Incentives for Residential Water Conservation: Water Price, Revenue, and Consumer Equity in Florida

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Selected Paper prepared for presentation at the Southern Agricultural Economics Association Annual Meeting, Orlando, FL, February 6-9, 2010

Introduction

Similar to other states in the Southern Region, Florida is facing the challenge of meeting the water demands of its growing population given a) competing demands for instream (or inground) and agricultural water uses, b) the stock of water resources that is very costly to extend (e.g., the estimated cost of water from the Tampa Bay Seawater Desalination Plant in 2006 was $3.19 per thousand gallons (Bernett 2007), which is above the average charge for water in the southern United States (AWWA and Raftelis 2006)), and c) periodic droughts and potential climate change effects on water resources (Griffin 2007, Dziegielewski and Kiefer 2008). State agencies and water utilities focus on reduction of discretionary water consumption per capita and water conservation, and conservation pricing is one type of policy instruments that is currently promoted (AWWA 2008).

Conservation rates are usually defined as uniform (where customers pay a set fee for each unit of water used) or inclining block rate structures, where unit water rate increases with rise in water use volume (Daniel and Lingo 1997). As oppose to water use restrictions, conservation water rates allow consumers the flexibility to decide if, when and how, to reduce water use (Olmstead and Stavins 2008). Empirical research suggests that water usage responds to price changes (Whitcomb 2005, Dalhuisen 2003); however, the response depends on specific characteristics of rate structures (such as the magnitude of unit price change in response to water use increase, unit rate for non-discretionary water use, etc.). Furthermore, water utility companies may not have strong incentives to implement conservation rates if the rates affect their revenues or revenue variability (Beecher, *et al* 1994). In addition, some conservation rate structures may be inequitable, in the sense that the "revenue burden" is borne disproportionately by some customer groups (Morgan 1987, Rogers *et al* 2002), which may make some rate structures unpopular with consumers and politically unfeasible.

Uniform and inclining block rate structures take many forms, based on the unit rates set for each price block, and water usage range covered by each price block. In addition to water unit rates, fixed fees are often used to stabilize utilities' revenues, and residential sewer bills are generally based on water bills. Thus, in Florida, there is wide variation in the water rate structures. There is also very limited empirical evidence in Florida about the advantages and disadvantages of using different rate structures. The purpose of this study is to provide evidence about tradeoffs faced by water utilities that implement conservation rates. Several specific research objectives contribute to this overall goal: 1) to analyze whether the number of price blocks affects the conservation incentives faced by residential consumers; 2) to test for statistical evidence that rate structure effects utility revenue or revenue variability; and 3) to analyze the impact of different rate structures on consumer equity.

Literature Review

The relationship between water rate and water usage / conservation has been traditionally explored by analyzing the elasticity of water demand. Price elasticity is defined as the percent change in water usage in response to the certain percent change in price (rate). For residential customers, a 10% increase in rate will most likely result in reductions in water usage within the range of 1% to 3% (AWWA 2000). Price elasticity depends on a variety of factors, such as: the size of wastewater and fixed charges in customer bills; percent of total income spent on water; price of water from alternative water sources (such as private wells); length of time over which rates and water demands are evaluated; climate and weather events; initial water rates against which the elasticity is measured; type of water use (indoor vs. outdoor); season and time of the day (peak vs. off-peak periods); geographical region; customers' knowledge of their water rates; and presence of other conservation and education programs (AWWA 2000; Carter and Milon 2005; Cavanaugh, *et al*. 2002, Dalhuisen *et al*. 2003, Espey *et al*. 1997; Howe 2002; Howe and Goemans 2002, Wang et al. 2005).

Economic research has also explored the relationship between water conservation and the revenue of water utilities. The National Regulatory Research Institute (1994) suggests that since water demand is inelastic, increased rates actually have the potential to *increase* revenue while reducing water use. Contrary to this, among the 23 utilities nationwide responded to the survey by Wang *et al*. (2005), 9% of utilities responded that conservation rates increased their revenues, while 26% reported that revenues decreased, 30% considered conservation rates to be revenue-neutral (35% did not know or gave no response).

The literature also discusses the potential for conservation rates to increase revenue variability (AWWA 2000, Chestnutt 1993). Increased revenue variability inflicts greater financial borrowing expenses and planning/informational expenses for water utilities (Chesnutt et al. 1993). Since utility companies generally have very high "up front" fixed costs, they often must dedicate a fairly large share of revenue servicing debt. As a result, utility companies have a vested interest in revenue stability (McLarty and Heany 2008). Generally, revenue streams from inclining block structures are more variable than revenue streams from declining block structures (AWWA 2000). Smaller utilities may be more affected by revenue variability than larger utilities. In a survey of North Carolina utilities, Nida and Eskaf (2009) observed larger fixed fees in smaller utilities and hypothesized that "smaller utilities may, on average, have less stable customer consumption and therefore decide to shift greater proportion of their operating costs into the base charge." (p. 5).

Finally, research on the topic of water rates and customer equity showed evidence that poorly designed conservation rate structures can lead to an inequitable billing of different customer groups (AWWA 2000). Renwick and Archibald (1998) find that water use of low income customers is more responsive to price increase than the water use of high income customers. "These results suggest that price policy will achieve a larger reduction in residential demand in a lower income community than in a higher income community, all other factors held constant. Results also suggest that if price policy is the primary DSM (demand side management) instrument in a particular locale, lower income households will bear a larger share of the conservation burden" (p. 357). However, Agthe and Billings (1987) demonstrate that with proper design of the inclining block rate structures, steeper price blocks will actually lead to greater distributional equity. The authors show that by making price blocks steeper, a utility could increase the incentive to conserve without adding any price burden to low income users.

Data and Methods

The analysis is based on 1998-2003 billing, water use, socio-demographic, and attitudinal data for a sample of 7200 households served by 16 Florida utilities (Whitcomb 2005). During the study period, a variety of rate structures were used, including uniform and inclining block with anywhere from two to six price blocks. Each period of time during which a utility used a distinct water rate was considered to be an independent "rate structure period." Between the 16 utilities and six years of the study, there are 66 different rate structure periods in the sample.

To explore the relationship between the number of price blocks and the "strength" of conservation price signals, average and marginal prices were calculated for each rate structure period. Higher prices are assumed to create stronger incentives to conserve water. There is no consensus in the literature about whether households respond to average prices, marginal prices, or both (EFC 2006), and hence, both average and marginal prices were estimated. The prices were estimated given the average monthly household water use level (9,360 gallons/month), calculated as an average of monthly use for all households in the sample and for the whole duration of the study period. Our hypothesis is that average and marginal prices are higher for water rate structures with the larger number of price blocks.

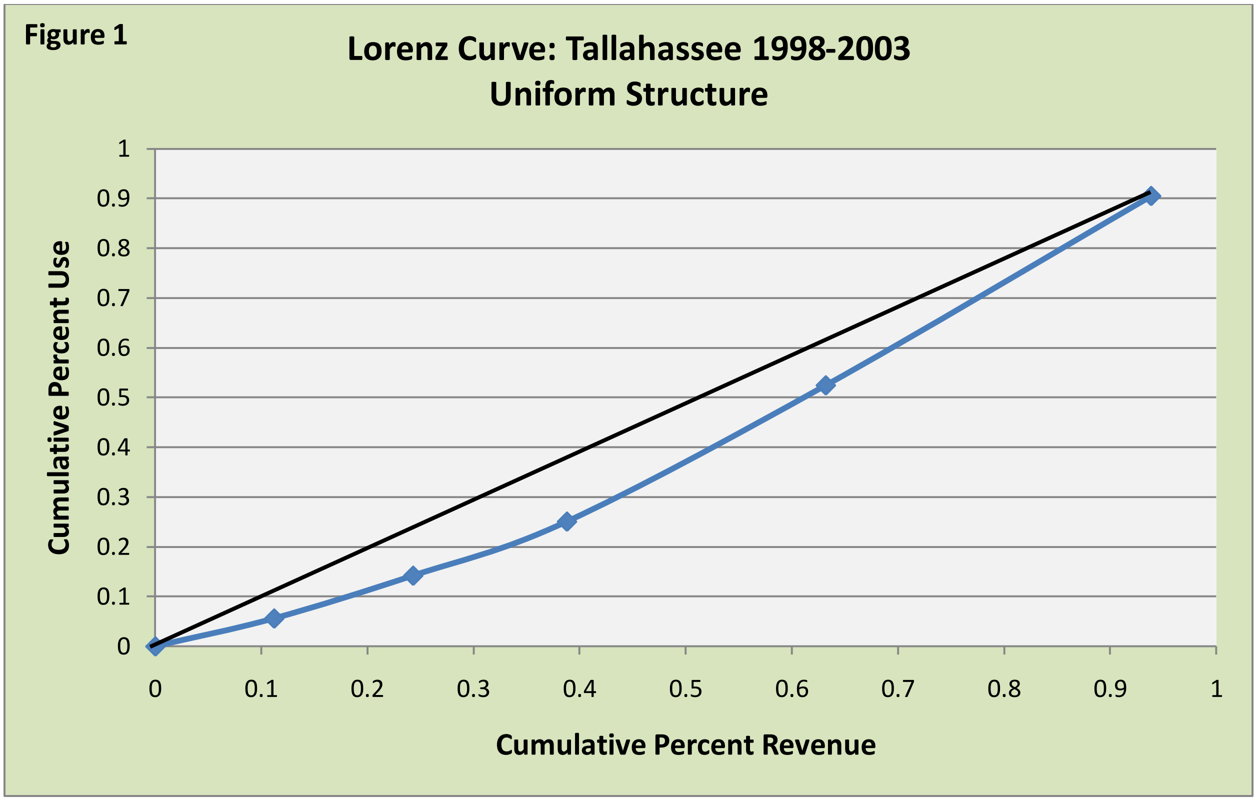
Also, following EFC (2006), reduction in water bill associated with a 40% reduction in water use was calculated for all rate structure periods. The greater the calculated savings, the stronger incentives households would have to reduce water usage. Both the actual value and the percent reduction from the total water bill were estimated. The 40% reduction was calculated for two different water use levels: 9,360 gallons/month (the average monthly water use for the whole sample and whole study period) and 12,000 gallons / month (the third quartile of household monthly use in the sample). In absolute terms, this meant a reduction from 9360 gallons to 5616 gallons per month in the first case, and a reduction from 12000 to 7200 gallons per month in the second case. Again, our hypothesis is that reductions in water bills are higher, and hence, the incentives to conserve water are "stronger", for water rate structures with a larger number of price blocks.

To meet the second objective (i.e, to examine the effect of water rate structure on utility revenue and revenue variability), monthly revenue was estimated for each rate structure period. Because revenue figures were not available, the sum of volumetric and fixed water charges for all households in the sample for each utility was used as a proxy for monthly utility revenue. The average monthly revenues were calculated for each rate structure period. To test if conservation pricing leads to increased revenue variability, the standard deviations of monthly household bills were calculated for each utility and each rate structure period. It is assumed that the greater variability in household bills results in greater variability of month-to-month utility revenues, since household water usage can to fluctuate from one price block to another (Chestnutt *et al* 1996). An OLS regression was used to examine if increase in the number of price blocks in water rate structures was related to increase in the standard deviation of household water bills.

The third research objective was to analyze the effect of different rate structures on consumer equity. Following Morgan (1987), Gini coefficient estimates and Lorenz curves were used to measure the equity implications of various rate structures. A Lorenz curve for a specific water rate structure maps the proportion of water use by different customer income groups against the proportion of utility revenue collected from these income groups. Each Lorenz curve is compared with the perfect equity line, where each customer income group contributes equal shares to the total utility water supply and the total utility revenue. In turn, the Gini coefficient is defined graphically as the ratio of the area between the Lorenz curve and perfect equity line and the total area under the perfect equity line. All Gini coefficient values are numbers between zero and one (Morgan 1987). The lower the coefficient, the more equitable a rate structure is. A Gini coefficent of zero represents a perfectly equitable distribution. Table 1 shows the five income groups used, and, **Figure 1** shows a sample Lorenz curve.

Table 1. Customer Income Groups.

Name	Income range
Income group 1	<$15,000 per year
Income group 2	$15,000-$29,999 per year
Income group 3	$30,000-$49,999 per year
Income group 4	$50,000-79,000 per year
Income group 5	$80,000-$100,000 per year
Income group 6	>$100,000 per year



Results

The analysis pertaining to the first objective (conservation "price signals") yielded mixed results. In the case of average and marginal prices, there is no strong evidence that any one type of rate structure sends stronger price signals than any other type. The highest observed average prices were in periods with uniform rates while the lowest average prices were observed for periods with multiple price blocks. **Figure 2** shows the six rate periods with the highest, and the six with the lowest, observed average prices. Similarly, no consistent trends were observed for marginal prices (**Figure 3)**.

Table 2. Color Code Legend for figures.

Type of Rate Structure	**Figure Color Code**
Uniform	
Inclining Block with three or less price blocks	
Inclining Block with more than three price blocks	

Figure 2

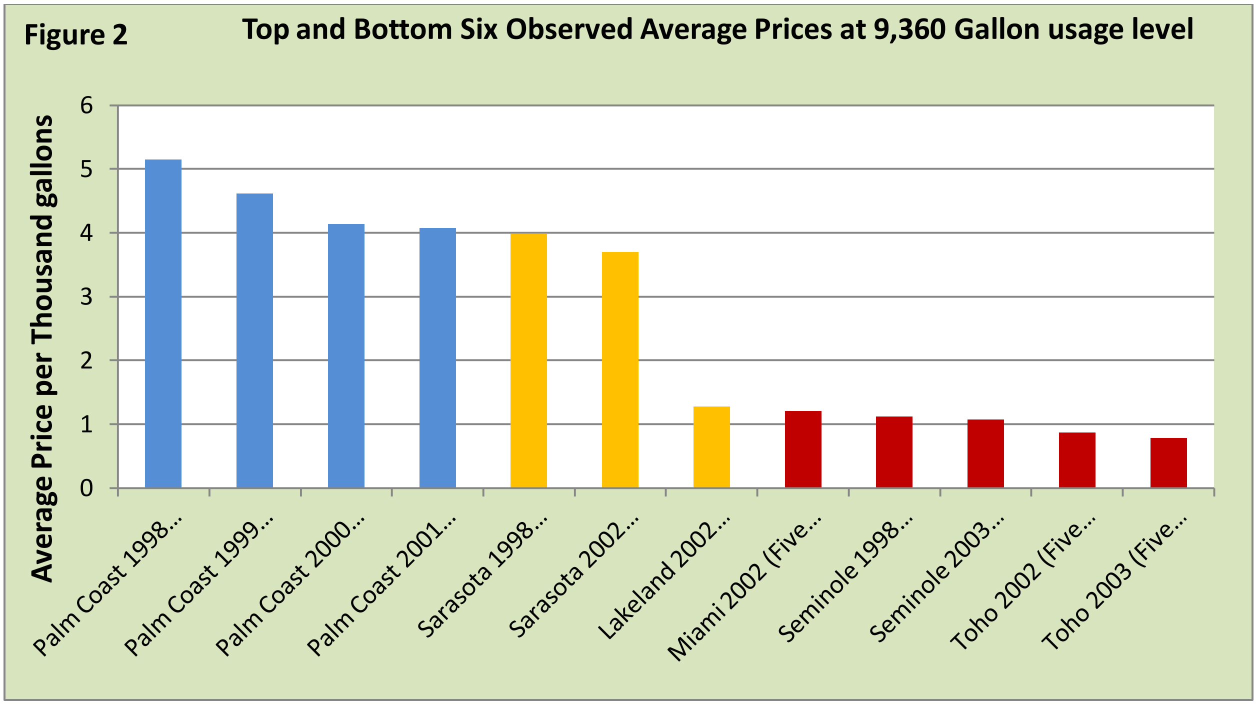
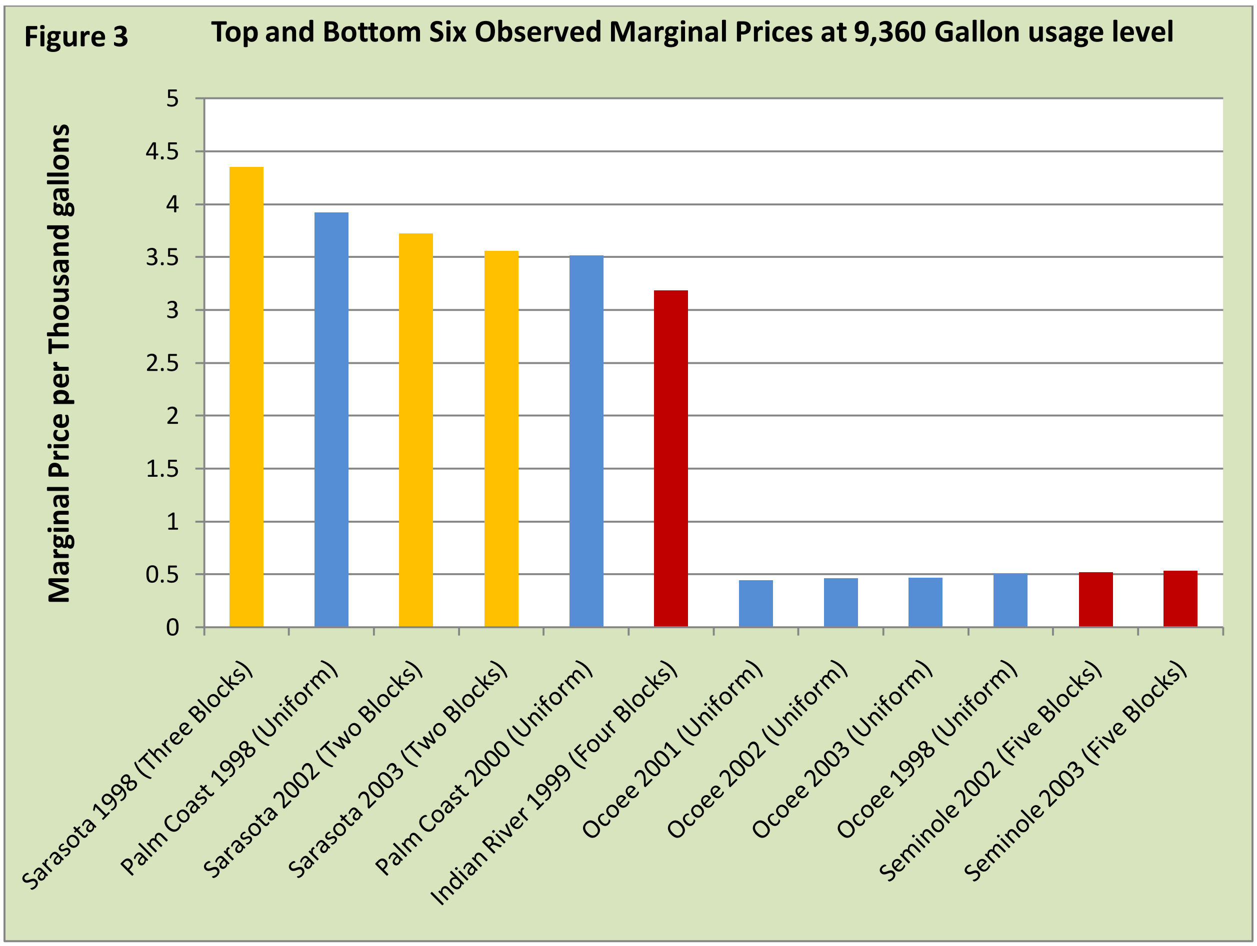
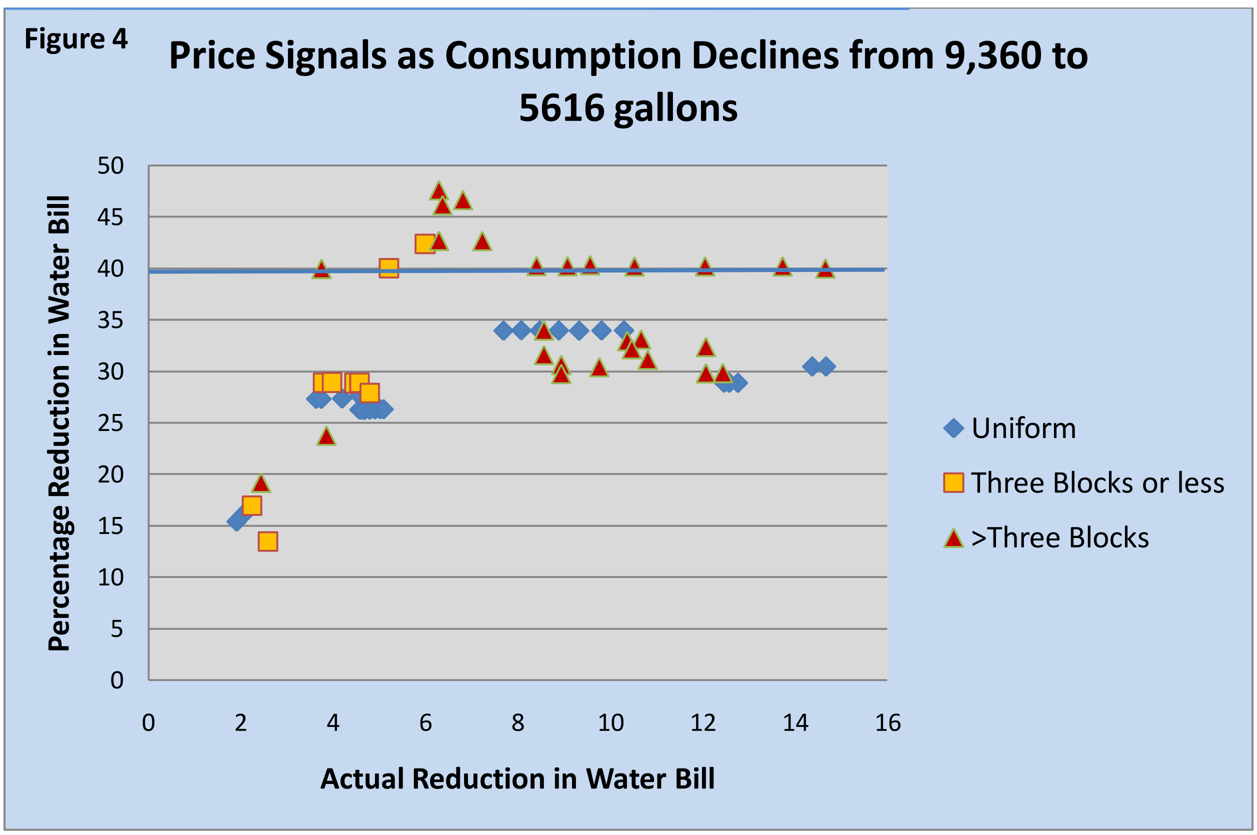
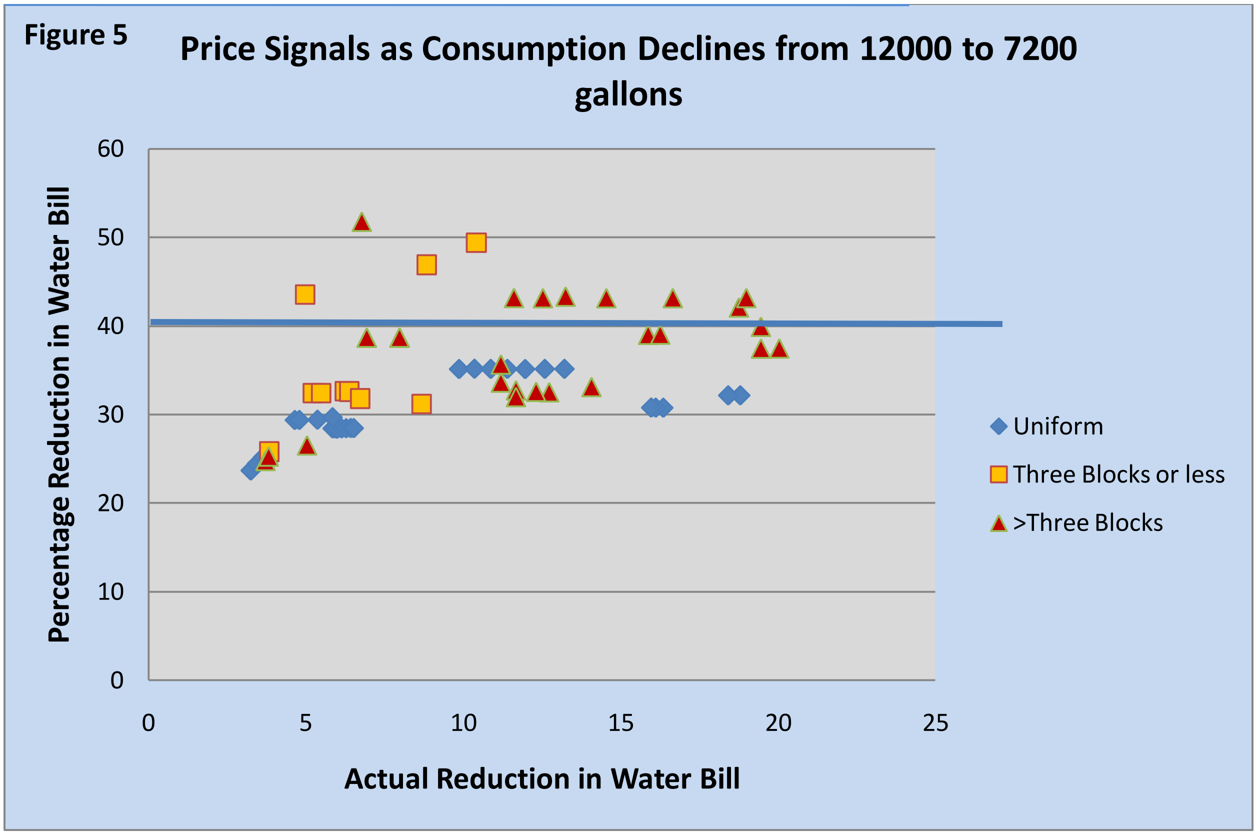


Figure 3



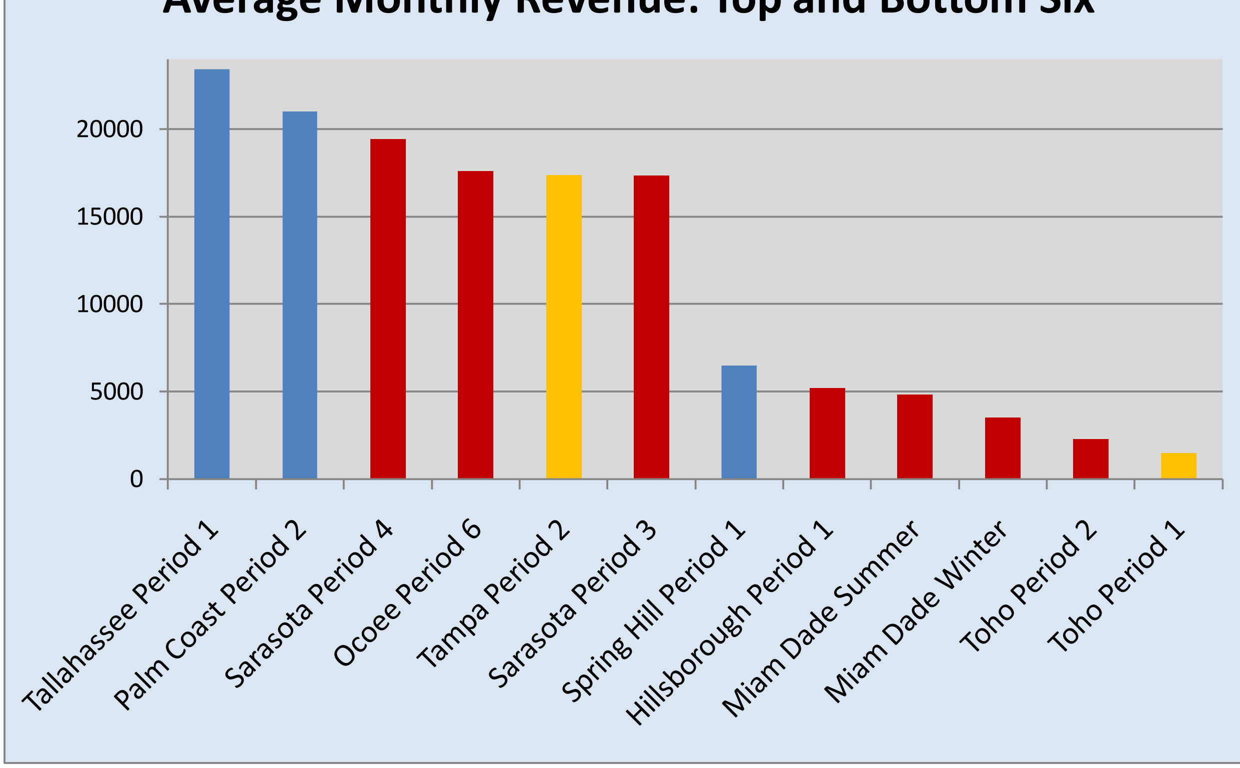
The analysis of household savings due to water use reduction, on the other hand, suggests that water rate structures with more than three price blocks tend to create stronger incentives to conserve water than other types of rate structures. **Figures 4** and **5** show the reduction in monthly water bill associated with a 40% reduction in use from the average household level and from the third quartile of household use, respectively. In both cases, the largest observed bill reductions (as percent from the total bill) were observed for the rate structure periods with more than three price blocks. In the Figures, a blue line shows the 40% threshold. Any point above this line represents a rate structure period where a 40% reduction in use would result in more than a 40% bill reduction. In both Figures, all points on or above this line represented periods with increasing block rates. All uniform rate periods appear below the line. However, it is important to note that results for some of the water rate structures with more than three price blocks are comparable with the results for other rate structures. Hence, large number of price blocks does not guarantee "stronger" incentives for the customers to conserve water.





The results pertaining to objective 2 (revenue and revenue stability) also tell an interesting story. **Figure 6** shows the rate structure periods with the six highest and six lowest average monthly utility revenue estimates. No evidence was found that adding price blocks decreases monthly utility revenue. That is, it does not appear that the objective of cost recovery becomes more (or less) difficult with the increase in the number of price block in utilities' water rate structures.

Figure 6



However, there is some evidence that the tradeoff between the number of price blocks and revenue variability does exist. **Figures 7, 8, and 9** show the histograms for household monthly bills for the following rate structure periods: uniform, inclining block rate with three of less blocks, and inclining block with more than three blocks. Visual comparison of the histograms implies that the variation in household bills is wider for the periods with more than three price blocks (**Figure 9**).

Figure 7

Histogram: Monthly Household Bills for Uniform Rate Structure Periods

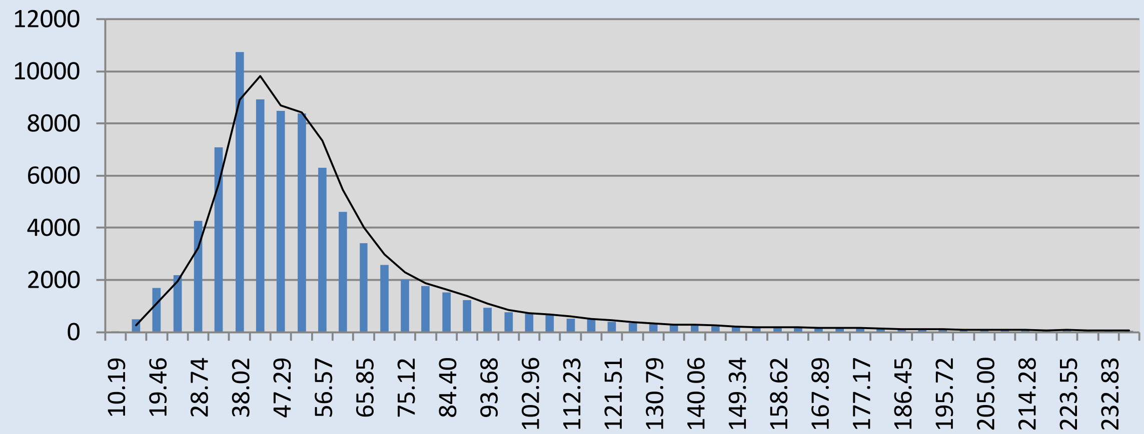


Figure 8

Histogram: Monthly Household Bills for Inclining Block Rate Structure Periods (three price blocks or less)

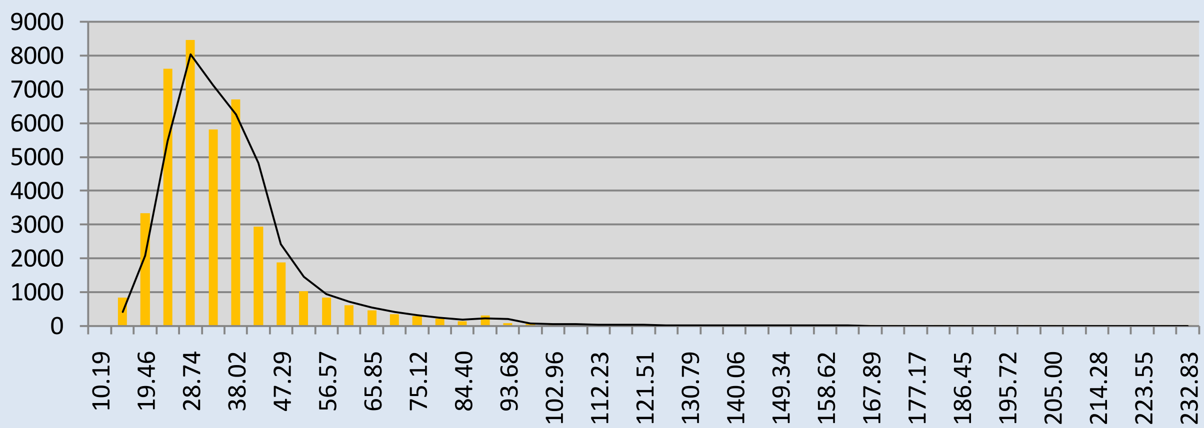
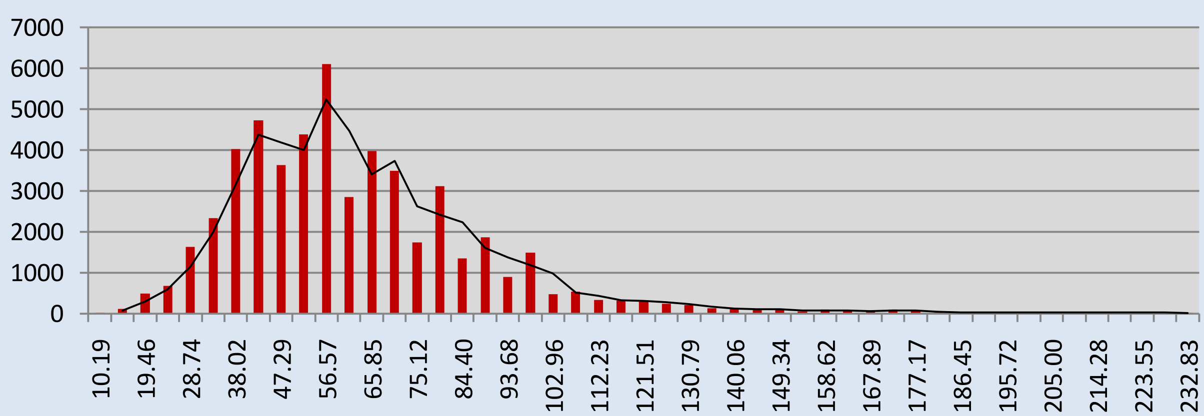


Figure 9

Histogram: Monthly Household Bills for Inclining Block Rate Structure Periods (more than three price blocks)



Descriptive statistics for the monthly household bills for the rate structure periods with uniform and inclining block rate structures is presented in Tables 2 and 3. Preliminary results for simple OLS models are presented in Tables 4 and 5. In the first model, the dependent variable is the standard deviation of the household monthly water bills given specific rate structure period, and the independent variable is the number of price blocks in the rate structure. In the second model, the dependent variable is the same, while the independent variable is the dummy variable indicating if the rate structure is uniform or inclining block. For both models, the coefficients for the independent variable are positive and statistically significant, indicating that increase in the number of price blocks results in increased standard deviation of monthly household bills.

For the objective 3 (customer equity), no evidence that certain types of rate structures were associated with more inequitable billing distribution were found. **Figure 11** shows the estimated Gini coefficients for a selected number of rate structure periods. In all five of these, the gini coefficients were low (less than 0.18). All coefficients were similar and close to zero, indicating an equitable distribution of revenue contribution among utility customers.

Table 2. Summary Statistics for Uniform Rate Structure Periods

Mean	**58.73**
Median	**53.3**
Standard Deviation	**41.23**
Sample Variance	**1699.50**
Kurtosis	**53.67**
Skewness	**5.59**
Minimum	**10**
Maximum	**478.862**
Count	**102357**

Table 3. Summary Statistics for Inclining Block Rate Structure Periods

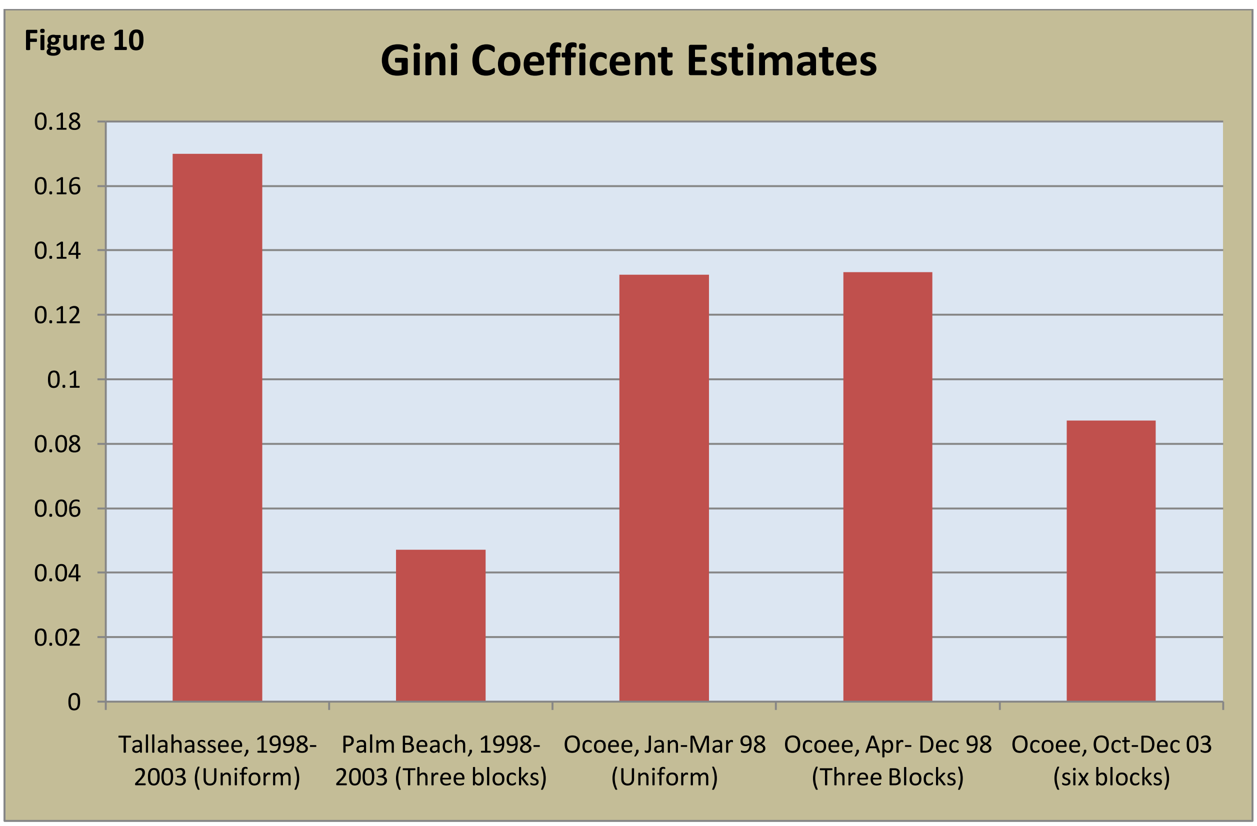
Mean	**7.55**
Median	**36.92**
Standard Deviation	**48.73**
Sample Variance	**2374.42**
Kurtosis	**92.85**
Skewness	**5.91**
Minimum	**5.54**
Maximum	**1192.35**
Count	**168021**

Table 4- OLS results for first regression (number of price blocks)

R^2	0.065460665
Standard Error	0.04846904
F value	3.85252
Coefficient (number of price blocks)	3.728288109
Standard Error (number of blocks)	1.899488667
T-statistic	1.962785129
p-value	0.054737

Table 5- OLS Results for second regression (rate structure as dummy variable)

R^2	0.09649089
Standard Error	24.84673287
F value	5.873763639
Coefficient (rate structure dummy)	16.25779247
Standard Error (rate structure dummy)	6.708158912
T-statistic	2.423584874
p-value	0.018685342



Conclusions and Implications

Our analysis shows that inclining block rate structures with more than three price blocks seem to create stronger incentives to conserve water. However, uniform rate structures and rate structures with three or less blocks can also be designed to create strong conservation incentives. The analysis also shows that there may be a tradeoff between conservation and revenue variability (however, to confirm and define this possible tradeoff, further statistical analysis is needed). Finally, we did not find any evidence of a tradeoff between equity and water conservation objectives for water utilities.

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