Do Steeply Tiered Rates Promote Conservation?

An Analysis using Aggregate Data

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Inclining Block Rates (IBR) for commodities such as electricity, water and natural gas, whereby higher usage blocks are charged higher rates, are postulated by conventional wisdom as promoting conservation in the residential sector. Such an assertion seems to be taken for granted and not many analyses based on empirical data are to be found to check whether this is verified in real life. A few studies have been carried out using data for water utilities[2] that point to some conservation resulting from a tiered rate structure, however water is a commodity whose scarcity may be more perceived, especially at times of drought; also, water discretionary use such as for landscaping is more understood by the consumer.

In the electricity industry, discussion of the conservation effect of IBR usually comes down to a discussion of price elasticity and quite a few studies have estimated the price elasticity of electricity[3]. This elasticity is generally found to be negative and fairly small. Price elasticity is traditionally estimated at the individual household level, examining the change in usage as a response to a change in prices, often a marginal price. The theory being that as the marginal price of the more elastic upper tier becomes higher, then overall usage decreases, producing the conservation effect. Faruqui (2008) and the Brattle Group constructed a model which derives conservation estimates by applying different price and income elasticities to different blocks.

More recently, Borenstein (2009) has advanced the notion that consumers may not necessarily respond to marginal price but to expected marginal price. Following in his steps, Ito (2014) has shown evidence that consumers respond to average prices rather than marginal prices in the case of non-linear pricing. Ito's empirical analysis used data from some 40,000 individual monthly household data from 1999 to 2007 in cities that straddle Southern California Edison's (SCE) and San Diego Gas & Electric's (SDG&E) shared service border.

As Ito pointed out, response to average rather than marginal price would have implications for the claim that high marginal rates promote conservation. Utilities function in a framework of revenue requirement; with a given revenue requirement, when rates are set higher on the upper tiers, they must be set lower in the remaining tiers. As a result, since average price increases relatively more for some consumers than for others, the aggregate result can be ambiguous. To show the possible perverse result, Ito used his estimated elasticity in a hypothetical demand function and calculated the changes in aggregate consumption in the two cases where: (i) customers respond to average price; and (ii) customers respond instead to marginal price. By comparing the two cases, he concluded that if consumers respond to average price, nonlinear pricing may not reduce aggregate consumption as intended.

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[1] Co-authored by Kiphan Kan, Tram Camba, and Steve Verdon.

[2] See Hogue et al. (2013), Great Lakes Commission (2011), Rawls et al. (2010)

[3] See literature survey of EPRI (2008), Faruqui and Sergici (2010), also Atamturk et al. (2012)

Data

Following Ito's work that compared neighboring utilities, SCE observed aggregate energy usage data between itself and some of its neighboring utilities while examining differences in their pricing structures. Some municipal utilities, such as the Los Angeles Department of Water and Power (LADWP) (Figure 1) and Anaheim Public Utilities (Anaheim) (Figure 2) constitute effective control groups for Southern California Edison (SCE) since they are located in areas that are surrounded by SCE's service territory. The residential customers served by these separate utilities can be presumed to face similar broad climate and economic conditions yet they have experienced somewhat different rate levels and tiered pricing structures through time. SCE examined aggregate energy consumption from the years 2000-2011, including the period beginning in 2001 when the energy crisis changed the pricing structure for SCE in a major way.

Figure 1: Map of LADWP and SCE service territory within the Los Angeles County

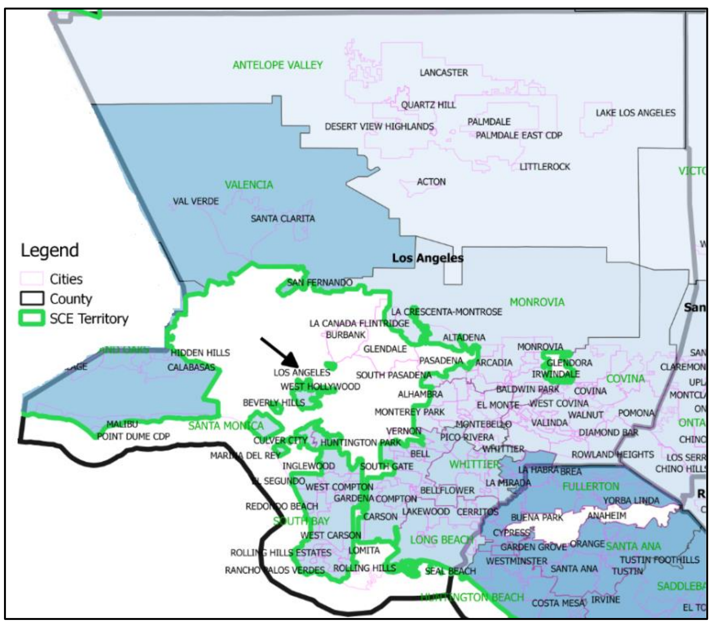
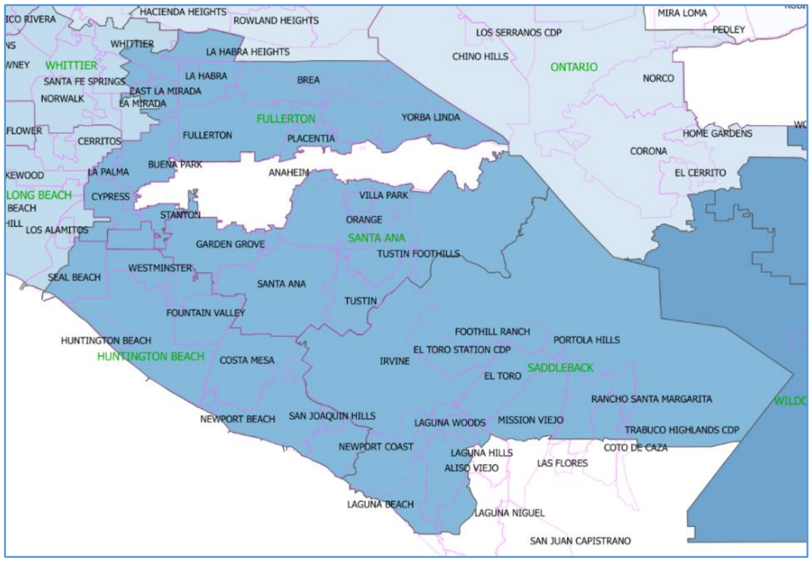


Figure 2: Map of Anaheim and neighboring cities in North and Central Orange County



Rate information was obtained directly from LADWP and Anaheim. In 2000, both SCE and Anaheim had a basic two-tier IBR structure with a modest difference between the first and second tier. In 2001, SCE adopted a 5-tier rate schedule in 2001 while Anaheim's rate structure remained the same (see Figure 4). Starting in 2006, the highest tier for SCE customers was twice that of the highest tier for Anaheim customers. From 2000 to 2008, LADWP had a flat residential rate. Tier rates and different zone allocations were only introduced in 2008.

Figure 3: Pricing Schedules of LADWP and SCE in 2000 through 2012

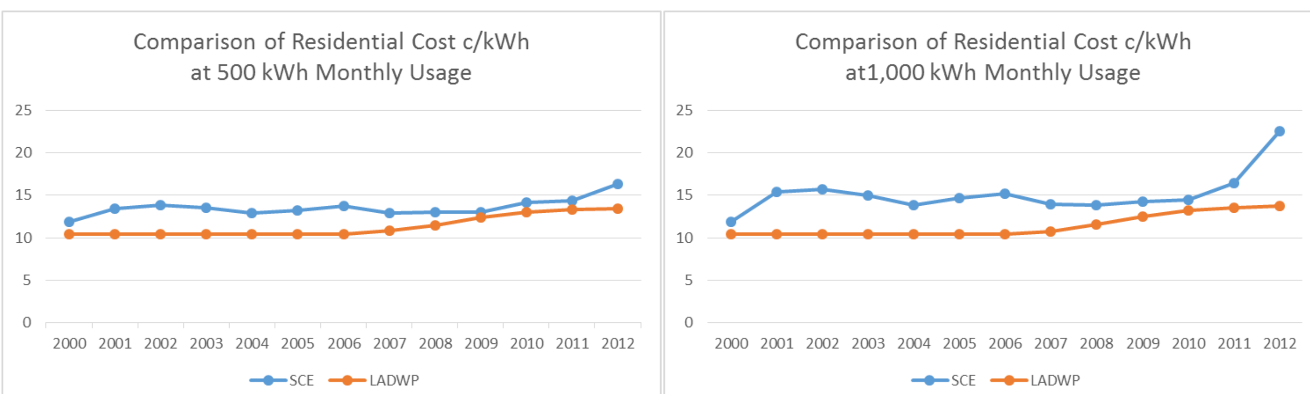
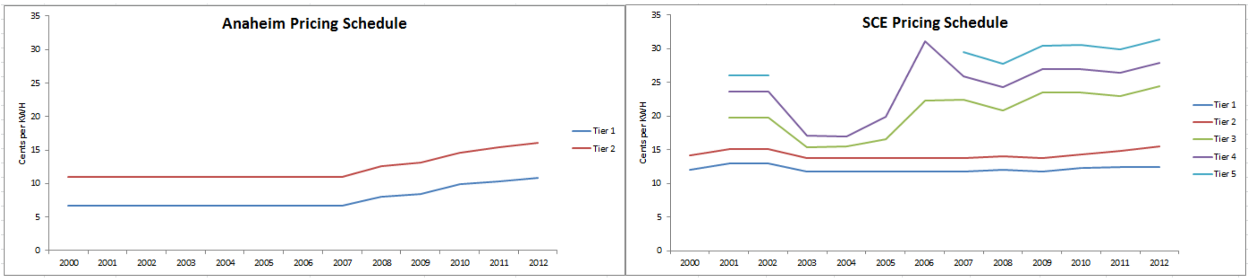
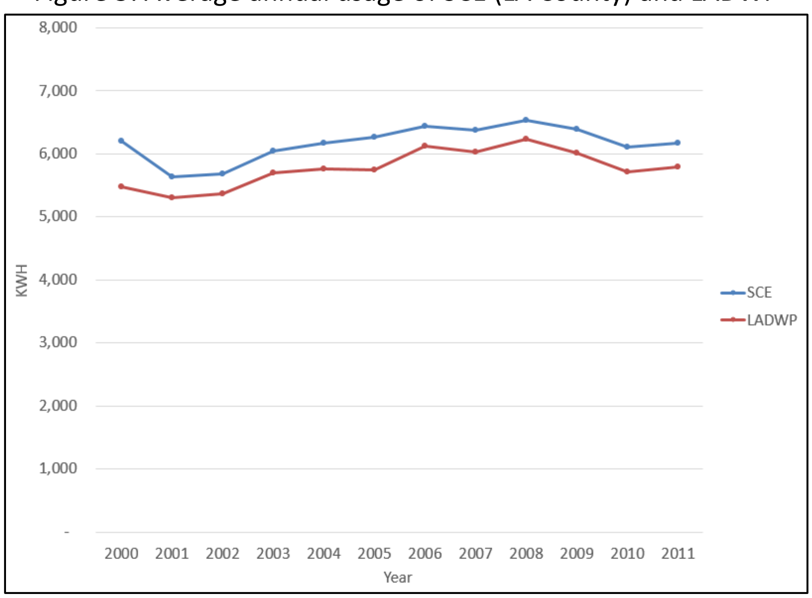


Figure 4: Pricing Schedules of Anaheim and SCE in 2000 through 2012[4]



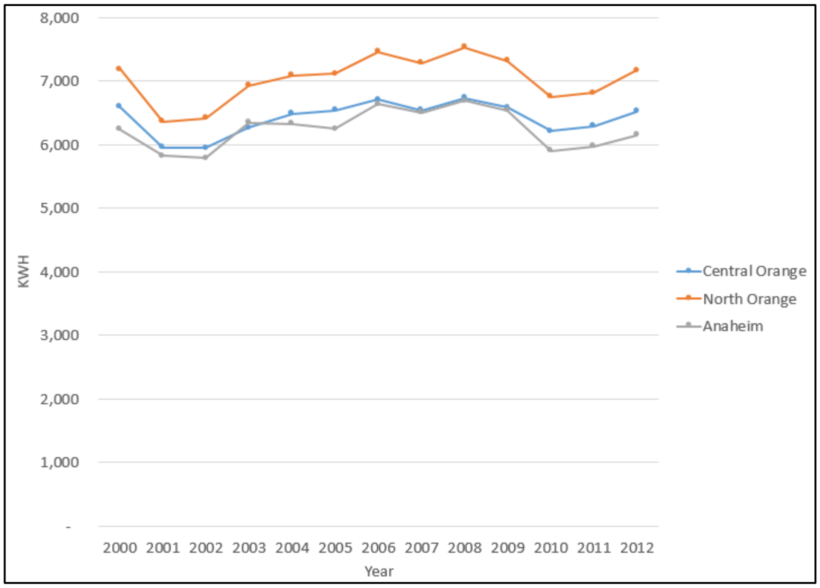
LADWP and Anaheim’s average annual residential usage was reported to the U.S. Energy Information Administration (EIA). We extracted the equivalent numbers for SCE’s areas that surround the two municipalities. For comparison with LADWP, we isolated the usage of our residential customers located in the Los Angeles County. With Anaheim, we separated out the usage of our customers in our North Orange and Central Orange service regions. By comparing neighboring areas that are subject to different price structures, we take advantage of a setup that fits the definition of a quasi-experimental approach, in the sense that some factors external to the ‘experiment’ are controlled. Here, the differences in price structures constitute natural experiments. Figures 5 and 6 reveal that LADWP and Anaheim customers consume on average slightly less energy than their comparison counterparts in SCE, while the usage from year to year consumption displays an almost parallel pattern, despite the differences in price structure.

Figure 5: Average annual usage of SCE (LA County) and LADWP



[4] SCE did not have a Tier 5 in the years 2003-2006.

Figure 6: Average annual usage of SCE (North and Central Orange) and Anaheim customers



Analysis

Using this aggregate data, our approach is two-pronged. First, we compare the year-to-year consumption growth rates of residential customers from SCE's delineated service territory subsets to the corresponding control groups for the years 2000 to 2012. Second, we use a simple regression analysis to assess the impacts of average rates and tiered rate differentials on residential usage.

Comparison of Usage Growth Rates

Figure 7 shows the actual growth ratios and predicted growth ratios from a basic linear regression model. The dependent variable is the ratio SCE year-over-year energy Growth/LADWP corresponding Growth. The independent variable is a yearly trend variable. While the graph shows an upward trend, the slope is statistically insignificant or equivalent to zero.[5] Figures 8 and 9 show similar results for SCE comparable areas to Anaheim. The residential usage growth rate of SCE with respect to LADWP or to Anaheim does not seem to vary much with time, despite the fluctuating gap in marginal prices between the utilities over the period of interest (Figure 4 above).

[5] Removing 2001 results in a nearly perfectly flat relationship (not shown).

Table 1: Regression results of SCE Growth/LADWP Growth vs. Time

Regression Statistics						
Multiple R	0.41430276					
R Square	0.171646777					
Adjusted R Square	0.07960753					
Standard Error	0.02218655					
Observations	11					
ANOVA						
	df	*SS*	*MS*	*F*	*Significance F*	
Regression	1	0.000917999	0.000917999	1.864930262	0.205210496	
Residual	9	0.004430187	0.000492243			
Total	10	0.005348186				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.977451108	0.014347372	68.12753674	1.59781E-13	0.944995098	1.009907118
Trend	0.002888848	0.002115405	1.365624495	0.205210496	-0.001896529	0.007674226

Figure 7: Linear regression model of SCE Growth/LADWP Growth vs. Time

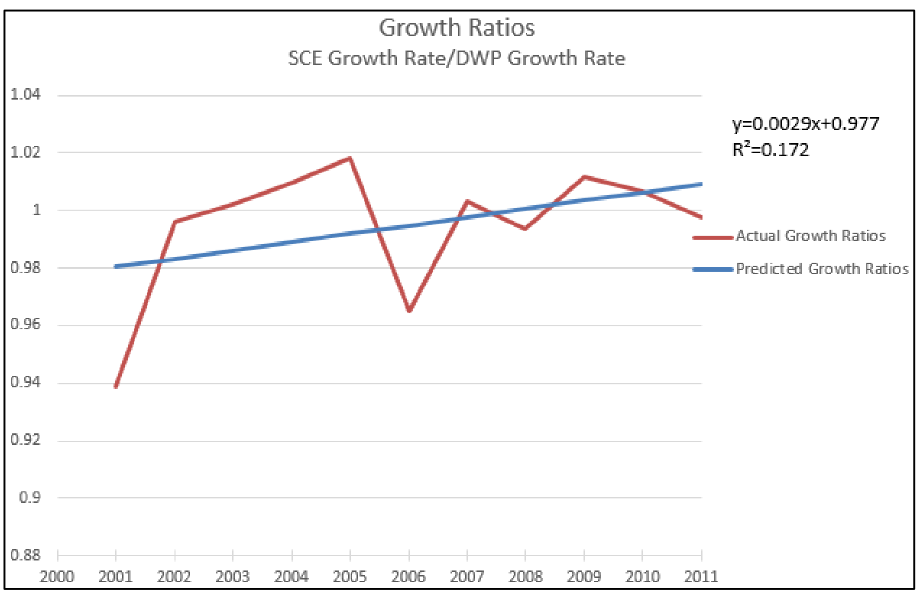
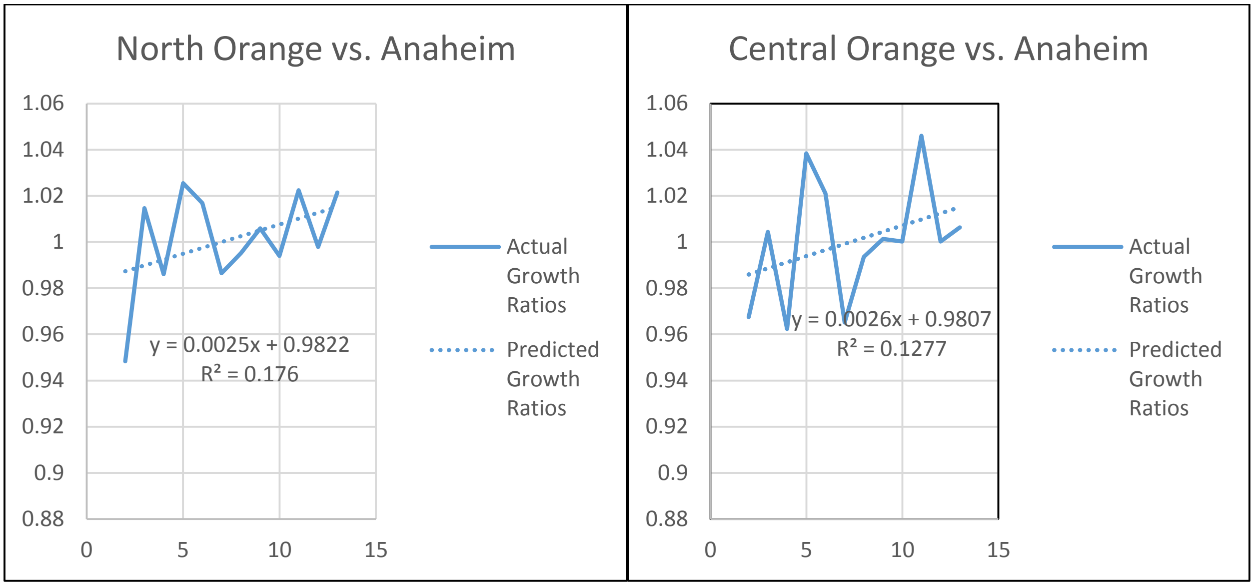


Figure 8 & 9: Linear regression model of SCE Growth/Anaheim Growth vs. Time



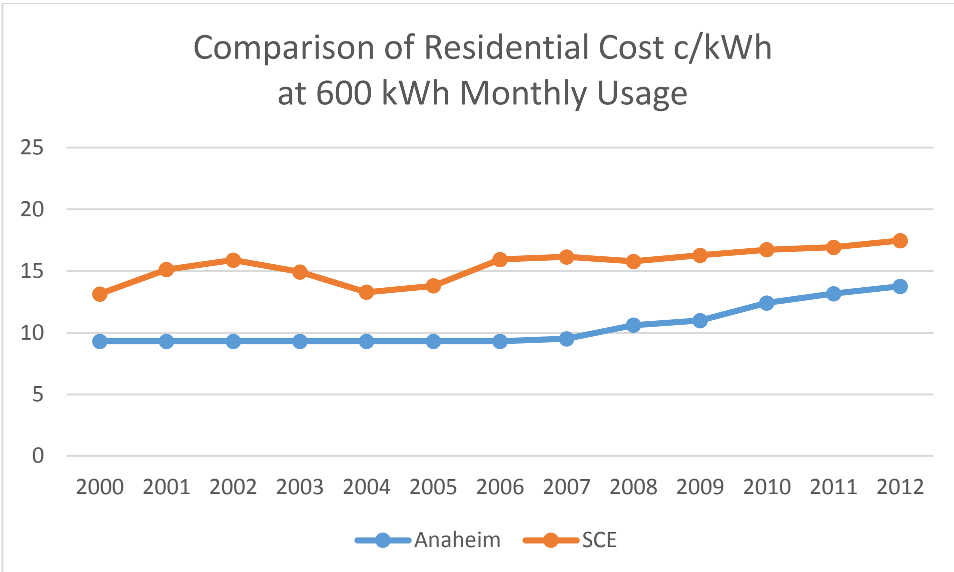
The ratios of growth rates oscillates around 1, which means that usage changes at approximately the same rate year after year across the utilities. The estimated slope, though positive, is not significant which means there is no meaningful divergence of the usage patterns between all the areas considered. It is interesting to consider that the slopes are positive indicating that if there is the germ of a trend, it points to SCE's usage increasing slightly more rapidly than the municipalities', despite SCE's highly tiered rates.

This analysis would suggest that aggregate usage does not seem to be responsive to steep inclining block rates and that there is no conservation resulting from them.

Regression Analysis on Price Variables

In our second approach, SCE performed a regression analysis modeling the average monthly usage for each of the years spanning 2000-2012, using data for Anaheim and SCE's nearby North and Orange County service centers. Among other factors, SCE attempted to test the hypothesis that average annual usage depends on the average price faced by the consumers and the effects of the tiered rate structure, represented by the ratio of the highest tiered rate to the lowest tiered rate. To sidestep the circularity of having usage as the dependent variable and total revenue divided by usage as the average price regressor, we built average price indicators for both SCE and Anaheim by calculating the annual bill for a customer who always consumes 600 kWh per month; the average price is then obtained by dividing the annual bill by 7,200 kWh. We chose a monthly usage of 600 kWh because that is close to the usage of the average residential customer. The price calculation takes into account the appropriate baseline allocation and tier rates for both utilities. Figure 10 charts both price indicators for SCE and Anaheim. Weather also tends to have a big influence on consumption but in this context, the area examined is subject to the same general weather variations. We also include a time trend to capture such effects as a changing mix of end-uses and energy efficiency improvement. The year 2001 stands out because of the energy crisis that affected the whole state of California so we included a dummy variable for that year.

Figure 10: Price Schedules for SCE and Anaheim between 2000 and 2012



The results of the analysis confirm the negative influence of average price on usage. In the three areas examined, an increase of the average price by 1 cent tends to decrease the average monthly usage by 10.7 kWh, other factors being held constant. However, when the gap between the rates in the top tier and the bottom tier widens, usually due to a relatively higher increase in the top tier rate, usage is not significantly affected. As Ito and Borenstein (2014) indicated, when tiered rates are steeply inclined, the more expensive kilowatt-hours are offset by relatively less expensive kilowatt-hours since average rate for the entire class is determined by revenue requirement. Therefore, the usage of some (lower usage) segments in the class may increase while usage for the remaining higher usage customers may decrease. SCE's analysis attempts to discern the aggregate impact of the countervailing effects.

The results also show the significant positive influence of hot weather, the dampening effect of the energy crisis of 2001, and a slight increasing time trend which may indicate that the use of more and bigger electricity end-uses tends to trump the energy efficiency savings made over time.

Regression Model	
Dependent Variable: mkwh	**Average Monthly Usage for Year: Total Annual Usage/Number of Customers/12**

Number of Observations Read	39	Year 2000-2012 for 3 groups: Anaheim, Central Orange, North Orange
Number of Observations Used	39	

Analysis of Variance					
Source	**Degrees of Freedom**	**Sum of Squares**	**Mean Square**	**F Value**	**Probability > F**
Model	7	50097	7156.78	41.7	<.0001
Error	31	5320.311	171.62		
Corrected Total	38	55418			
Root Mean Square Error	13.10	R-Square	0.90		
Dependent Mean	547.25	Adjusted R-Square	0.88		
Coefficient of Variation	2.39				

Parameter Estimates							
Variable	**Label**	**DF**	**Parameter Estimate**	**Standard Error**	**t Value**	**Probability > |t|**	
Intercept	Intercept	1	508.60	29.68	17.14	<.0001	Anaheim is base group
C_Orange	Central Orange	1	69.96	14.65	4.77	<.0001	1 if Central Orange, 0 else
N_Orange	North Orange	1	121.55	14.65	8.3	<.0001	1 if North Orange, 0 else
price600	Average Price Indicator in c/kWh	1	-11.48	2.85	-4.02	0.0003	Sum of monthly bills for usage of 600 kWh/ 7,200
tier_ratio	Max Tier Rate/Min Tier Rate	1	4.45	7.27	0.61	0.5455	
CLDD	Annual Cooling Degree Days	1	0.06	0.01	6.12	<.0001	
t	Trend	1	3.67	1.12	3.28	0.0025	1 for year 2000, 2 for year 2001,
y01	Year 2001	1	-21.03	9.31	-2.26	0.031	1 if year 2001, 0 else

Results

All these results point to the fact that aggregate usage is significantly affected by changes in average price, it seems to be fairly insensitive, with an insignificantly positive relationship to the degree of tiered price structure. Whether we have flat rates or tiered rates and whether the rate differential between the tiers is smaller or larger, the usage patterns seem to parallel each other in neighboring areas, indicating that their variations are influenced more heavily by factors other than the tiered price differential.

Advocates of high marginal tier rates tout them as necessary incentives for conservation. However, as Ito pointed out, consumers do not tend to respond to marginal prices in cases of non-linear pricing, mainly because the information cost of acquiring the understanding is high and because it is difficult for consumers to get a sense of cumulative usage in a billing period. Moreover, the estimated response to average price or elasticity seems to be very low. In his own estimation, Ito pegged the elasticity at around -0.1. Even in earlier studies, estimates of price elasticities calculated with changes in marginal price did not yield very high values. For example, the often cited study of Reiss and White (2005) gives a range between -.08 and -0.1 for California households depending on whether they have air conditioning or electric space heating. With low elasticities, it would take big increases in prices to start seeing decrease in usage. Also for IBR to have an effect, as Ito, Faruqui, Kahn and Wolak (2013) have called out, customers have to be well informed and well educated about the pricing scheme and real time data should be more accessible. So far, the discussion has focused mainly on the household or customer level but how does this behavior translate to the macro level? Ito only offered a simulation. Our goal here was to bridge the gap, to examine whether historical aggregate data for SCE and its neighboring utilities support the claim of the conservation effect of highly tiered rates. The results indicate that other factors may affect aggregate electricity usage more than price. Year to year changes show that such factors probably include weather, and the propensity of consumers to acquire more energy consuming appliances.

References

Atamturk, N., M. Zafar and P.Clanon.2012. “Policy and Planning Division Literature Review”. California Public Utilities Commission.
http://www.cpuc.ca.gov/puc/emergingissues

Borenstein, S. 2009. “To What Electricity Price Do Consumers Respond? Residential Demand Elasticity Under Increasing-Block Pricing.”
http://faculty.haas.berkeley.edu/borenste/download/NBER_SI_2009.pdf

EPRI. 2008. “Price Elasticity of Demand for Electricity: A Primer and Synthesis,” Palo Alto, California.

Faruqui, A. 2008. “Inclining Toward Efficiency – Is Electricity Price-Elastic Enough for Rate Designs to Matter?” *Public Utilities Fortnightly.*

Faruqui, A. and S. Sergici. 2010. “Household Response to Dynamic Pricing of Electricity: a Survey of 15 Experiments.” *Journal of Regulatory Economics* 38(2), pp. 193-225.

Great Lakes Commission. 2011. “Literature Review of the Influence of Water Rate Structures and Price on Water Usage and Associated Benefits.”
http://glpf.org/sites/default/files/project_files/921%20Literature%20Review%20of%20the%20Influence%20of%20Water%20Rates%20on%20Usage.pdf

Hogue, T. S., S. Pincetl and C. Mini. 2013. "Los Angeles Residential Water Consumption: Patterns and Key Drivers." Presentation at UCLA Symposium, February 26.

Ito, K. 2014. "Do Consumers Respond to Marginal or Average Price? Evidence from Nonlinear Electricity Pricing." *American Economic Review* 104(2), pp. 537-63.

Kahn, M. and F. Wolak. 2013. "Using Information to Improve the Effectiveness of Nonlinear Pricing: Evidence from a Field Experiment"
http://web.stanford.edu/group/fwolak/cgi-bin/sites/default/files/files/kahn_wolak_July_2_2013.pdf

Rawls, C., T. Borisova, S. Berg, and J. Burkhardt. 2010. "Incentives for Residential Water Conservation: Water Price, Revenue, and Consumer Equity in Florida." Selected Paper prepared for presentation at the Southern Agricultural Economics Association Annual Meeting, Orland, FL, February 6-9, 2010.
http://ageconsearch.umn.edu/bitstream/56510/2/Incetives%20for%20Residential%20Water%20Conservation%20a.pdf

Reiss, P. and M. White, 2005. Household electricity demand revisited. *Review of Economic Studies* 72, 853-858.

U. S. Energy Information Administration
http://www.eia.gov/electricity/sales_revenue_price