valley

	$NetET$	ET & $Rain$	ET & $RainDay$	Int. $NetET$	Int. ET & $Rain$	Int. ET & $RainDay$
R^2	0.104	0.108	0.109	0.160	0.165	0.166
AP	-0.36	-0.37	-0.36	-0.35	-0.36	-0.36
HomeValue	0.02	0.02	0.02	0.03	0.02	0.02
Pool	0.04	0.04	0.04			
Yard	0.0002	0.0002	0.0002			
$NetET$	2.86					
ET		3.20	3.11			
Rainfall		-0.60				
RainDay			-0.65			
Pool * $NetET$				0.0041		
Yard * $NetET$				0.000048		
Pool * ET					0.0046	0.0046
Yard * ET					0.000052	0.000050
Yard * Rain					-0.000023	
Yard * RainDay						-0.000018

All variables significant at 99.9% level.

dramatic in the other communities, but considering the size of yards and popularity of pools in Paradise Valley, it is logical that the greatest gains from interacting should be had there. That interacting weather variables with property characteristics improves the model is a particularly important finding because such interaction terms have been not been used prior to this thesis.

The usage of $NetET$, that is the net evapotranspiration needs after considering rainfall, $ET - Rain$, has lower predictive value than the two variables separately. Based on the way R^2 is calculated, this is not surprising, but based on the difference between the two models, by combining the two it understates the individual effects of each. It is also not surprising that $ET - Rain$ does not effectively explain water usage, since ET is calculated for 3-6" tall grass, whereas most home lawns are trimmed shorter than that. Whether consumers respond to the occurrence of rain or the amount of rain, this data appears to support number of rainy days over the amount of rainfall. Similar analysis of the other three communities in the sample show the converse relationship with respect to R^2, although there is minimal difference between the two. Calculation of the marginal effects for amount of rain, however, leads to illogical conclusions such as one inch of rain reducing average usage in Sun City West to 0. Therefore, in accordance with Miaou (1990), number of rainy days is chosen to be used in interaction with yard size.

The good news is that the weather specification does not significantly alter the coefficients on price or the income proxy, so regardless of what weather data is available to the researcher, the price elasticity is not significantly biased as a result of omitted variables or misspecification. Given the rarity of household level data, particularly with detailed information about lot size and pool size, it is a relief to see that the variables of interest are not sensitive to the use of other weather specifications.

5.2.3 Demographic Effects

Consumer preferences are usually at least partially determined by their demographic characteristics. For household water demand this is even more important, since the age and number of residents can have a big impact on water usage. In addition to the number and ages of residents, studies have also found Hispanic ethnicity to correlate to different water usage preferences. Education is an issue which has not previously been explored in terms of water demand, but it seems reasonable that more educated consumers might be more environmentally conscious. On the other hand, education is correlated with income, so there may be a positive income effect from education which is not captured by home value.

Table 5.14 shows that the added demographic variables improve R^2, and many of the variables are statistically significant at the household level in spite of the aggregation. Similarly, there is significance in Table 5.15, but the improvements in R^2 are less than 0.001. Unfortunately, for Paradise Valley the addition of demographic variables increases the price effect, implying that the lack of demographics in the other communities may introduce bias. However, it is important to note that Paradise Valley has the fewest households and the highest usage, and is not representative of the other three communities in the sample. A comparison to Table 5.15 reveals that for Sun City, the addition of demographic variables does not significantly alter the price coefficient. Since Sun City is very representative of Sun City West, and is more similar to Anthem than Paradise Valley, the lack of demographic data on those two communities is unlikely to cause a bias in measuring the price elasticity.

One would generally expect children to increase water usage, and both the ag-

Table 5.14: Effect of Demographic Variables: Paradise Valley

Variable	**Model 1**		**Model 2**		**Model 3**	
R^2	0.165		0.168		0.168	
(Intercept)	4.52	***	-55.50	***	-24.69	***
AP_{t-1}	-0.365	***	-0.405	***	-0.406	***
Home Value	0.0228	***	0.0207	***	0.0203	***
Pool*ET	0.00464	***	0.00467	***	0.00467	***
Yard*ET	0.000052	***	0.00005	***	0.000052	***
Yard*Rain	-0.000023	***	-0.00002	***	-0.000023	***
% Under 18			0.85	***		
% Under 5					-0.48	
% Between 5 and 9					0.77	**
% Between 10 and 14					1.03	***
% Between 15 and 17					0.62	*
% Over 55			0.33	***	0.26	**
% Bachelor's Degree			0.79	***	0.23	
% Grad/Prof Degree			0.83	**	0.43	
Household Size			-9.30	**	-5.10	
% Hispanic			-0.19	+	-0.12	

Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '+' 0.1

Table 5.15: Effect of Demographic Variables: Sun City

Variable	**Model 1**		**Model 2**		**Model 3**	
R^2	0.049		0.049		0.049	
(Intercept)	8.81	***	3.45	***	3.42	***
AP_{t-1}	-0.747	***	-0.743	***	-0.743	***
Home Value	0.0120	***	0.0104	***	0.0103	***
Pool*ET	0.00090	***	0.00088	***	0.00088	***
Yard*ET	0.000023	***	0.000023	***	0.000022	***
Yard*Rain	-0.00070	***	-0.00069	***	-0.00069	***
HomeAge	-0.083	***	-0.057	***	-0.057	***
HomeAge^2	0.00084	***	0.00068	***	0.00069	***
% Under 18			0.036	+		
% Under 5					0.029	
% Between 5 and 9					0.090	+
% Between 10 and 14					0.024	***
% Between 15 and 17					-0.021	***
% Over 55			0.018	**	0.019	**
% Bachelor's Degree			0.07	***	0.07	***
% Grad/Prof Degree			-0.0015		-0.00055	
Household Size			1.31	***	1.30	***
% Hispanic			-0.028	***	-0.029	***

Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '+' 0.1

gregated Model 2 and the more specific Model 3 indicate that children do increase usage. The marginal effect of an additional 1% of the population being under 18, *ceteris paribus*[4], is 850 gallons in Paradise Valley and 36 gallons in Sun City. Since Sun City proper[5] is a retirement community, children are not permitted. It is likely that the effect in Anthem (and other "normal" neighborhoods) lies somewhere between these two values.

It is particularly notable that when further dividing the age groups, children less than 5 do not have a significant effect, and Paradise Valley even shows a negative effect. Although this is unexpected, it seems reasonable to expect that having children less than 5 years of age, parents may still be in a "starter home", and would be less likely to have a pool (for financial and safety reasons). Starter homes are probably less likely to have a grass lawn, and since the data does not distinguish between types of landscaping, that effect would not be picked up by the other variables. However, once children are older then 5, they have a significant effect in both communities. It is a positive effect in Paradise Valley for all age groups, with the "tween" age range of 10-14 having the largest effect (1030 gallons per 1%). This contradicts the finding of Lyman (1992) that those aged 10-20 add the least to water usage, although the findings in Sun City are more in line with his findings.

The over 55 age category is significant and positive for both communities, although the magnitude of the effect is low. The magnitude is particularly low in Sun City because of the low variance of the variable as demonstrated in Table 4.7. It is actually surprising that the variable achieves any statistical significance for Sun City. These positive results stand in contrast to the literature, where both Nauges

[4]Since this means holding household size and educational attainment variables unchanged, it is measuring the effect of replacing non-college educated adults with children. This is not a realistic scenario.

[5]The water district includes homes which are not actually in Sun City.

and Thomas (2000) and Martínez-Espiñeira (2003) found negative coefficients for the higher age bracket. This could be the result of a regional difference, particularly since many people who retire in Arizona come from the Midwest, and may not be satisfied with traditional desert landscaping.

Since education has not been included in water demand studies before, it is interesting that it does come out significant in half of the cases. Bachelor's degrees are associated with higher usage (significant in 3 out of the 4 models), suggesting that there is either a difference in preferences, or there is an income effect which has not been accounted for in home value. Graduate and professional degrees are only significant in 1 of the 4 models, and in the one significant case the effect is positive. Surprisingly, the results for graduate and professional degrees are essentially zero in Sun City. The percentage of the population with such degrees is significantly lower in Sun City than in Paradise Valley, and Paradise Valley may be drawing a very different type of professional (lawyers, doctors, consultants), which could account for the difference in the effect.

The most surprising result among the demographic variables is the negative result for household size in Paradise Valley. It is only statistically significant in Model 2, but it is an odd finding nevertheless. Given the lavish mansions of Paradise Valley, the numbers may be driven by the neighboring Scottsdale residences which are also considered a part of the Paradise Valley Water District. Scottsdale, although more expensive than other areas of Phoenix, tends to have similar housing, and it is likely that families of four or more would be living in a Scottsdale home than a Paradise Valley mansion. Indeed, for Paradise Valley, household size is negatively correlated with home value, square footage, and yard size. Thankfully, household size has the expected positive and significant coefficient for Sun City, and the magnitude of approximately 1300 gallons per person per month is intuitively satisfying. A similar correlation check with property characteristics reveals significantly lower correlations, -0.05 compared to -0.35 for assessed value, with similar magnitudes on the other characteristics.

Although Arizona is home to numerous Hispanics, they tend to cluster together in small communities. Sun City and Paradise Valley do not have many such enclaves, as evidenced by the average Hispanic populations of 2.7% and 4.5% respectively. Nevertheless, the results agree with the negative and significant findings of Murdock et al. (1988) and Gaudin et al. (2001). The magnitudes are quite low (120-190 gallons per 1% in Paradise Valley, 28-29 gallons per 1% in Sun City), but this makes the statistical significance all the more noteworthy. For a variable as broadly defined as the U.S. Census definition of ethnicity as "Hispanic or Latino" and "Not Hispanic or Latino", it is curious that it has a significant effect on water usage, and this finding merits a more sociological examination.

5.2.4 Regression Results

With the questions regarding which variables to include and what specification to use answered, the final versions of the analytical models can be estimated. For the sake of comparison, OLS, Random Effects, and Fixed Effects model results are presented for each community. Since OLS ignores the cross-sectional heterogeneity, it does not provide efficient estimates. It is reassuring to observe that for both the random and fixed effects models, the coefficients on variables estimated in both models are very similar. Since home value only varies over time due to adjustment for inflation, by subtracting the mean home value over time the fixed effects model reduces the variable's reliability as a proxy for income, and it is excluded.

Table 5.16: Regression Results: Anthem

	OLS		Random Effects		Fixed Effects	
(Intercept)	-4.25	***	-5.38	***		
AP_{t-1}	-0.61	***	-0.37	***	-0.35	***
Home Value	0.020	***	0.015	***		
Pool * ET	0.00043	***	0.00042	***	0.00038	***
Yard * ET	0.000071	***	0.000056	***	0.000055	***
Yard * RainyDay	0.0000121	***	-0.0000020	***	-0.0000029	***
Home Age	2.25	***	2.68	***		
Home Age^2	-0.12	***	-0.15	***		

Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '+' 0.1

Table 5.17: Regression Results: Paradise Valley

	OLS		Random Effects		Fixed Effects	
(Intercept)	-23.61	***	-25.97			
AP_{t-1}	-1.14	***	-0.40	***	-0.39	***
Home Value	0.029	***	0.021	***		
Pool * ET	0.0051	***	0.0047	***	0.0045	***
Yard * ET	0.000028	***	0.000050	***	0.000051	***
Yard * RainyDay	-0.000037	***	-0.000019	***	-0.000018	***
% Under 5	-0.56	***	-0.51			
% Between 5 and 9	0.77	***	0.74	**		
% Between 10 and 14	0.95	***	1.01	***		
% Between 15 and 17	0.61	***	0.62	*		
% Over 55	0.21	***	0.26	**		
% Bachelor's Degree	0.21	***	0.26			
% Grad/Professional	0.53	***	0.46	+		
% Hispanic	-0.08	***	-0.12			
Household Size	-4.87	***	-5.03			

Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '+' 0.1

Table 5.18: Regression Results: Sun City

	OLS		Random Effects		Fixed Effects	
(Intercept)	6.56	***	3.47	***		
AP_{t-1}	-1.57	***	-0.74	***	-0.70	***
Home Value	0.0082	***	0.0097	***		
Pool * ET	0.00089	***	0.00088	***	0.00088	***
Yard * ET	0.000025	***	0.000024	***	0.000024	***
Yard * RainyDay	-0.0000046	***	-0.0000092	***	-0.0000094	***
Home Age	-0.089	***	-0.059	***		
Home Age^2	0.001	***	0.001	***		
% Under 18	0.035	***	0.038	+		
% Over 55	0.016	***	0.019	**		
% Bachelor's	0.061	***	0.069	***		
% Grad/Professional	-0.001		0.001			
% Hispanic	-0.027	***	-0.028	***		
Household Size	0.95	***	1.29	***		

Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '+' 0.1

Table 5.19: Regression Results: Sun City West

	OLS		Random Effects		Fixed Effects	
(Intercept)	0.15	*	-0.91	***		
AP_{t-1}	-0.601	***	-0.277	***	-0.274	***
Home Value	0.0219	***	0.0223	***		
Pool * ET	0.00081	***	0.00073	***	0.00068	***
Yard * ET	0.000020	***	0.000010	***	0.000009	***
Yard * RainyDay	0.0000003	***	-0.000010	***	-0.000010	***
Home Age	0.22	***	0.26	***		
Home Age^2	-0.002	***	-0.002	***		

Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '+' 0.1

5.2.5 Price Elasticity

It is the own price elasticity that has been the primary interest of research on water demand. Many studies have used the double log model which yields a constant elasticity as the coefficient. However for linear models, such as those used in this thesis, calculation of the price elasticity requires one to choose a price-quantity pair. By definition, the price elasticity, ϵ_p is defined as

$$\epsilon_p = \frac{dY}{dP} * \frac{P}{Y} = \hat{\beta}_{AP_{t-1}} * \frac{P}{Y} \tag{5.1}$$

where Y is water usage, and the last portion is the formula for elasticity in this thesis. The result represents the percentage change in usage resulting from a percentage change in price. When $-1 < \epsilon_p < 0$, the good is considered to have inelastic demand, and when $\epsilon_p < -1$ it is said to have elastic demand. Almost all past studies have found water demand to be inelastic.

In order to calculate ϵ_p for the linear model, values of Y and P must be chosen, and commonly the elasticity calculation is made employing $\overline{Y}$ and $\overline{P}$. For a more complete look at the elasticity, values of $\overline{Y}$ and $\overline{AP}$ corresponding to the individual tiers are also used.

As expected, demand is price inelastic for all four communities at all chosen price/quantity pairs in Table 5.20a. Sun City exhibits the most elastic demand, while Paradise Valley has the least elastic demand. Based on the average home value for each community, the order of elasticities supports the conclusion that water demand is less elastic at higher income, as noted in several papers (Agthe et al., 1988; Ito, 2010; Mieno and Braden, 2011).

The way elasticity decreases with the tiers in Table 5.20b is a result of the

Table 5.20: Elasticity Results

(a) Elasticity at Sample Means

	Anthem	**Paradise Valley**	**Sun City**	**Sun City West**
All Tiers	-0.164	-0.034	-0.214	-0.145

(b) Elasticity At Tier Group Means: Pooled Model

	Anthem	**Paradise Valley**	**Sun City**	**Sun City West**
Tier 1	-0.779	-0.049	-0.607	-0.451
Tier 2	-0.172	-0.015	-0.157	-0.072
Tier 3	-0.069	-0.008	-0.071	-0.034

(c) Elasticity At Tier Group Means: Subsetted Tier Models

	Anthem	**Paradise Valley**	**Sun City**	**Sun City West**
Tier 1	-0.079	-0.091	-0.084	-0.062
Tier 2	-0.214	-0.010	-0.313	-0.126
Tier 3	-0.294	0.088	-0.291	0.090

form of Equation 5.1, since the denominator Y increases while the numerator AP decreases with usage, while $\hat{\beta}_{AP_{t-1}}$ is constant in the pooled model. Because this effect is primarily a result of the chosen functional form, it should not be assumed to represent true elasticities for the different classes of consumers. A quantile regression would be one way to allow for the elasticities at different usage levels to respond more flexibly. But, one argument in favor of these results is that a household using 10 kgal per month may respond to a price change by reducing usage to 9 kgal per month , while a household using 100 kgal per month may reduce usage to 95 kgal per month. Although in this hypothetical scenario, a larger response is made by the household in the third tier, it is only a 5% change, whereas the first household has changed its usage by 10%. Since such a scenario is intuitively more appealing than a constant elasticity, it may actually be another argument in favor of the linear model. If decreasing elasticity with usage is to be believed, in addition to the aforementioned income relationship, price increases will tend to be strongly regressive.

However, by estimating models separately for households ending the month in a given tier, flexible results, less constrained by the functional form, can be obtained. A household may be in different tiers in different months of the year, therefore to ensure the panel estimation has sufficient sample size for each household, each household must have at least 10 months in a given tear to be included, and each observation in the subset ended the month in the tier. The segmented results, shown in Table 5.20c, indicate that for all communities except Paradise Valley, households in Tier 1 exhibit less elastic demand than those in Tier 2. Since Tier 1 covers households using less than 3 or 4 kgal in these communities, it seems likely that there are very few means available for these households to reduce usage, and their low usage may even cause ignorance of rate changes, since their bills may only increase by a few dollars with each rate change. In Paradise Valley, Tier 1 covers the first 25 kgal, so more of the households are able to reduce usage as rates change, which would explain the higher elasticity.

Since Tier 2 price/quantity pair averages are going to be the closest to the mean, it is not surprising that the subset model Tier 2 elasticities are similar to the overall sample mean elasticities. Yet the subset of Tier 2 is noticeably more elastic than the means for everywhere but Paradise Valley. These results indicate that these households have more discretionary usage than Tier 1 households, and therefore a greater ability to adjust their usage with rate increases. Again, the marked difference in block sizes for Paradise Valley is the probable cause for its divergent behavior.

Most surprisingly, for the subset of Tier 3 households, elasticity is *positive* in Paradise Valley and Sun City West. This is most likely the result of mean reversion, where households using more than normal one month (and paying a lower average price) reduce back to normal in the next month, and vice versa. This behavior would lead to the positive estimates of the price coefficient in the model, although there may be other causes, such as apathy or wealth. Tier 3 elasticity estimates for Anthem and Sun City appear more believable. That Tier 3 would have the highest elasticity for Anthem is unexpected, but the middle class residents there were hit heavily by the recession in 2008. That could have caused some of the reduction in usage, while the heavy publicity of the rate changes in Anthem may further have driven some households to reduce usage. Sun City results indicate that Tier 3 is more elastic than Tier 1 but less so than Tier 2, suggesting that households using significant amounts of water are more financially able to withstand increased water bills and value water more highly than households in Tier 2.

It is also important to remember that the price variable used here is the average price *inclusive* of any fixed charges. Therefore, when predicting the effect of future rate changes, the rate schedule should be converted into average prices before making predictions.

5.2.6 Marginal Effects of Interacted Weather Variables

Because the weather effects have been interacted with property characteristics, the marginal effects are functions of the estimated coefficients and property characteristics. In order to convey these effects, tables with summer and winter conditions, no pool and median sized pool, and several quantiles of yard size are included in Tables 5.21-5.24. Figure 4.9 is used to determine reference ETo values over the course of the seasons, with 3" chosen for winter, and 10" chosen for summer.

Since such interaction variables have not been used in previous studies, these tables provide valuable insight about the use of water in these communities. For example, the magnitude of the difference between Paradise Valley and the other three communities is indicative of not just the difference in yard size (Q1 for Paradise Valley is close to the median for the other three), but it also gives a glimpse into how water-intensive the landscapes are. Even for the Q1 yard size in Paradise Valley, only Anthem is close in water usage. This indicates that both Paradise Valley and Anthem have many landscaped yards, while the Sun Cities probably have little landscaping[6]. The absolutely ETo-insensitive response of Sun City West points to low maintenance landscaping, such as gravel and native species that can survive on rainfall.

It should also be noted that the coefficient on the pool interaction term is significantly higher in every case than the coefficient on the yard interaction term. The conclusion can therefore be made that a landscaped area uses less water than an equally sized pool. In Phoenix, this is even true in the winter.

It is interesting that the coefficient on the pool interaction term is so much higher in Paradise Valley than elsewhere. Although there are many factors which could influence the need for refilling pools, such as chlorinated versus saltwater pools, different depths, or color of the concrete, one would expect evaporation to to be constant regardless of location. So unless Paradise Valley residents are draining and refilling the pool on a monthly basis in the summer (an unlikely event), there is probably some unobserved preference correlated with pool size which is increasing the estimated coefficient.

By interacting the number of rainy days with the yard size variable, a measure can be obtained relative to the amount of watering households do , as well as

[6]Having grown up in Phoenix and driven through many of these neighborhoods, my personal experience agrees with this conclusion. In Sun City, most “yards” are just gravel with a cactus or two.

Table 5.21: Marginal Effects of Weather in Anthem

		No Pool			Pool	
		Winter	Summer		Winter	Summer
Yard Size	Q1	1.0	3.3		1.5	5.1
	Median	1.3	4.2		1.8	6.1
	Q3	1.7	5.6		2.2	7.5

Table 5.22: Marginal Effects of Weather in Paradise Valley

		No Pool			Pool	
		Winter	Summer		Winter	Summer
Yard Size	Q1	1.0	3.5		8.2	27.4
	Median	5.3	17.7		12.5	41.6
	Q3	6.8	22.7		14.0	46.6

Table 5.23: Marginal Effects of Weather in Sun City

		No Pool			Pool	
		Winter	Summer		Winter	Summer
Yard Size	Q1	0.5	1.8		1.6	5.5
	Median	0.6	2.1		1.7	5.8
	Q3	0.7	2.3		1.8	6.0

Table 5.24: Marginal Effects of Weather in Sun City West

		No Pool			Pool	
		Winter	Summer		Winter	Summer
Yard Size	Q1	0.26	0.86		1.20	3.98
	Median	0.28	0.92		1.21	4.04
	Q3	0.31	1.03		1.25	4.15

their responsiveness to rainfall. Many households have automated sprinkler systems, which would require that someone shut it off temporarily, and later reactivate it. Many households forget to turn it off, or may prefer to over-water the lawn. To present the marginal effects, graphs have been included representing the differences across communities for the median yard in Figure 5.1, and within one community for various quantiles of yard size in Figure 5.2. Since 12 is the maximum number of rainy days during any sample month, that has been chosen as the maximum for the graphs as well.

From Figure 5.1, it appears that Paradise Valley is the most sensitive to rainfall, while Anthem is the least sensitive. Sun City and Sun City West are almost identical in their sensitivity to rainfall, which is not too surprising given the overall similarity of the communities. Since the marginal effect changes with yard size, Figure 5.2 shows how the effect differs within Paradise Valley for different yard sizes. The first quantile yard is closer to the median for the other communities, so a quick comparison to the medians reveals that rain does have a stronger effect in Paradise Valley than in the other three communities, but the magnitude of the difference for similarly sized yards is not as dramatic (-1 kgal for Sun Cities, -1.5 kgals for PV at 12 days of rain).

Given the sensitivity to ET in Anthem shown in Table 5.21, it is therefore probable that the insensitivity to rain is due to residents not disabling their automated sprinkling systems after a rain. If programmable sprinkling systems could be made to automatically respond to rainfall by reducing sprinkling over the next several days, the net savings could add up over a number of households to significantly aid in water conservation.

Figure 5.1: Effect of Rainfall on Median Households

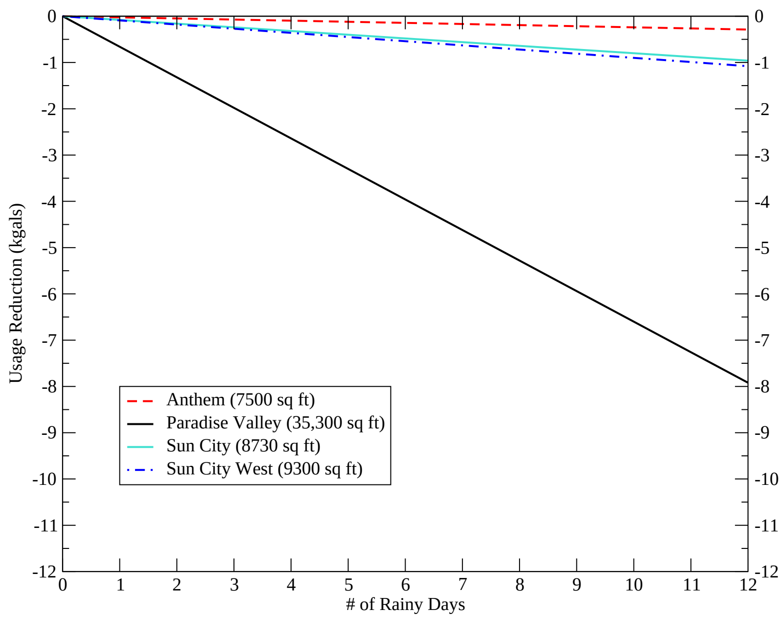
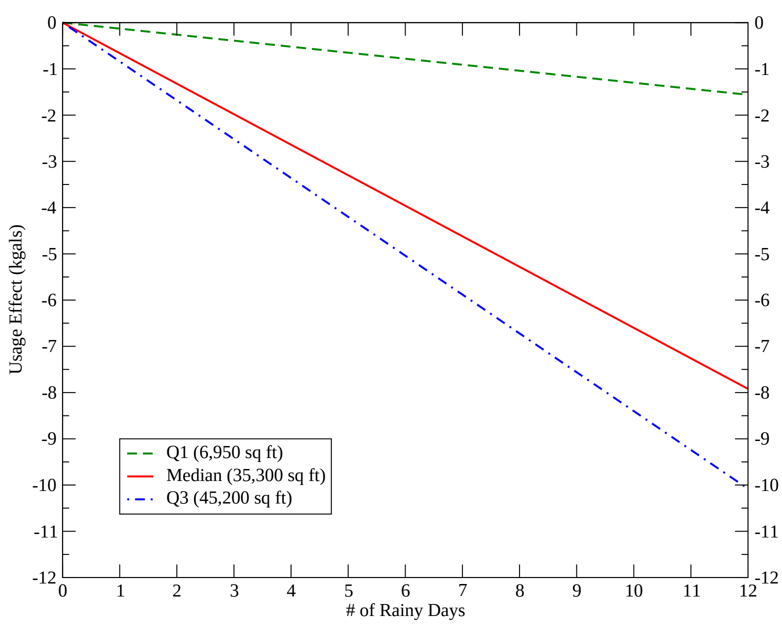


Figure 5.2: Effect of Yard Size on Rainfall Effects: Community of Paradise Valley



5.2.7 Effect of Construction Year

The age of the home has been used in previous studies as a measure of the technology for water-using appliances at the time of construction. In older homes, many of these have been replaced over the life of the house, or as the home changes ownership. Allowing the age of the home to have a parabolic effect is employed in Olmstead et al. (2007), who report that there is a concave relationship, with homes aged 20-40 years using the most water. In this thesis, age is calculated as $2010 - ConstructionYear$, because yearly changes are not believed to be important. Unfortunately, construction year was not collected for Paradise Valley.

Because Anthem is so new, the range of homes in the sample are only 5 - 11 years old. Nevertheless, both variables are statistically significant, and the resulting quadratic is concave. The maximum occurs for homes built in 2001, predicting about 2.5 more kgal than for homes built in 2005.

Sun City has a much wider range, but the result is surprisingly convex and negative. However, the effect is minimal, as the minimum effect of -0.9 for homes built in 1985 is not much different than the -0.3 effect for homes built in 2005. A confex finding has not been previousl reported in the literature.

The effect in Sun City West is very different, as it is concave and monotonically increasing with age. The monotonically increasing effect is also found in Nauges and Thomas (2000). The effect for homes built in 1960 is predicted to be almost 7 kgal more than homes built in 2005.

CHAPTER 6

Policy Implications

6.1 Pricing Strategies

Increasing block rate pricing has become the standard in Arizona water pricing, and many other places as well. It is popular with politicians because of the perceived fairness of providing cheaper water to those who use less, whether motivated by protecting low income constituents or a desire to reward conservation. Charging higher rates for those who use more is believed to encourage conservation, so as water rates increase, the increasing block rates are becoming more progressive, placing more and more of a burden on users in the upper brackets.

The problem with block rate pricing is that they are usually implemented with the hopes that consumers will understand and respond to them. Previous research has shown that this is rarely the case, because the water bill is such a small part of the household budget, and it is so difficult to determine the exact details of the rate structure. If consumers are not aware of the marginal price, or even unaware that there is an increasing block rate tariff, then conservation goals are unlikely to be met by increasing the block rates. There may be some conservation benefit to be had from greater publicity for the details of utility rate structures, as it has been shown that greater awareness of the rate structure increases price elasticity (Gaudin, 2006).

Even more unfortunate for conservation, the results of this study indicate that, with the exception of Anthem those who use the most water have less elastic demand than mid-level users. If those groups encouraging price increases as a conservation tool base their recommendations on the already low marginal price elasticities, and consumers do in fact react more to the average price, then their price recommendations will still fall short of meeting the goal. While this is bad news for those who hope to see water conserved, it is good news for utility companies, which are increasingly urged by regulatory bodies to place more of the cost burden on heavy users. Increasing prices for the upper tiers should increase revenue, as these users only reduce usage by 3% for a 10% increase in Anthem and Sun City, and do not appear to reduce usage in Paradise Valley or Sun City West (based on Table 5.20c).

However, the results of Section 5.1 shows that there appears to be a modest gradual change in the distribution of households across tiers after a price change. Since over 80% of the utilities' expenses are fixed, but less than half of their revenue is fixed, revenue uncertainty is a real problem for the utilities. Because the Arizona Corporation Commission (ACC) assumes perfectly inelastic consumers across all price levels, and limits the predicted return on equity, utilities have found themselves continually on the back half of the treadmill as the price elasticity leads to lower return on equity than expected by the ACC when the rates were approved. Although there is still uncertainty about whether consumers respond to marginal or average price, the overwhelming evidence shows that aggregate demand for water goes down when the price increases. This price response, though small, needs to be acknowledged by the ACC and other governing bodies across the nation in order for utility companies to operate effectively.

As far as consumer well-being is concerned, the inelasticity of demand means that when water prices increase, less money is left for all other purchases and saving. Increases in the fixed service charges can be particularly painful, since it affects everyone, and drives up the average price. Based on the results of this thesis, although the low-usage household show low elasticities in the segmented models, their increase in average price after a rate change will be the highest. These households will be doubly hurt by price increases, as household utility is reduced when the household conserves water, and disposable income is reduced after the water bill takes up a greater share of income. Sadly, even the most progressive tariff structures are likely to have some regressive effect.

There has also been interest in implementing seasonal water rates in Arizona, charging more for summer usage. Seasonal rates have already been implemented in Arizona electricity rates and in Salt Lake City water rates. Since households do not appear to increase their usage after the 2008 rate *decreases*, shown in Table 5.5, if increased summer rates are effective in inducing longer run water conservation measures such as changing landscaping or appliances, then the conservation is likely to extend into the winter months. Consumers are not likely to keep close track of their water bills over time, so the yearly total or average bill would not be as noticeable as the "peak bill". If consumers actually respond to peak bills[1], even a seasonal pricing plan that left the average bill unchanged but increased costs in summer would be likely to reduce usage year-round.

6.2 Residential Configuration Policies

Based on the demographic and property characteristics results in Section 5.2 there are some non-price options to manage water consumption. Obviously smaller lots will lead to lower usage, as will a higher proportion of multi-family housing in a community, each of which could be incentivized by tax structures. Furthermore, within

[1] A theory which has not been tested with regards to water usage.

the context of multi-family housing, the addition of individual metering could also encourage conservation, although without a private yard or pool there is not likely to be much excess usage to trim. Although it cannot be tested here, it is probable that in Anthem, a planned community with community parks, a water park, and an aquatic center, residents may choose to forgo their own landscaping or pool knowing that they can enjoy most of the benefits without directly incurring the monetary and personal costs of their upkeep. The Anthem HOA mandate for native or near-native plants is an example for other communities desiring to be more environmentally conscious, both with respect to invasive species and water conservation. Since Sun City and Sun City West are also Del Webb planned communities, community parks and pools may substitute for private ones there as well. Yet the target demographics (retirees as opposed to young families) and the time of construction (1970s as opposed to 2000s) differ by so much that one cannot assume the planning goals or the consumer behavior would be the same across the communities.

6.3 Climate Change Preparedness

The use of the novel weather variable gives a better indication of how climate change could affect residential water usage. It is apparent from the results that landscaping plays a huge role in determining discretionary water use, so the Sun Cities would hardly be affected by less frequent rain and hotter, drier days, whereas Paradise Valley would see usage increase dramatically. Given the price inelasticity of demand, in order to counteract climate change such that usage remains constant, prices would need to be increased in such magnitudes that the regulated returns on equity would be violated. Even if the ACC decides that returns on equity are less important than conserving water resources, and allows such a price change, the public outrage would lead to serious problems for the water utilities and local governments. Although most people acknowledge the scarcity of water in the desert, their belief that lawns and pools are an inalienable right makes them resentful of the price increases intended to communicate the scarcity and encourage conservation.

Appendix

Arizona American Water
PO Box 7150
Pasadena, CA 91109-7150

For Service To:

ACCOUNT NUMBER	
AMOUNT DUE	
DUE DATE	Dec 29, 2008
Amount Paid	ELECTRONIC PAYMENT DO NOT PAY

Please return this portion with check
▼Payable to the address below ▼

Arizona American Water
PO Box 7150
Pasadena, CA 91109-7150

The basic service charge includes the cost of meter readings, customer billings, accounting and maintaining the meter and service line to the residence and varies by meter size. The basic service charge is paid regardless of the use of water.

Customer Account Information

For Service To:

Account Number:
Premise Number:

Billing Period & Meter Information
Billing Date: Dec 05, 2008
Billing Period: Nov 03 to Dec 02 (29 days)

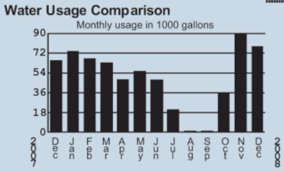
Next reading on/about: Jan 30, 2009
Rate Type: Residential

Meter readings in current billing period:
Meter Number 079809616 is a 5/8-inch meter.

Present-actual	1087
Last-actual	1009
T-gal used	78

The amount of water, in thousands of gallons, used in the previous month.

Water Usage Comparison



Billing Summary

Prior Balance		
Balance from last bill		$228.37
Payments as of Dec 05, 2008. Thanks!		-228.37
Total prior balance, Dec 05, 2008		.00
Current Water Charges		
Basic Service		9.50
Water Volume	($ .760 x 25.00)	19.00
	($ 1.650 x 53.00)	87.45
Total Use Billed	78.00	115.95
Other Current Charges		
CAP Surcharge - Residential		2.54
Arsenic Recovery (EPA mandate)		58.23
ACC Resid Reg Assmnt Fee		.34
Land Sale Credit		-.90
Total other charges, Dec 05, 2008		60.21
Taxes		
City Tax - Paradise Valley		2.91
County Tax - Maricopa		1.24
State Tax		9.89
Water Use Tax		.51
ADWR Withdrawal Fee		.70
Total taxes, Dec 05, 2008		15.25
TOTAL AMOUNT DUE		$191.41

Do not send payment. Total Amount Due will be deducted from your bank account on Dec 29, 2008

The water volume charge is the cost relating to maintaining the source of supply, water treatment, distribution of water and general operating expenses. Currently, there is three-tiered pricing based on the amount of water used.

The cost associated with Colorado River water purchased through the Central Arizona Project.

The arsenic recovery surcharge was implemented in 2007 to pay for the treatment facility and costs for fulfilling an EPA mandate to lower arsenic levels in drinking water.

Fees imposed by state and local governments.

Messages to you from Arizona American

*** Please call our customer service center at 1-800-383-0834 to update your contact information. In the event of a water emergency, your contact information is one of the sources available to reach you.***

** The company can calculate the impact of its rate increase proposal on your account. Please call 1-800-383-0834 or e-mail azrates@amwater.com and provide your account number and service address.*

** Most Arizona plants use much less water in the winter, so now is a good time to adjust your irrigation timer accordingly. This will save water and money. Winter is also a good time to examine your irrigation system for leaks.*

** The Water Education Foundation produced a 90-minute documentary called Liquid Assets: The Story of Our Water Infrastructure. The Liquid Assets program will air on KAET-TV in Phoenix on Sunday, January 4, 2009 from 2-3:30 p.m. The focus is on the serious issues facing the nation's water infrastructure. For more information, visit www.liquidassets.psu.edu*

** Customers may use their credit card, debit card or pay by electronic check only by calling toll free: 1-866-271-5522. Customers may also pay on-line at www.water.paymybill.com. A service fee will apply.*

** Arizona American Water takes great pride in the water we deliver to you. Our water meets or exceeds all standards. For more information, please visit us at www.arizonaamwater.com.*

Customer Service & Emergencies: 1-800-383-0834 (24 Hours)
AZ Corporation Commission: 602-542-4251 or 1-800-222-7000
Visit us on the INTERNET: www.arizonaamwater.com
AMW76i P1M1A 1

ARIZONA
AMERICAN WATER

**WE CARE ABOUT WATER.
IT'S WHAT WE DO.**

**www.arizonaamwater.com
(800) 383-0834**

Table 1: Sample Electronic Record of a Bill for Paradise Valley

Description	**Usage**	**Rate**	**Amount**	**Bill Date**	**Bill Begin**	**Bill End**	**Bill Days**
Basic Service	0	0.00	15.85	20091119	20091017	20091116	31
Water Volume 25.00 @ .7600000	25	0.76	19.00	20091119	20091017	20091116	31
55.00 @ 1.6500000	55	1.65	90.75	20091119	20091017	20091116	31
10.00 @ 2.1800000	10	2.18	21.80	20091119	20091017	20091116	31
CAP Surcharge - 45.00 @ No Charge	45	0.00	0.00	20091119	20091017	20091116	31
45.00 @ .0769000	45	0.08	3.46	20091119	20091017	20091116	31
Arsenic Recovery (EPA mandate)	0	0.00	28.02	20091119	20091017	20091116	31
90.00 @ .5140000	90	0.51	46.26	20091119	20091017	20091116	31
High Block Surcharge 80.00 @ No Charge	80	0.00	0.00	20091119	20091017	20091116	31
10.00 @ 1.0000000	10	1.00	10.00	20091119	20091017	20091116	31

Dates are YYYYMMDD

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