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Equity Effects of Increasing-Block Electricity Pricing

Severin Borenstein[1]

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Abstract: Utility regulators frequently attempt to use tariff structures to pursue both distributional and efficiency goals. Efficiency necessitates setting prices as close to marginal costs as possible while still allowing the firm to cover its costs. The common distributional goal is to protect low-income customers from high prices. Perhaps nowhere is the conflict between these goals greater than in the use of increasing-block residential utility pricing, in which the marginal price to the customer increases as the customer's usage rises. Since the 2000-01 California electricity crisis, the state has adopted some of the most steeply increasing-block tariffs in electric utility history, but the distributional and efficiency effects have not been analyzed in detail. Using a novel approach for matching customer bill data with census data on area income distributions, I derive estimates of the income redistribution effected by the increasing-block tariffs used by California regulated electric utilities. I find that the rate structure does redistribute income to lower-income groups, but that the effect is fairly modest, particularly compared to a means-tested program also in use. While the distributional impact of these tariffs do not seem to be large, the efficiency costs may not be great either. Examining the distribution of customer demand quantities, I find preliminary evidence that customers do not respond to the increasing marginal prices they face.

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I. Introduction

With rising energy costs and growing awareness of the threat of climate change, policy makers are increasingly coming to the realization that retail energy prices are going to have to rise. At the same time, there is concern that higher energy prices, attributable to resource scarcity, market power or greenhouse gas policies, will disproportionately impact the poor. In the electricity utility sector, this tension between income distribution concerns and high energy prices has been recognized for decades. Since the 1980s, it has led to widespread adoption of increasing-block electricity rate schedules in the United States. Supporters of increasing-block pricing argue that these tariffs promote conservation by setting high marginal prices for many consumers while protecting small energy consumers, and especially the poor, by keeping the price for a baseline level of consumption relatively low.[2]

California's regulated utilities adopted increasing-block residential electricity tariffs in the 1980s. Prior to the California electricity crisis in 2000-01, all three of the regulated utilities in California—Pacific Gas & Electric (PG&E), Southern California Edison (SCE), and San Diego Gas & Electric (SDG&E)—had two-tiered residential rate structures where the marginal price in the second tier was 15%-17% higher than in the first tier. That was in line with the structure in many other states.

After the California electricity crisis, these three investor-owned utilities (IOUs) needed to raise substantial revenues, but regulators and State legislators were concerned about the impact on lower-income households. Regulators adopted a five-tier increasing-block retail pricing structure where the prices on the first two tiers were frozen at pre-crisis levels and incremental revenue needs were to be collected by raising prices on tiers 3, 4 and 5. The result has been a much more extreme increasing-block tariff structure. By 2008, the price on the highest block—which is the marginal price for about 6%-9% of all residential customers—ranged from about 80% higher to more than triple the price on the lowest

[2] Declining-block pricing—under which the marginal price of electricity to the customer is lower for units of consumption beyond a certain baseline level—had been common in the 1960s and 70s. In the following decades, with increasing focus on conservation, it became seen as promoting wasteful consumption of power.

block, depending on the utility.

Regardless of one's views of the externality costs of electricity consumption and the need for conservation, it is clear that increasing-block electricity pricing distorts the relative marginal prices that different customers face. Evidence that heavy residential users impose higher costs on society per unit of consumption is scarce.[3] Thus, the use of increasing-block pricing presents a classic tradeoff between efficiency and distributional effects in regulated tariff design. There is, however, very little firm evidence on the magnitude of this tradeoff, and none that is based on a large-scale systematic empirical study.

Combining residential bill data with income data at the census block group level from the U.S. Census, I first develop an approach that yields upper and lower bounds on the income redistribution effects of the steeply-tiered residential rate structure. With further analysis, I then develop a better estimate of where between the bounds that the effect lies. I find that low-income customers receive modest benefit from California's current steeply-tiered rate structure compared to the bills they would have paid had the utilities continued using a two-tier structure that has only a small price differential between the tiers.

Separate from the analysis of electricity rates, this approach to analyzing redistributional effects using income data from the U.S. census has implications for a wide variety of studies that use census block group level data to look at the effect of public policies on income distribution or vice versa. Many studies use the median household income for a census block group to represent the income of all households in that area. There is, however, great heterogeneity of household incomes within census block groups, so use of the available data on distribution across income brackets may be much more informative, particularly for analyzing impacts on low-income households.

While the primary focus of this paper is on redistributional effects, a complete analysis of the effects of increasing-block electricity pricing would also require study of the efficiency

[3] Suggestions of such a differential are based on the correlation between the timing of consumption patterns and overall use, but the increasing-block tariff takes no account of the timing of use. See Marcus (2007).

effects of such pricing. A critical component of such an analysis would be estimation of the elasticity of demand that customers exhibit with respect to changes in the marginal price that they face. A number of papers have estimated such elasticities on the maintained assumption that customers optimize, possibly imperfectly, against the rate schedule that they face. In the penultimate section, I present preliminary evidence on this assumption, evidence that seems to sharply contradict it.

II. Increasing-Block Residential Electricity Rates in California

The October 2007-September 2008 averages of the standard residential tariffs for each of the three IOUs in California are shown in the top panel of table 1. The increasing-block tariff structure implies an increasing *marginal* price for electricity. A PG&E customer whose consumption level puts him or her on the fifth tier, for instance, still pays the lower-tier rates for consumption up to 300% of baseline.[4]

The marginal rate that a residential customer pays increases as consumption increases relative to a "baseline" consumption level. A household's baseline allocation is supposed to correspond to a minimal basic electricity usage. The baseline, however, is the same for all residential customers in a region regardless of the size of the residence or the number of people who live there. Within the region, a studio apartment receives the same baseline allocation as a four-bedroom house.[5] Baseline allocations do differ by geographic regions within the utility area: PG&E's service territory is divided into 10 different baseline regions, SCE's into 6 different regions, and SDG&E's into 4 regions. This is argued to reflect variation in basic electricity need due to climate differences, but in practice baselines are set based on different average usage across regions. As a result, variation is driven not only by climate differences, but also by wealth levels, average residence size, and choices to install air-conditioning.

[4] For example, under the standard residential rate shown in table 1, a PG&E customer with a baseline consumption allocation of 300 kWh during a given billing period who actually consumes 1100 kWh would pay 11.53¢ for each of the first 300 kWh, 13.11¢ for each of the next 90 kWh, 22.56¢ for each of the next 210 kWh, 31.28¢ for each of the next 300 kWh, and 35.85¢ for each of the last 200 kWh.

[5] The baseline allocation is higher for customers who have electric heating systems and some other electrical appliances.

Tier	% of Baseline Quantity	Pacific Gas & Electric Standard Residential Rate	Pacific Gas & Electric CARE Low-income Rate	Southern California Edison Standard Residential Rate	Southern California Edison CARE Low-income Rate	San Diego Gas & Electric Standard Residential Rate	San Diego Gas & Electric CARE Low-income Rate
Benchmark Rates (usage-weighted average rates October 2007-September 2008)							
1	0-100%	$0.1153	$0.0832	$0.1172	$0.0837	$0.1294	$0.1287
2	100%-130%	$0.1311	$0.0956	$0.1374	$0.1058	$0.1500	$0.1488
3	130%-200%	$0.2256	$0.0956	$0.2176	$0.1666	$0.2076	$0.1911
4	200%-300%	$0.3128	$0.0956	$0.2533	$0.1673	$0.2250	$0.1926
5	300%+	$0.3585	$0.0956	$0.2893	$0.1683	$0.2363	$0.1956
Alternative Two-Tier Rates for non-CARE only (CARE rates same as in Benchmark case)							
1	0-100%	$0.1521	*same as*	$0.1506	*same as*	$0.1503	*same as*
2	100%+	$0.1764	*above*	$0.1748	*above*	$0.1744	*above*
Alternative Flat-Rate Tariff for non-CARE only (CARE rates same as in Benchmark case)							
	0%+	$0.1618	*same as above*	$0.1615	*same as above*	$0.1607	*same as above*
Alternative Five-Tier Rates with no CARE program							
1	0-100%	$0.1020		$0.1076		$0.1287	
2	100%-130%	$0.1178		$0.1278		$0.1493	
3	130%-200%	$0.2123		$0.2080		$0.2069	
4	200%-300%	$0.2995		$0.2437		$0.2243	
5	300%+	$0.3452		$0.2797		$0.2356	
Alternative Two-Tier Rates with no CARE program							
1	0-100%	$0.1375		$0.1390		$0.1482	
2	100%+	$0.1595		$0.1612		$0.1720	
Alternative Flat-Rate Tariff with no CARE program							
	0%+	$0.1459		$0.1483		$0.1579	

Table 1: Benchmark and Alternative Retail Electricity Rates

Prior to the California electricity crisis in 2000-01, each of the three utilities had a two-tier rate structure with prices near those on the first two tiers of the structure shown in top panel of table 1. All consumption above the baseline level was charged at the second-tier rate.

Clearly, there are now substantial differences across the utilities, owing in part to the differences in economic losses they incurred during the California electricity crisis. As a result, the top-tier consumption for SDG&E customers faces a marginal rate of about 83%

higher than the rate for baseline consumption, while PG&E customers on the top tier face a marginal rate 211% higher than the price for consumption below the baseline level. The figure is 147% for SCE.

Not all residential customers of the IOUs are on the standard tariff. The largest exception from the standard tariff is customers who are on the CARE (California Alternate Rates for Energy) program, which is an income-based program that offers lower rates to low-income customers.[6] Across the three utilities, 24.4% of all residential customers were on CARE in 2006, comprising 21.4% of residential electricity consumption. At all three utilities, the CARE program is advertised as offering "a 20% discount" off the standard residential rates, but not all components of the bill are included in the discount and the exact implementation varies across utilities. In practice, the discount is 20%-30% on the lowest two tiers of consumption and can be greater than that for higher tiers. The standard residential rate for customers on the CARE program are shown in the right-hand column of the top panel of table 1.

A small number of customers are on special tariffs that incorporate time-of-use electricity pricing, interruptible air-conditioning use, mobilehome/RV/marina accounts, or other idiosyncratic rate structures. In aggregate, these nonstandard tariffs cover 3.6% of residential customers, who consume 5.9% of residential power. Most of these customers still face a five-tier tariff with the same baseline allocation and breakpoints between the tiers as if they were on the standard residential tariff, but with somewhat different rates.

Regardless of the tariff that a customer is on, the customer has a baseline allocation and his or her monthly consumption can be allocated across the five tiers shown in the left-hand column of the top panel of table 1. The top panel of table 2 shows the total quantity of residential consumption that was billed on each of the tiers during 2006, the year on which this analysis focuses.[7] The lower-income customers who are on the CARE

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[6] For June 2008 through May 2009, a residence with one or two occupants must have a household income no higher than $30,500 in order to qualify for CARE, with the threshold increasing by $5,300 for a third occupant, and by $7,400 for each additional occupant.

[7] As explained below, the "2006" data for PG&E cover December 1, 2005-November 30, 2006.

		Residential Usage	Percentage of Total Residential Usage					CARE/Non-CARE Shares	
		(million-kWh)	tier 1	tier 2	tier 3	tier 4	tier 5	% Usage	% customers
PG&E	Non-CARE	22,448	60.1%	11.1%	15.9%	8.9%	3.9%	78.7%	76.9%
PG&E	CARE	6,073	67.7%	10.4%	13.3%	6.4%	2.2%	21.3%	23.1%
SCE	Non-CARE	21,129	55.2%	11.1%	16.9%	10.8%	6.0%	76.7%	72.7%
SCE	CARE	6,401	66.5%	10.8%	13.6%	6.7%	2.5%	23.3%	27.3%
SDG&E	Non-CARE	5,967	56.8%	10.6%	15.7%	10.2%	6.7%	85.5%	80.9%
SDG&E	CARE	1,013	73.5%	9.2%	10.5%	4.8%	2.0%	14.5%	19.1%

		Percentage of Customers on Each Tier for Marginal Consumption				
		tier 1	tier 2	tier 3	tier 4	tier 5
PG&E	Non-CARE	37.6%	14.7%	24.8%	15.5%	7.4%
PG&E	CARE	47.5%	15.7%	21.8%	11.0%	4.0%
SCE	Non-CARE	32.0%	14.5%	25.5%	17.5%	10.4%
SCE	CARE	45.3%	16.8%	22.9%	10.9%	4.1%
SDG&E	Non-CARE	38.1%	14.3%	23.2%	14.8%	9.7%
SDG&E	CARE	58.9%	14.8%	17.0%	6.9%	2.5%

Table 2: Distribution of Retail Consumption Across Tariff Tiers

program consume less on average than other residential customers, but there is substantial overlap in the distributions with many low-consuming customers who are not on CARE, and some CARE customers with consumption levels even out to the fifth tier. The bottom panel of table 2 shows the proportion of households whose average daily consumption puts them on each of the five tiers in the rate structure. Among PG&E's non-CARE customers, for instance, 37.6% consume less than the baseline and therefore face the tier 1 price for their marginal consumption, while 7.4% consume more than 300% of baseline so face the tier 5 price for their marginal consumption.

With billing data alone, comparison of CARE to non-CARE customers is about all one can do to analyze the consumption patterns of richer versus poorer customers. This is, however, not the most useful comparison for analysis of the five-tier tariff system, because restructuring of that tariff system could, and likely would, be designed to treat CARE customers separately. The more useful analysis for a policy debate about the five-tier tariff would be a comparison among customers who are not on the CARE program. This is not possible with the billing data alone, but merging the billing data with census data on income levels by location can be very informative. That is what the remainder of the paper does.

III. Data Sources

The data for this analysis come from utility residential billing records and the U.S. census. Utility residential billing records were made available to the U.C. Energy Institute by all three California investor-owned utilities (IOUs) on a confidential basis. The data used in this analysis include virtually all residential bills for 2006. Customers who were not individually metered, but instead are part of a "master-metered" building or other location, were not included in the data. In aggregate, such accounts constitute less than 3% of residential consumption at each of the utilities.

The data do not include the address or the name of the customer. They do, however, include the nine-digit ZIP code, which allows a fairly precise neighborhood matching with census data. The utility data also include usage on each of the five tiers, days in the billing period, tariff (including whether or not the customer is on the CARE program), total amount billed, and (for PG&E and SCE) assigned baseline quantity.

Actual billing periods do not begin and end exactly at the beginning and end of the calendar year, so annual bills were created by interpolating usage and charges for bills that overlapped the beginning and end of the year.[8] Data for PG&E, unfortunately, did not extend beyond the end of 2006, so billing periods that ended after December 31, 2006 would be lost if I were to apply this procedure to PG&E. To avoid this problem, the period of analysis for PG&E was shifted by one month and I instead studied December 2005-November 2006.[9]

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[8] For instance, a bill that included 13 days at the end of 2005 and 18 days at the beginning of 2006 was incorporated into the annual bill by adding 18/31 of the usage and 18/31 of the billed amount to the annual bill.

[9] I also dropped bills with outlier quantities, which were defined as less than 2 kWh/day or more than 80 kWh/day. A refrigerator typically uses at least 1-2 kWh/day, so it is implausible that an occupied primary residence would fall below 2 kWh/day. The 80 kWh/day translates to a constant consumption of 3.33 kW at all time which would require a central air conditioning unit to be running (not just turned on, but never cycling off) practically continuously. Including these observations does not change the qualitative results, but does increase the estimated redistribution.

Summary household income data are available from the U.S. Census at the level of census block group (CBG), a geographic designation that on average includes about 800 households. Census block groups are considerably larger than the areas associated with nine-digit ZIP codes. Each nine-digit ZIP code is assigned to the CBG in which it was located.[10] The analysis presented here was then carried out at the CBG level. Results presented here use 2000 census data updated to 2007 by Geolytics, but the results are very similar if the analysis is based on the original 2000 data.

Census Measures of Household Income

Household income data at the CBG level includes median household income and mean per capita income.[11] These summary measures are frequently used by associating them with every household in the CBG. Unfortunately for the purpose of economic analysis, there is considerable income heterogeneity within CBGs. This is evident from other data released by the Census that break down households into five different income brackets for each CBG in the 2000 census: $0-$20,000, $20,000-$40,000, $40,000-$60,000, $60,000-$100,000, and over $100,000. In the 17768 census block groups I consider in California — those served by the three investor-owned utilities — the breakpoints between these categories correspond to the 18th, 41st, 59th and 82nd percentiles in the distribution of household income.

It would be very convenient for this analysis if all of the population in a given CBG fell into one of these income brackets, but unfortunately that appears to be far from the case. Looking at the shares of households in each bracket, one can calculate a Herfindahl index to measure concentration of households within the income brackets for a given CBG. This index is the sum of the squared shares of population in each bracket. With five groups, it has a minimum of 0.2 (if households were evenly divided across the five brackets) and

[10] A small number of customer records did not include a nine-digit ZIP code, or did not match to a nine-digit ZIP code in the census data. In the case of nine-digit ZIP codes that did not match to the census data, I used the numerically closest nine-digit ZIP code. In the case of having only a five-digit ZIP code, those customers were allocated probabilistically among all of the nine-digit ZIP codes within the five-digit ZIP code based on the share of households that were in each of the nine-digit ZIP codes.

[11] Household income data from the U.S. Census are based on the "long form" questionnaire that is distributed to about 17% of all households.

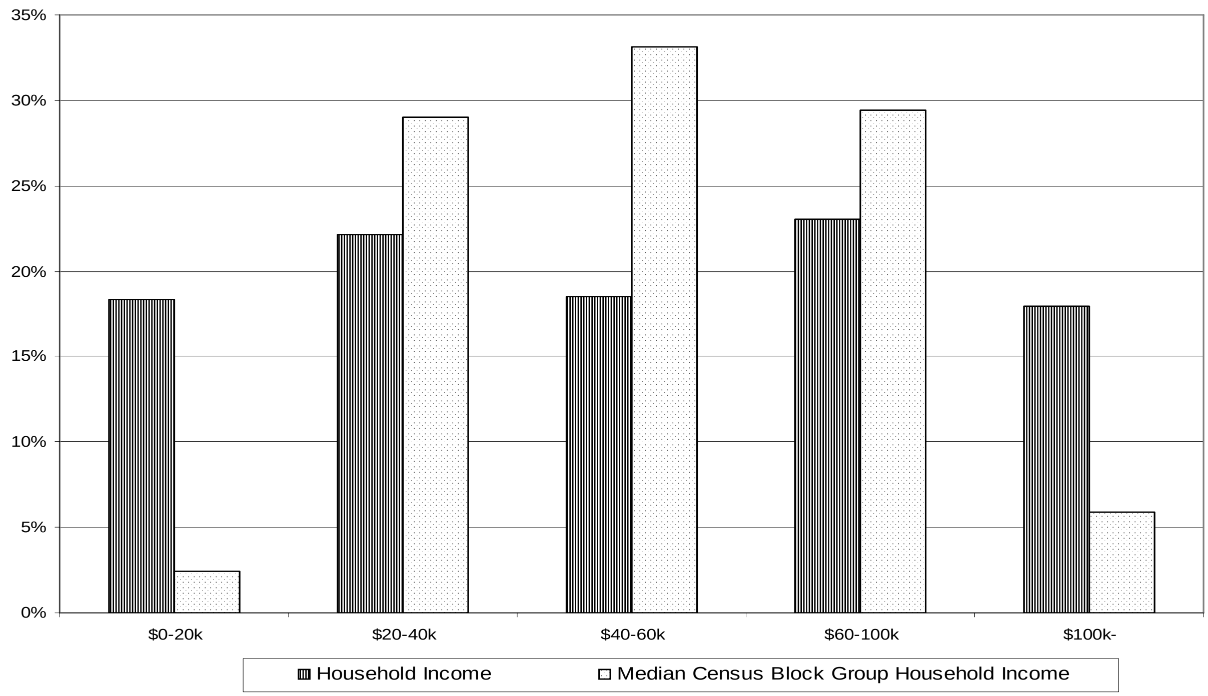

Figure 1: Distribution of Household Income and Median Household Income (weighted by households) By Census Block Group

a maximum of 1 (if households were all in the same bracket). Calculating this index for the census block groups I examine in California, the average value is 0.29, indicating more dispersion than if the population within each CBG were evenly divided across three income brackets (which would yield a value of 0.33).

A common approach in studying various aspects of income distribution is to assign every household within a CBG the median household income or mean per capita income for that CBG. Doing so tends to move the income associated with all households towards the center of the overall income distribution. More extreme high and low income levels tend to be underrepresented. Figure 1 illustrates this effect by showing the households-weighted distribution of median household incomes within CBGs and the assignment of individual households to each of the five income brackets. About 18% of households report income below $20,000, but only about 2.5% of households live in CBGs with a median income below $20,000.

Thus, it will be important for this analysis to account for income heterogeneity within the CBGs. I do that in a variety of ways, as explained in the next section.

IV. Creating Benchmark and Counterfactual Bills

I begin the analysis by constructing the bills that each customer would face under alternative tariff structures. Essentially, this amounts to calculating the alternative tariff structures under the constraint that they all generate the same total revenue. Implicit in this exercise is the assumption that demand is completely inelastic, so that a customer will consume the same quantities regardless of which tariff they face. Obviously, this is not completely realistic if customers exhibit some elasticity with respect to the marginal price variation after controlling for the system average price. I return to this issue in section VII. The focus in this study, however, is transfers of the revenue burden, not economic efficiency. Electricity demand is generally considered to be fairly inelastic, but incorporating a small demand elasticity that is uniform for all customers does not substantially change the results.[12]

The first set of bills calculated are referred to as the "benchmark" bills and are based on the prices in the top panel of table 1. All customers not on the CARE program are assumed to be charged the standard residential rates and all customers on the CARE program are assumed to be charged the CARE rates. As mentioned earlier, a small percentage of customers are not on either of these rates, but exclusion of them from the sample does not noticeably change any results. Using the rates in effect for October 2007-September 2008 in combination with quantities consumed during 2006 is imperfect, though it is consistent with the zero-elasticity demand assumption. Given that the consumption data are from 2006, one could use the rate structure in effect during 2006—or at least some average of

[12] The intuition for why this is so is as follows: Elasticity increases the gains that high-consumption customers would receive from a flattening of the tariff structure only for the additional units that such customers consume when the marginal price is lower. There are few of such units if demand is fairly inelastic and the gains from consuming those units are on average about half of the difference between the old and the new marginal price. Similarly, elasticity reduces the losses that low-consumption customers would suffer from a flattening of the tariff structure only for the marginal units that such customers stop consuming when the marginal price is higher. There are few of such units if demand is fairly inelastic and the loss they would incur from consuming those units are on average about half of the difference between the old and the new marginal price.

the rate structures in effect, since they changed frequently throughout the year—but since the goal is to examine the likely effects of a change in tariff structure going forward, using the most recent tariff seems to be more appropriate.[13]

The primary alternative tariff structure that I consider, shown in the second panel of table 1, leaves the CARE rates unchanged (remaining at the prices in the top panel of table 1), but imposes a two-tier tariff on all non-CARE customers with the rate on the second tier set to 16% above the rate on the first tier. This figure was chosen because each of the IOUs had a two-tier tariff prior to the California electricity crisis with approximately a 16% rate differential between the two tiers. The level of these two-tier rates is calculated to raise the same revenue in aggregate from non-CARE customers as the five-tier non-CARE rates in table 1, holding constant the quantities consumed.

One could also calculate an alternative untiered or flat-rate structure, a single price charged for every kWh consumed by all non-CARE customers, and I have done that. They are fairly similar to the two-tier results, though with slightly larger redistributional effects. A policy shift to a completely flat retail rate structure appears, however, to be quite unlikely.[14]

Because the focus of this analysis is the effect of the multi-tiered rate structures on the poor, for comparison purposes it also seems worthwhile to consider the effect of the CARE program on the electricity costs of the poor. In order to do that, I create counterfactual tariffs in which there is no CARE program and all customers are on the same tariff. The third and fourth panels of table 1 present five-tier and two-tier tariffs in the absence of the CARE program that generate the same total revenue that results from the tariffs in the top panel with the existence of the CARE program.[15]

[13] The changes between 2006 and 2008, however, have been fairly small. Earlier calculations using 2006 tariffs yielded very similar results.

[14] These results are presented in the appendix B.

[15] The five-tier no-CARE rate is created by calculating the constant c that would be deducted from the price on each of the five tiers in the standard residential rate in order for this tariff to yield the same total revenue after inclusion of the formerly-CARE customers as is generated by the tariffs in the top panel of table 1. The basis for using a constant c per kWh is that the CARE program is financed in part with an constant per-kWh charge for all non-CARE customers. The two-tier no-CARE rate is created

With these tariffs, the quantities consumed by each customer, and the assumption of no demand elasticity, it is straightforward to generate the total amount each customer would be billed under each of these tariffs. The more challenging aspect of the analysis is to match customers with income brackets, as is discussed in the next section.

V. Matching Customers to Income Brackets

As explained earlier, with very high accuracy each customer can be matched to a census block group. The census data include the distribution of household income across five income brackets, as was described in the data section. The income brackets are helpful in capturing the tails of the distribution, but they are especially useful if one can use other information to allocate households within a CBG across the income brackets. Two pieces of information in the billing data are valuable in this regard.

First, we know from the billing data which customers are on a CARE tariff. These customers are disproportionately from the poor end of the income distribution. Based on utility reports, I assume that 65% of all customers who are eligible for the CARE program are on it. This is slightly lower than the participation rates that the utilities report, but for reasons that I explain in appendix A, the reported participation rates may overstate actual rates among eligible households. That said, using a 70% participation rate that more closely reflects the rates reported by the utilities in 2006 doesn't substantially change the results.

To incorporate this information, the CBG income distribution data are first used to determine the share of the households in the CBG that will fall into each of the five income brackets. From the billing data, we know the total number of CARE customers in the CBG. So, starting from the lowest income bracket we allocate 65% of the household "slots" to CARE customers.[16]

For instance, if the total number of CARE customers in the CBG is less than 65% of the

by imposing a 16% step between tiers and finding the levels that generate the same total revenue.

[16] I present the algorithm in terms of household "slots," but it is somewhat more complicated because many households are in the sample for less than the full 365 days of the year. In practice, this means that household-days, rather than households, are allocated across the income brackets.

household "slots" in the lowest income bracket, then all CARE customers are assumed to fall in the lowest income bracket.[17] If the total number of CARE customers in the CBG is greater than 65% of the household slots in the lowest bracket, then 65% of the slots in that bracket are allocated to CARE customers and remaining CARE customers are carried over to the second lowest income bracket. The same algorithm is then applied to the second lowest income bracket and if there are remaining customers, they are carried over to the third lowest income bracket, and so on. In the extremely small number of cases where this algorithm yielded leftover CARE customers beyond the highest income bracket, *i.e.,* the number of CARE customers exceeded 65% of the total number of households that received utility bills in the CBG, the CARE customers were simply divided proportionately across the population.

To be concrete, assume that a census block group has H households that receive electricity bills and the billing data indicate that H_c of them are on the CARE program. Assume that, according to the census, the shares of population in the income brackets are $s_1, ..., s_5$ where s_1 is the lowest income bracket. Finally, assume that the share of customers eligible for CARE who actually sign up, *i.e.,* the CARE participation rate, is p. Then, with s_{ic} representing the share of all customers who are in income bracket i and are on the CARE program, the allocation can be broken into six cases:

1. If $Hps_1 > H_c$ then $s_{1c} = \frac{H_c}{H},\ s_{2c} = s_{3c} = s_{4c} = s_{5c} = 0$;
2. If $Hps_1 < H_c < Hp(s_1 + s_2)$ then $s_{1c} = ps_1,\ s_{2c} = \frac{H_c - s_{1c}H}{Hs_2},\ s_{3c} = s_{4c} = s_{5c} = 0$;
3. If $Hp(s_1 + s_2) < H_c < Hp(s_1 + s_2 + s_3)$ then $s_{1c} = ps_1,\ s_{2c} = ps_2,\ s_{3c} = \frac{H_c - (s_{1c} + s_{2c})H}{Hs_3},\ s_{4c} = s_{5c} = 0$;
4. If $Hp(s_1 + s_2 + s_3) < H_c < Hp(s_1 + s_2 + s_3 + s_4)$ then $s_{1c} = ps_1,\ s_{2c} = ps_2,\ s_{3c} = ps_3,\ s_{4c} = \frac{H_c - (s_{1c} + s_{2c} + s_{3c})H}{Hs_4},\ s_{5c} = 0$;
5. If $Hp(s_1 + s_2 + s_3 + s_4) < H_c < Hp(s_1 + s_2 + s_3 + s_4 + s_5)$ then $s_{1c} = ps_1,\ s_{2c} = ps_2,\ s_{3c} = ps_3,\ s_{4c} = ps_4,\ s_{5c} = \frac{H_c - (s_{1c} + s_{2c} + s_{3c} + s_{4c})H}{Hs_5}$;
6. If $Hp < H_c$ then $s_{1c} = \frac{H_c}{H}s_1,\ s_{2c} = \frac{H_c}{H}s_2,\ s_{3c} = \frac{H_c}{H}s_3,\ s_{4c} = \frac{H_c}{H}s_4,\ s_{5c} = \frac{H_c}{H}s_5$.

[17] All of these customers should be signing up for the CARE program, but the participation rate is only about 65% among eligible customers.

Income Bracket		1	2	3	4	5
Income Range		0-$20k	$20k-$40k	$40k-$60k	$60k-$100k	$100k +
PG&E	Non-CARE	8.3%	15.1%	19.8%	29.9%	26.9%
	CARE	46.3%	38.6%	11.8%	2.8%	0.4%
SCE	Non-CARE	9.2%	15.7%	20.7%	31.1%	23.3%
	CARE	41.7%	39.5%	14.3%	3.9%	0.5%
SDG&E	Non-CARE	8.3%	18.4%	21.6%	29.0%	22.6%
	CARE	51.1%	39.3%	7.7%	1.6%	0.3%

Table 3: Allocation of CARE and non-CARE Customers to Income Brackets
(assumes 65% CARE participation rate among eligible households)

For each case, the share of all customers who are in income bracket i and are not on the CARE program, is $s_{in} = s_i - s_{ic}$. The share of all CARE and non-CARE customers that this approach allocated to each income bracket is shown in table 3.

Once the household slots for CARE and non-CARE customers have been allocated across the five income brackets, there remains the question of which households should be assigned to which slots, *i.e.,* which income brackets. None of the data allow a direct matching of households in the utility billing data with income brackets. It is almost certainly the case, however, that within a census block group household usage is positively correlated with income. Unfortunately, I know of no direct studies of the level of that correlation within a CBG or, more specifically for this analysis, how closely the ranking of households by usage would correspond to the ranking by income. Nor do the data for this study allow such inference.

There are, however, two boundary cases that can easily be studied and provide a form of upper and lower bounds on the degree of income redistribution associated with the different tariffs. For the lower bound, one can assume that within a CBG usage is distributed randomly among households, completely uncorrelated with household income.[18] Since there is surely some positive correlation in reality, this assumption will incorrectly associate too many poor households with high usage and too many wealthy households with low

[18] It is technically possible that income and electricity usage could be negatively correlated, but a negative correlation is not supported by any empirical studies of larger populations.

usage within each CBG. So, it will tend to understate the degree of income redistribution associated with moving to a less steeply-tiered retail electricity tariff. Note again that this allocation is only occurring *within* each CBG, so this will still capture the income redistribution *across* CBGs from different average income and usage levels.

For the upper bound, one can assume that usage is perfectly ranked correlated with household income within a CBG, so that households can be ranked by usage in order to allocate them across income brackets. In reality, the rank correlation is certainly not perfect, so this assumption will incorrectly associate too many poor households with low usage and too many wealthy households with high usage within each CBG. This will tend to overstate the degree of income redistribution associated with moving to a less steeply tiered retail electricity tariff.

Each of these ranking criteria, the "random ranking method" and "usage ranking method," is used within each CBG, separately for CARE and non-CARE customers, to allocate households across the slots in each income bracket. Results are then calculated for each of these ranking criteria under each of the tariff structures.

VI. Results: Tariff Designs and Income Bracket Payment Shares

Under each of the within-CBG ranking methods, table 4 presents the average annual electricity bills for non-CARE customers in each of the income brackets under the benchmark five-tier tariff and the alternative two-tier tariff, *i.e.,* the non-CARE tariffs presented in the top two panels of table 1. These tariffs are applied only to customers who are not on the CARE program. Customers on CARE are not included in any of the results presented in table 4.

In the overall population, the share of households in each of these five income brackets is roughly equal, but the "Share of Customers" column in table 4 indicates that is not the case here. This is because CARE customers have been disproportionately removed from the lower income brackets, as explained in the previous section. The share of non-CARE customers allocated to each of the five income brackets reflects the slots remaining for non-CARE customers after the CARE customer slots are allocated according to the algorithm

PG&E				**Average Annualized Bill**				**Share of Total Revenue**		**Average Price ($/KwH)**	
	Income Range	Share of Customers	Daily Use (kWh)	*Bench*	*Two-tier*	Percent Change	Dollar Change	*Bench*	*Two-tier*	*Bench*	*Two-tier*
random	$0-$20k	8.34%	17.44	$990	$1,024	3.4%	$34	7.4%	7.6%	$0.155	$0.161
rank	$20k-$40k	15.07%	18.20	$1,047	$1,071	2.2%	$24	14.1%	14.4%	$0.158	$0.161
method	$40k-$60k	19.84%	18.61	$1,078	$1,096	1.6%	$18	19.1%	19.4%	$0.159	$0.161
	$60k-$100k	29.89%	19.03	$1,119	$1,124	0.4%	$5	29.9%	30.0%	$0.161	$0.162
	>$100k	26.87%	19.96	$1,228	$1,185	-3.4%	-$42	29.5%	28.5%	$0.168	$0.163
usage	$0-$20k	8.34%	5.33	$228	$297	30.4%	$69	1.7%	2.2%	$0.117	$0.153
rank	$20k-$40k	15.07%	9.84	$439	$555	26.6%	$116	5.9%	7.5%	$0.122	$0.155
method	$40k-$60k	19.84%	14.20	$679	$814	19.9%	$135	12.0%	14.4%	$0.131	$0.157
	$60k-$100k	29.89%	19.91	$1,080	$1,168	8.1%	$88	28.9%	31.2%	$0.149	$0.161
	>$100k	26.87%	30.69	$2,143	$1,859	-13.3%	-$284	51.5%	44.7%	$0.191	$0.166
SCE				**Average Annualized Bill**				**Share of Total Revenue**		**Average Price ($/KwH)**	
	Income Range	Share of Customers	Daily Use (kWh)	*Bench*	*Two-tier*	Percent Change	Dollar Change	*Bench*	*Two-tier*	*Bench*	*Two-tier*
random	$0-$20k	9.17%	17.45	$978	$1,019	4.2%	$41	7.6%	8.0%	$0.153	$0.160
rank	$20k-$40k	15.74%	18.24	$1,037	$1,068	2.9%	$31	13.9%	14.3%	$0.156	$0.160
method	$40k-$60k	20.68%	19.28	$1,115	$1,133	1.6%	$18	19.6%	19.9%	$0.158	$0.161
	$60k-$100k	31.09%	20.26	$1,194	$1,195	0.0%	$0	31.6%	31.6%	$0.161	$0.162
	>$100k	23.32%	22.22	$1,373	$1,320	-3.9%	-$53	27.3%	26.2%	$0.169	$0.163
usage	$0-$20k	9.17%	6.07	$265	$336	27.0%	$71	2.1%	2.6%	$0.119	$0.152
rank	$20k-$40k	15.74%	10.38	$468	$580	24.0%	$112	6.3%	7.8%	$0.124	$0.153
method	$40k-$60k	20.68%	14.82	$717	$845	17.8%	$128	12.6%	14.9%	$0.133	$0.156
	$60k-$100k	31.09%	21.46	$1,199	$1,261	5.1%	$62	31.7%	33.4%	$0.153	$0.161
	>$100k	23.32%	34.35	$2,383	$2,084	-12.6%	-$300	47.3%	41.4%	$0.190	$0.166
SDG&E				**Average Annualized Bill**				**Share of Total Revenue**		**Average Price ($/KwH)**	
	Income Range	Share of Customers	Daily Use (kWh)	*Bench*	*Two-tier*	Percent Change	Dollar Change	*Bench*	*Two-tier*	*Bench*	*Two-tier*
random	$0-$20k	8.34%	14.83	$843	$862	2.3%	$19	6.8%	7.0%	$0.156	$0.159
rank	$20k-$40k	18.41%	15.76	$903	$919	1.7%	$16	16.2%	16.4%	$0.157	$0.160
method	$40k-$60k	21.59%	16.68	$963	$974	1.2%	$12	20.2%	20.4%	$0.158	$0.160
	$60k-$100k	29.02%	17.91	$1,049	$1,051	0.2%	$2	29.6%	29.6%	$0.160	$0.161
	>$100k	22.64%	20.36	$1,238	$1,205	-2.7%	-$33	27.2%	26.5%	$0.167	$0.162
usage	$0-$20k	8.34%	4.73	$226	$261	15.3%	$35	1.8%	2.1%	$0.131	$0.151
rank	$20k-$40k	18.41%	8.52	$416	$473	13.9%	$58	7.4%	8.5%	$0.134	$0.152
method	$40k-$60k	21.59%	12.78	$650	$723	11.2%	$73	13.6%	15.2%	$0.139	$0.155
	$60k-$100k	29.02%	18.91	$1,063	$1,104	3.8%	$41	30.0%	31.1%	$0.154	$0.160
	>$100k	22.64%	32.41	$2,142	$1,961	-8.5%	-$181	47.1%	43.1%	$0.181	$0.166

Table 4: Average Bill By Income Bracket Under Benchmark and Alternative Two-Tier Tariff Using Random-Rank and Usage-Rank Within-CBG Allocation Methods

in the previous section. The allocation of those slots across income brackets is independent of whether the matching of specific households to slots is done using the random ranking approach or the usage ranking approach.

The two groups of results presented show the important difference between assuming there is zero usage/income correlation within a census block group (the "random ranking method") and assuming there is perfect usage/income correlation (the "usage ranking method"). Average daily consumption is far more differentiated across the income brackets when perfect rank correlation is assumed, and the resulting bills are of course then also far more differentiated across income brackets. As a result, the estimated percentage change in bills that would result from switching to a two-tier rate structure is substantially greater under the assumption of perfect usage/income correlation. This is particularly true for the lowest income bracket, which is likely of the greatest public policy concern. In levels, the two methods yield more similar estimates of bill changes for the lowest income bracket, but for the second lowest bracket the difference is still fairly large. This bracket includes households earning between \$20,000 and \$40,000 per year, so there is likely still substantial public policy concern about the impact of rate changes on these customers. In the next subsection, I explore where between these bounds the best estimates lie.

Refining the Redistribution Estimates

As shown in table 4, the two approaches to allocating customers to income brackets within census block groups imply not only different levels of wealth transfers, but also substantially different average consumption quantities by income bracket. The random ranking approach results in a smaller implied average consumption differential across brackets than does the usage ranking approach. I exploit these implied average consumption levels to calibrate the estimates and potentially to get a better estimate of income redistribution than either approach affords in isolation.

Of course, it is not possible to compare the implied average consumption quantities by income bracket to a direct calculation, because I do not have the income categories for individual customers. The data do, however, include variation across CBGs in both average household consumption and distribution of household incomes across brackets. Under reasonable restrictions, these are sufficient to estimate the actual average consumption quantities by income bracket. These estimates can then be compared to the usage rates by income bracket that are implied by the random-ranking and usage-ranking methods.

A customer h whose income falls in bracket b consumes $q_{hb} = \bar{q}_b + \epsilon_h$ where $\bar{q}_b$ is the mean of consumption of customers in bracket b, and ϵ is orthogonal to customer income bracket over the entire population, by definition, because $\sum_h \epsilon_h = 0$ within each income bracket.

Therefore, in a CBG, g, with H households the average consumption per household, $\bar{q_g}$, will be

$$\bar{q_g} = \sum_{b=1}^{5} \bar{q_b} s_{bg} + \frac{\sum_{h=1}^{H} \epsilon_h}{H}, \qquad [1]$$

where s_{bg} are the shares of customers in each income bracket within that CBG.

One could run a regression with observations at the census block group level, g,

$$\bar{q_g} = \sum_{b=1}^{5} \alpha_b s_{bg} + \eta. \qquad [2]$$

The α_b are then the least-squares estimates of income bracket mean consumption levels that generate the set of mean household consumption levels across the CBGs. The goal here is not to estimate the full causal model for $\bar{q_g}$, but rather to extract the best estimate of the mean consumption within each income bracket. Therefore, we are not, for instance, interested in the fact that wealthy people tend to own more air conditioning units and it is the air conditioning that raises electricity demand.

Still, the α_b will be unbiased estimates of $\bar{q_b}$ only if the s_b are orthogonal to η. This will not be the case if differentiation in average consumption across CBGs is affected by another factor that is correlated with the s_b. For instance, if wealthy people tend to live in milder climates, then it may appear that CBGs with more wealthy people consume less power, leading to downward biased estimates of the $\bar{q_b}$ for higher income brackets and upward biased estimates for lower income brackets. Controlling for climate effects parametrically, however, will impose fairly arbitrary structure on how climate differences affect the relative consumption of households in different income brackets. To avoid doing this, [2] is instead modified and estimated with separate α_{bz} within each climate zone of each utility, 10 climate zones for PG&E, 6 for SCE, and 4 four SDG&E:

$$\bar{q}_{gz} = \sum_{b=1}^{5} \alpha_{bz} s_{bgz} + \eta \qquad [3]$$

The $\hat{\alpha_{bz}}$ can then be compared to the average usage rates by income bracket and climate zone, the $\bar{q}_{bz}$, under each of the ranking methods. The set of α_{bz} generated by [3] can be tested against the null hypothesis that they are equal to the average usage levels by income bracket/climate zone that are generated by either of the ranking methods. This approach, however, strongly rejects both ranking methods and, by itself, offers no further guidance on which is closer.[19]

Taking this approach slightly further, however, is potentially more revealing. Essentially, the idea is to calibrate the ranking method in order to produce usage averages by income bracket and climate zone (the $\bar{q}_{bz}$) that are most similar to the estimated averages from [3] (the $\hat{\alpha_{bz}}$). The actual rank correlation between usage and income within a CBG can be seen as an outcome of the relative variation in the two terms of the demand relationship $q_h = f(I_h) + \epsilon_h$ where ϵ_h is orthogonal to $f(I_h)$.[20] This is not a causal demand function, but simply a relationship between income and quantity demanded, and a residual term that is orthogonal to the income function. If the variance of the first term is much larger than the variance of the second, then the usage-rank approach will closely reflect actual usage by income bracket. If the second term has a much larger variance, then the random-rank approach will be more informative. The exact relationship between the variances and the resulting rank correlation between income and usage will depend on the empirical distributions of the $f(\cdot)$ values and ϵ, about which theory tells us very little. So, it would be difficult to justifying imposing further structure on the relationship.

Instead, I take a practical approach to the calibration by examining the full range of (positive) weights, zero to one, on each of the ranking methods. To be concrete, with N (non-CARE) households in a CBG, they are assigned integer rankings from 1 to N, which are then used to assign them to the income bracket slots as was described earlier. In the case of random ranking, these integer ranks are assigned based on random number generation, while in the case of usage ranking, they are assigned in order of daily average usage. For any weighting factor w, where $0 < w < 1$, each household is assigned a weighted ranking value, $v_h = w \cdot r_{rh} + (1 - w) \cdot r_{uh}$, where r_{rh} and r_{uh} are the integer rankings from

[19] There are a few climate zones in California that have very few CBGs, less than 100 and in three cases only 6. I exclude these from the estimation and F-tests. The three climate zones with 6 observations have only one degree of freedom and extremely small standard errors that skew the results. The others have very imprecise estimates, though inclusion of them does not noticeably change the results.

[20] Implicitly, I am assuming here the $f(I_h)$ is monotonic.

the random-rank and usage-rank methods, respectively. They are then assigned to the income bracket slots based on the ranking of their v_h values. For a given w, the resulting average usage levels by income bracket and climate zone, the $\bar{q}_{bz}$, can then be tested against the estimated $\hat{\alpha_{bz}}$. The w that yields the lowest F-statistic in this test is $w*$, the weighting that best calibrates the $\bar{q}_{bz}$ to the estimated $\hat{\alpha_{bz}}$.[21] The income redistribution effects calculated using a weighted ranking, with weight equal to $w*$, are then likely to be a better indication of the true redistribution effect than either the random-ranking or usage-ranking approaches.

The results of this weighted-ranking approach are shown in table 5, along with estimates of $w*$ for each utility. For comparison, it replicates the table 4 results from the previous two methods. The $w* = 0.49$ for PG&E, for instance, implies that taking a weighted average of the random-ranking and usage-ranking with a 0.49 weight on random-ranking and 0.51 weight on usage ranking, yields usage estimates by income bracket and climate zone that most closely match the regression estimates from equation [3], as measured by the F-statistic. That weighted-ranking approach yields the estimated average bill changes by income category shown in the PG&E panel of the table. And likewise for SCE and SDG&E. The PG&E and SCE weights suggest approximately equal weighting of the two rankings, but the SDG&E weight suggests that the usage-ranking approach alone is not improved by adding information from the random-ranking method, a somewhat surprising result.

The $w*$ results in table 5 for PG&E and SCE suggest that for the lower income bracket the best estimate of the percentage bill changes is closer to the usage-ranking results, while the best estimate of the change in bill level is actually somewhat *larger* than the usage-ranking result for the lowest income bracket. The results imply that for both PG&E and SCE the best estimate is that a change to the alternative two-tier structure would raise the average bill of a household in the lowest income bracket by between \$7 and \$8 per month or about 25%. In fact, the $w*$ results for PG&E and SCE are quite consistent with one another. The effect of the change to a two-tier structure within SDG&E is substantially

[21] Because the degrees of freedom and the number of observations are the same across any value of w*, the objective is just to minimize the F-value.

smaller, in part because the SDG&E 5-tier tariff is much less steep than the other two utilities.

Aggregate Transfers Under Alternative Tariffs

Since a primary goal of the five-tier electricity tariffs in California is to allocate more of the utility revenue burden towards higher income brackets and away from the low income households, it is worth investigating how effectively the program accomplishes this goal in aggregate. Table 5 addresses this issue by presenting the share of the utility's total revenue received from non-CARE residential customers that comes from households in each of the income brackets. Estimated using the weighted ranking method, it appears that switching to the two-tier tariff would have a fairly modest impact on the revenue shares coming from each of the income brackets. The two right-hand columns of the table indicate why this is the case: the average prices paid by the customers in the different income brackets differ far less than the marginal prices even under the five-tier tariff.

To put these transfers in more context, they can be compared to the transfers that occur under the primary program for low-income customers, CARE. To do this, I examine the entire residential revenue pool including amounts paid by CARE customers and calculate revenue shares under five-tier and two-tier tariffs both with and without the CARE program. In this case, the tariffs are calculated so that the total revenue pool inclusive of CARE customers is the same under all four alternatives. These are the tariffs presented in lower panels of table 1.

Table 6 presents the results of this exercise using the weighted-ranking method. Revenues and revenue share calculations for this table include all residential customers, both on the CARE program and on a standard residential tariff. The "Bench w/CARE" column presents the revenue shares of each income bracket under the benchmark five-tier pricing schedules with the CARE program. The "2-tier w/CARE" presents revenue shares under the alternative two-tier pricing schedule that was examined in table 5, but with no change to the price schedule faced by CARE customers. The adjoining "Change" column presents the percentage point difference from the "Bench w/CARE" column. The next pair of columns presents the revenue share if there were no CARE program and all customers were

PG&E				Average Annualized Bill				Share of		Average Price	
	Income	Share of	Daily Use			Percent	Dollar	Total Revenue		($/KwH)	
	Range	Customers	(kWh)	*Bench*	*Two-tier*	Change	Change	*Bench*	*Two-tier*	*Bench*	*Two-tier*
random	$0-$20k	8.34%	17.44	$990	$1,024	3.4%	$34	7.4%	7.6%	$0.155	$0.161
rank	$20k-$40k	15.07%	18.20	$1,047	$1,071	2.2%	$24	14.1%	14.4%	$0.158	$0.161
method	$40k-$60k	19.84%	18.61	$1,078	$1,096	1.6%	$18	19.1%	19.4%	$0.159	$0.161
	$60k-$100k	29.89%	19.03	$1,119	$1,124	0.4%	$5	29.9%	30.0%	$0.161	$0.162
	>$100k	26.87%	19.96	$1,228	$1,185	-3.4%	-$42	29.5%	28.5%	$0.168	$0.163
weighted	**$0-$20k**	**8.34%**	**8.01**	**$356**	**$451**	**26.6%**	**$95**	**2.7%**	**3.4%**	**$0.122**	**$0.154**
rank	**$20k-$40k**	**15.07%**	**12.33**	**$597**	**$707**	**18.4%**	**$110**	**8.0%**	**9.5%**	**$0.133**	**$0.157**
method	**$40k-$60k**	**19.84%**	**15.92**	**$838**	**$926**	**10.5%**	**$88**	**14.9%**	**16.4%**	**$0.144**	**$0.159**
w*=0.49	**$60k-$100k**	**29.89%**	**20.10**	**$1,161**	**$1,186**	**2.2%**	**$25**	**31.0%**	**31.7%**	**$0.158**	**$0.162**
	>$100k	**26.87%**	**26.97**	**$1,807**	**$1,623**	**-10.2%**	**-$184**	**43.4%**	**39.0%**	**$0.184**	**$0.165**
usage	$0-$20k	8.34%	5.33	$228	$297	30.4%	$69	1.7%	2.2%	$0.117	$0.153
rank	$20k-$40k	15.07%	9.84	$439	$555	26.6%	$116	5.9%	7.5%	$0.122	$0.155
method	$40k-$60k	19.84%	14.20	$679	$814	19.9%	$135	12.0%	14.4%	$0.131	$0.157
	$60k-$100k	29.89%	19.91	$1,080	$1,168	8.1%	$88	28.9%	31.2%	$0.149	$0.161
	>$100k	26.87%	30.69	$2,143	$1,859	-13.3%	-$284	51.5%	44.7%	$0.191	$0.166

SCE				Average Annualized Bill				Share of		Average Price	
	Income	Share of	Daily Use			Percent	Dollar	Total Revenue		($/KwH)	
	Range	Customers	(kWh)	*Bench*	*Two-tier*	Change	Change	*Bench*	*Two-tier*	*Bench*	*Two-tier*
random	$0-$20k	9.17%	17.45	$978	$1,019	4.2%	$41	7.6%	8.0%	$0.153	$0.160
rank	$20k-$40k	15.74%	18.24	$1,037	$1,068	2.9%	$31	13.9%	14.3%	$0.156	$0.160
method	$40k-$60k	20.68%	19.28	$1,115	$1,133	1.6%	$18	19.6%	19.9%	$0.158	$0.161
	$60k-$100k	31.09%	20.26	$1,194	$1,195	0.0%	$0	31.6%	31.6%	$0.161	$0.162
	>$100k	23.32%	22.22	$1,373	$1,320	-3.9%	-$53	27.3%	26.2%	$0.169	$0.163
weighted	**$0-$20k**	**9.17%**	**7.92**	**$353**	**$441**	**25.0%**	**$88**	**2.8%**	**3.4%**	**$0.122**	**$0.153**
rank	**$20k-$40k**	**15.74%**	**11.65**	**$550**	**$659**	**19.8%**	**$109**	**7.4%**	**8.8%**	**$0.129**	**$0.155**
method	**$40k-$60k**	**20.68%**	**15.62**	**$798**	**$900**	**12.7%**	**$102**	**14.0%**	**15.8%**	**$0.140**	**$0.158**
w*=0.40	**$60k-$100k**	**31.09%**	**21.81**	**$1,262**	**$1,286**	**1.9%**	**$24**	**33.4%**	**34.0%**	**$0.159**	**$0.162**
	>$100k	**23.32%**	**31.58**	**$2,137**	**$1,907**	**-10.8%**	**-$230**	**42.4%**	**37.9%**	**$0.185**	**$0.165**
usage	$0-$20k	9.17%	6.07	$265	$336	27.0%	$71	2.1%	2.6%	$0.119	$0.152
rank	$20k-$40k	15.74%	10.38	$468	$580	24.0%	$112	6.3%	7.8%	$0.124	$0.153
method	$40k-$60k	20.68%	14.82	$717	$845	17.8%	$128	12.6%	14.9%	$0.133	$0.156
	$60k-$100k	31.09%	21.46	$1,199	$1,261	5.1%	$62	31.7%	33.4%	$0.153	$0.161
	>$100k	23.32%	34.35	$2,383	$2,084	-12.6%	-$300	47.3%	41.4%	$0.190	$0.166

SDG&E				Average Annualized Bill				Share of		Average Price	
	Income	Share of	Daily Use			Percent	Dollar	Total Revenue		($/KwH)	
	Range	Customers	(kWh)	*Bench*	*Two-tier*	Change	Change	*Bench*	*Two-tier*	*Bench*	*Two-tier*
random	$0-$20k	8.34%	14.83	$843	$862	2.3%	$19	6.8%	7.0%	$0.156	$0.159
rank	$20k-$40k	18.41%	15.76	$903	$919	1.7%	$16	16.2%	16.4%	$0.157	$0.160
method	$40k-$60k	21.59%	16.68	$963	$974	1.2%	$12	20.2%	20.4%	$0.158	$0.160
	$60k-$100k	29.02%	17.91	$1,049	$1,051	0.2%	$2	29.6%	29.6%	$0.160	$0.161
	>$100k	22.64%	20.36	$1,238	$1,205	-2.7%	-$33	27.2%	26.5%	$0.167	$0.162
weighted	**$0-$20k**	**8.34%**	**4.73**	**$226**	**$261**	**15.3%**	**$35**	**1.8%**	**2.1%**	**$0.131**	**$0.151**
rank	**$20k-$40k**	**18.41%**	**8.52**	**$416**	**$473**	**13.9%**	**$58**	**7.4%**	**8.5%**	**$0.134**	**$0.152**
method	**$40k-$60k**	**21.59%**	**12.78**	**$650**	**$723**	**11.2%**	**$73**	**13.6%**	**15.2%**	**$0.139**	**$0.155**
w*=0.00	**$60k-$100k**	**29.02%**	**18.91**	**$1,063**	**$1,104**	**3.8%**	**$41**	**30.0%**	**31.1%**	**$0.154**	**$0.160**
	>$100k	**22.64%**	**32.41**	**$2,142**	**$1,961**	**-8.5%**	**-$181**	**47.1%**	**43.1%**	**$0.181**	**$0.166**
usage	$0-$20k	8.34%	4.73	$226	$261	15.3%	$35	1.8%	2.1%	$0.131	$0.151
rank	$20k-$40k	18.41%	8.52	$416	$473	13.9%	$58	7.4%	8.5%	$0.134	$0.152
method	$40k-$60k	21.59%	12.78	$650	$723	11.2%	$73	13.6%	15.2%	$0.139	$0.155
	$60k-$100k	29.02%	18.91	$1,063	$1,104	3.8%	$41	30.0%	31.1%	$0.154	$0.160
	>$100k	22.64%	32.41	$2,142	$1,961	-8.5%	-$181	47.1%	43.1%	$0.181	$0.166

Table 5: Average Bill By Income Bracket Under Benchmark and Alternative Two-Tier Tariff Using Random-Rank, Usage-Rank and Weighted-Rank Within-CBG Allocation Methods

	Share of Customers	Share of Usage	Share of Total Residential Revenue						
			Bench w/CARE	*2-tier w/CARE*	*Change*	*5-tier no-CARE*	*Change*	*2-tier no-CARE*	*Change*
PG&E									
$0-$20k	17.2%	10.2%	6.7%	7.3%	0.6%	8.3%	1.6%	9.9%	3.2%
$20k-$40k	20.5%	17.2%	12.7%	14.0%	1.3%	15.5%	2.8%	17.0%	4.3%
$40k-$60k	18.0%	16.5%	15.0%	16.4%	1.4%	15.2%	0.2%	16.3%	1.3%
$60k-$100k	23.6%	25.8%	27.6%	28.2%	0.6%	25.7%	-1.9%	25.9%	-1.7%
>$100k	20.7%	30.2%	38.0%	34.1%	-3.9%	35.3%	-2.7%	30.9%	-7.1%
SCE									
$0-$20k	18.1%	9.5%	6.6%	7.1%	0.6%	7.6%	1.0%	9.2%	2.6%
$20k-$40k	22.2%	17.5%	13.7%	14.9%	1.2%	15.5%	1.8%	17.1%	3.5%
$40k-$60k	18.9%	17.1%	15.3%	16.8%	1.5%	15.6%	0.3%	16.9%	1.6%
$60k-$100k	23.7%	27.4%	28.9%	29.4%	0.5%	27.5%	-1.4%	27.5%	-1.4%
>$100k	17.1%	28.5%	35.6%	31.8%	-3.8%	33.8%	-1.8%	29.4%	-6.2%
SDG&E									
$0-$20k	16.6%	7.2%	6.1%	6.4%	0.2%	6.2%	0.1%	6.9%	0.8%
$20k-$40k	22.4%	14.7%	12.8%	13.7%	0.9%	13.0%	0.2%	14.2%	1.3%
$40k-$60k	18.9%	15.2%	13.5%	14.8%	1.3%	13.5%	0.0%	14.8%	1.2%
$60k-$100k	23.8%	27.1%	26.4%	27.4%	1.0%	26.3%	-0.1%	27.1%	0.6%
>$100k	18.4%	35.8%	41.1%	37.6%	-3.5%	40.9%	-0.1%	37.1%	-4.0%

Table 6: Share of Total Residential Revenues Derived from Each Income Bracket (using weighted-rank within-CBG allocation method)

on a five-tier tariff, where the price per kWh on each tier has been adjusted by the same (negative) amount from the benchmark non-CARE tariff in order to maintain the same total revenue as when some customers were on the CARE program. And the "Change" column again presents the percentage point difference from the "Bench w/CARE" column. The final pair of columns presents the case with a two-tier pricing schedule and no CARE program, and the percentage point difference from the"Bench w/CARE" column.

Comparing both the "5-tier, no-CARE" and the "2-tier w/CARE" to the benchmark case indicates that the CARE program has a substantially larger impact in lowering the electricity payments of customers in the lowest income bracket than does the steeply-tiered rate schedule. The effect is about 65% larger for SCE customers and about two and a half times larger for PG&E customers. The effect of both the tiering and the CARE program is quite small for SDG&E customers. This is both because of the less steep rate tiering, as discussed earlier, and because the SDG&E's CARE rates are much less generous than those offered by the other two utilities.

These differences suggest that if reducing the electricity bills of low income customers is a major public policy goal it may be pursued more effectively with an income-based approach such as the CARE program, rather than the less-direct steeply-tiered retail tariff. For instance, improving the participation rate of CARE customers among those who are eligible may be more successful in pursuit of the policy goal than maintaining the five-tier rate structure. Of course, a complete comparison would have to include the relative costs of these alternatives as well as their relative benefits.

Lastly, the right-hand pair of columns in table 6 is interesting for its implication about the effect of tiered rate structures in the absence of a CARE-type program. The difference between the revenue shares resulting from five-tier versus two-tier tariffs is substantially greater in the absence of the CARE program (comparing the two no-CARE cases) than when the CARE program is present. Thus, the CARE program substantially reduces the impact of bill tiering on low-income customers.

VII. Demand Elasticity

These estimates of the impact of the steeply increasing-block rate structure on low-income households are based on the assumption that customers would not change their consumption in response to a revenue-neutral change in the prices on the tiers. Adjusting the calculations for any assumed price elasticity of demand, as was done in Borenstein (2007), would be straightforward. There are, however, important issues in estimation of electricity demand elasticity that should also be addressed for this analysis. Probably foremost among them is the question of what price a customer actually responds to. Numerous analyses have estimated demand elasticity on the assumption that customers respond to the marginal price that they face,[22] but it seems likely that the vast majority of customers in California not only do not know what tier their consumption puts them on, but even that the rate structure is tiered at all. In that case, the response to increasing-block pricing is likely to be more muted, possibly much more muted. Customers might respond to some

[22] In electricity, see Taylor (1975), Shin (1985), Herriges & King (1994), Reiss & White (2005) and Bushnell & Mansur (2005). Of these, Shin and Bushnell & Mansur considers in depth the possibility that customers cannot or do not optimize on the marginal price they face. A similar literature exists in water pricing. See Hewitt & Hanemann (1995) and Olmstead, Hanemann and Stavins (2007). Liebman and Zeckhauser (2004) treat directly the issue of sub-optimizing consumer behavior in the face of complex price schedules.

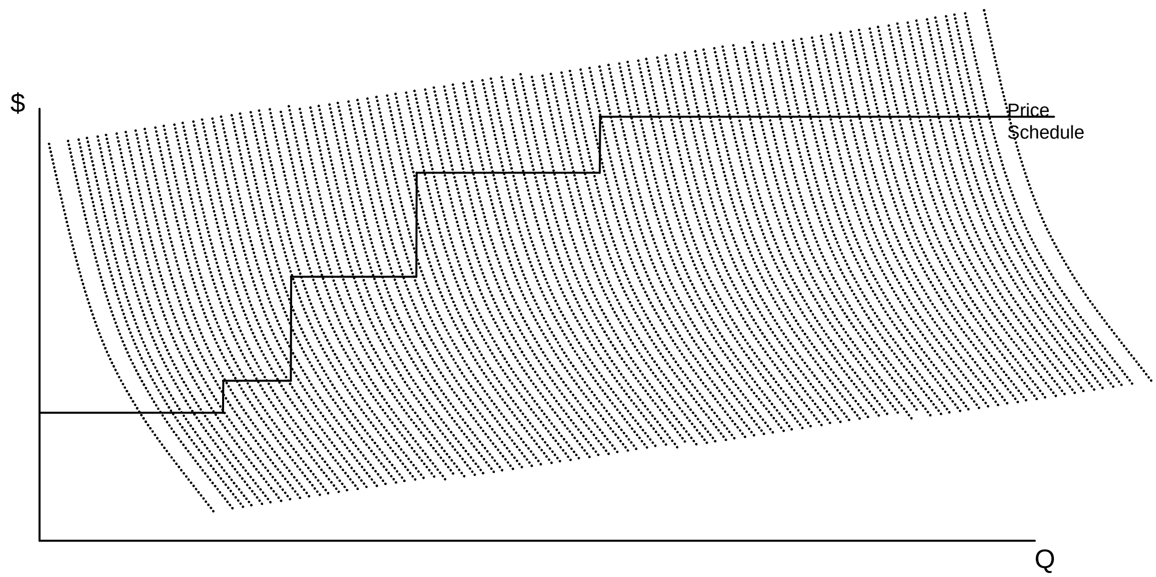

Figure 2: Uniform Distribution of Demand Functions and Bunched Quantities Demanded

inference about the average price they have paid over the prior few billing periods rather than the precise marginal price that they face.[23] This, of course, would have important implications for use of the tiered structure, reducing the conservation effect some suggest comes from the high marginal prices, but also reducing the inefficiencies that some suggest result from having marginal prices that deviate substantially from marginal cost.

One examination of the billing data used in this study supports the view that customers are not very responsive to changes in their marginal electricity price on the increasing-block schedule. If they were, one would expect to see customers "bunched" around the points where the marginal price increases. This is the standard result of a kinked budget constraint. Saez (2002) examines a similar phenomenon regarding labor supply decisions around income levels at which marginal income tax rates change, an issue that was discussed two decades earlier by Heckman (1982, 1993) and Hausman (1981, 1982). Saez finds no evidence of such bunching, suggesting that individuals are not optimizing against changes in their marginal tax rate. I find a similar result for changes in marginal electricity rates.

Figure 2 illustrates why one would expect to find bunching at the quantities where

[23] Shin (1985) suggests that it is more likely that customers respond to the average price they face than the marginal price for the next kWh of electricity.

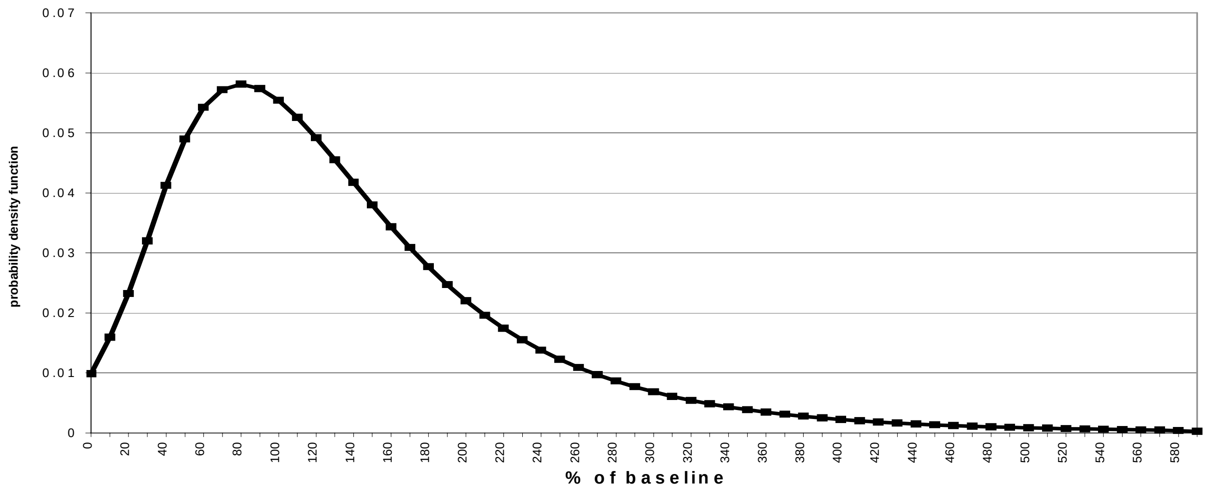

Figure 3: Distribution of Quantity Without Retail Bill Tiering

marginal electricity price increases. If the distribution of customer demand functions is smooth around these marginal price changes, then a disproportionate share of customers should be observed choosing consumption that is exactly at the point of price increase. While in practice customers are not likely to target their consumption down to the last kilowatt-hour, one would expect to see a tendency to be much more careful about further consumption increases as the marginal price increases, and that would result in bunching.

The potential magnitude of this effect is illustrated in figures 3 and 4. Figure 3 shows a fairly typical distribution of customer demand quantities under a flat-rate tariff.[24] If this distribution were the result of a population of customers each with a demand function $q_i = a_i p^{\epsilon}$, then one can determine the distribution of the a_i, $h(a_i)$, for any p, ϵ, and population of q_i. With that empirical distribution of a_i, it is straightforward to calculate the share of customers that should be observed consuming in any quantity interval. Figure 4 illustrates this exercise using the distribution from figure 3, assuming a demand elasticity of -0.2 and the benchmark 5-tier price schedule of PG&E presented in table 1. The figure is constructed using quantity intervals of 10% of the baseline consumption quantity for the frequency calculations. Customers who would, theoretically, consume exactly at

[24] This is actually taken from the distribution of SCE customer quantities demanded in 1999 when there were only two-steps to the tariff with a 16% price increase.

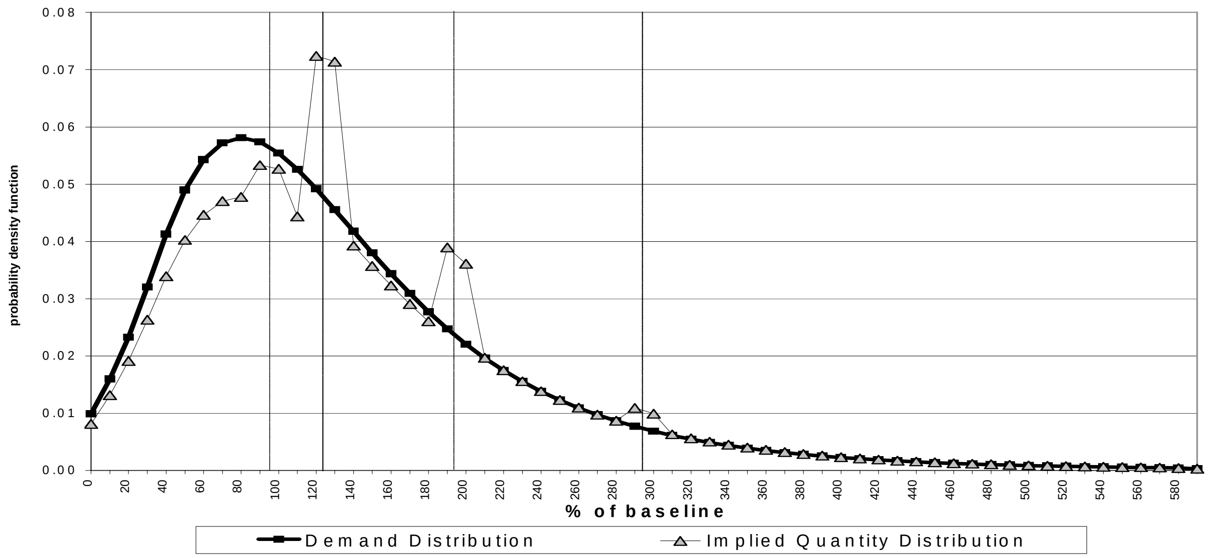

Figure 4: Expected Distribution of Quantity Demanded Under PG&E's Five-Tier Tariff

the quantity at which a price change occurs are allocated equally to the two adjoining intervals. This allows for implementation error – the failure of a household to hit exactly the consumption level it targets – equal to plus or minus 10% of baseline quantity or about 7% of the average household's consumption. The calculation suggests that for the largest step in PG&E's tariff, which occurs at 130% of baseline, there should be bunching in the adjoining 10 percentage point intervals that creates about a 60%-90% bump in the population of those intervals compared to adjoining intervals. For the second largest step in PG&E's tariff, at 200% of baseline, the bump should be about 50%-90%. Assuming that implementation error instead spreads actual consumption (uniformly) by 20% of baseline instead of 10% cuts the size of these peaks in the distribution by half, but still leaves them quite large. Assuming a possibly more realistic long-run demand elasticity of -0.3 or larger makes the peaks more pronounced.

Figure 5 presents the actual observed effect of the increasing marginal prices for PG&E customers for all bills in December 2005 through November 2006 or, more accurately, the absence of such an effect. Similar non-effects are evident for SCE and SDG&E. I have not done statistical tests, but given that there are nearly 50 million billing observations over more than four million households, it is clear that the actual observed distribution is significantly different from the theoretical bunching that one would expect if customers

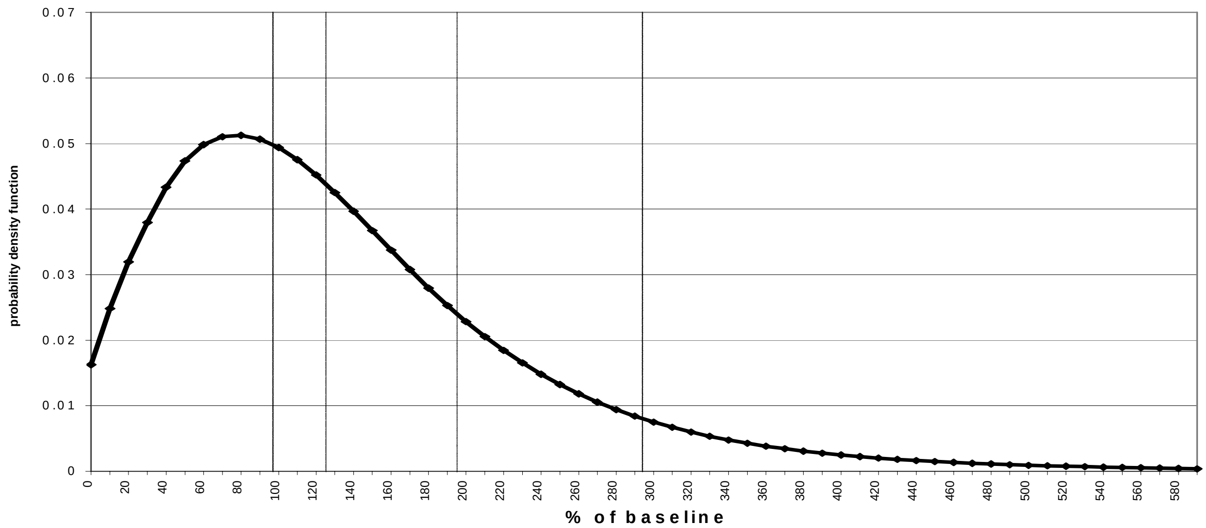

Figure 5: Actual Distribution of Quantity Demanded Under PG&E's Five-Tier Tariff

responded to marginal prices. This leaves the question of what, if any, notion of price customers do respond to, and how sensitive this is to the amount and type of information the utility gives the customer. In ongoing research, I am investigating these issues.

VIII. Conclusion

The regulatory response to California's 2000-01 electricity crisis led to steep increasing -block retail electricity tariffs. Similar tariffs have been suggested to cover rising energy costs and new costs of electricity generation that will result from pricing greenhouse gases. While it is generally agreed that wealthier customers on average consume larger quantities of electricity per household, it is less clear how strong that association is, particularly after adjusting for differential numbers of household members and other factors that are not incorporated in the increasing-block residential rate structure. The impact of the steeply-tiered rates in protecting low-income customers is also no doubt mitigated by the existence of the CARE program in California that offers a lower, and less steeply tiered, rate structure to customers who state that their household income is sufficiently low. The CARE program has also been growing rapidly over the last decade.

California has now operated with the five-tier increasing block rate structure for nearly 8 years, but I believe that this is the first detailed analysis of its distributional impact. The analysis suggests that, compared to the two-tier increasing block rate structure that was in effect prior to the California electricity crisis, the steep five-tier rate structure benefits low income customers, but that benefit is fairly modest. For PG&E and SCE, which have the most steeply increasing prices – the best estimates suggest that returning to a two-tier structure similar to the pre-2000 utility tariffs in California would raise the annual electricity bill of the poorest households – those will annual income below $20,000 – by slightly less than $100 per year or about $7-$8 per month.

To carry out this analysis, I utilized what may be a novel approach to matching census data on income with the data for the program to be evaluated. Previous studies I am aware of have assigned the median household income of each census block group to all households in the CBG. Actual household incomes within CBGs, however, are quite heterogeneous. Simply matching to median income compresses the apparent income distribution substantially and fails to take account of the within-CBG correlation of households income with the program variable of interest. The approach explored here seems likely to be adaptable to other situations in which household-level data are available on the program variable.

While the redistributional benefits of steep electricity-tariff tiering may be modest, the costs might not be large either. These tariffs are frequently criticized for sending different marginal price signals to different customers when the cost of serving them is the same.[25] The same tariffs are also occasionally lauded for encouraging conservation among heavy electricity users. Either effect would require that consumers are cognizant of and respond to the marginal electricity price that they face. I am investigating this effect in ongoing research. The preliminary results presented here suggest that at least in this population, consumers are not be responsive to changes in the marginal price.

[25] Some have argued that high-use customers are in fact more costly to serve per kWh, because they tend to consume proportionally more at times when wholesale electricity prices are high. See Marcus and Ruszovan (2007). Given the time patterns of consumption and of wholesale electricity prices, however, it is not really plausible that the average marginal cost of serving different residential customers differs nearly as much as the marginal prices they faced under California's tariffs.

Appendix A: CARE participation rates

Reports from the utilities suggest that the CARE participation rate was 70%-75% among eligible households in 2006. The figures, however, appear to come from dividing the number of participating households by an estimate of the number of eligible households, based on census data. Implicitly, that assumes that all households on CARE are eligible. There is some evidence that this is not a good approximation.

One issue is that households may be qualified when they sign up, but then become ineligible due to an income increase or a decrease in the number of household residents. The calculation implicitly assumes that households report immediately when they become ineligible, which seems to be fairly rare. Instead, it appears that households that are no longer eligible simply do not recertify when their two-year certification requires renewal. Given that 5% to 10% of households that are on CARE do not recertify when their renewal is required, it seems quite likely that at least a few percent of households on CARE have become ineligible since they enrolled.

In addition, some households may not be eligible at the time they join. The sign-up process requires a statement of eligibility, but does not require supporting evidence to be submitted. Much of CARE enrollment comes from contacting households that have qualified for other low-income programs, but one can also sign up through the websites of the utilities or by mail. In their monthly and annual reports, the utilities report the results of random eligibility verification which is requested of less than 1% of participants. A surprisingly high number of participants selected for the random verification do not respond to the request supporting information, 30% or more, and as a result are dropped from the CARE program. A much smaller share are found to be ineligible based on documentation submitted. It is difficult to know how many of the non-respondents are unable or unwilling to provide documentation, but are actually eligible, but that seems unlikely to be the explanation for all or nearly all of the non-respondents.

Based on these considerations, in the study I have assumed a CARE participation rate of 65% rather than the 70%-75% rate reported by the utilities for this period. A lower rate of CARE participation means that fewer of the households in the lowest income brackets and more of the households in higher income brackets are assumed to be CARE participants. Assuming that fewer of the CARE participants are in the lowest brackets leads to the conclusion of somewhat higher redistribution as a result of increasing-block pricing. If a much larger share of CARE participants were actually ineligible, then the redistributive impact of CARE would be smaller than is commonly assumed and the redistributive impact of increasing-block pricing would be greater than I have concluded.

Appendix B

PG&E					**Average Annualized Bill**			**Share of**		**Average Price**	
	Income	Share of	Daily Use			Percent	Dollar	**Total Revenue**		**($/KwH)**	
	Range	Customers	(kWh)	*Bench*	*Flat*	Change	Change	*Bench*	*Flat*	*Bench*	*Flat*
random	$0-$20k	8.34%	17.44	$990	$1,030	4.0%	$40	7.4%	7.7%	$0.155	$0.162
rank	$20k-$40k	15.07%	18.20	$1,047	$1,075	2.7%	$28	14.1%	14.5%	$0.158	$0.162
method	$40k-$60k	19.84%	18.61	$1,078	$1,099	1.9%	$21	19.1%	19.5%	$0.159	$0.162
	$60k-$100k	29.89%	19.03	$1,119	$1,124	0.5%	$6	29.9%	30.0%	$0.161	$0.162
	>$100k	26.87%	19.96	$1,228	$1,178	-4.0%	-$50	29.5%	28.3%	$0.168	$0.162
weighted	**$0-$20k**	**8.34%**	**8.01**	**$356**	**$473**	**32.8%**	**$117**	**2.7%**	**3.5%**	**$0.122**	**$0.162**
rank	**$20k-$40k**	**15.07%**	**12.33**	**$597**	**$728**	**22.1%**	**$132**	**8.0%**	**9.8%**	**$0.133**	**$0.162**
method	**$40k-$60k**	**19.84%**	**15.92**	**$838**	**$941**	**12.2%**	**$102**	**14.9%**	**16.7%**	**$0.144**	**$0.162**
w*=0.49	**$60k-$100k**	**29.89%**	**20.10**	**$1,161**	**$1,187**	**2.2%**	**$26**	**31.0%**	**31.7%**	**$0.158**	**$0.162**
	>$100k	**26.87%**	**26.97**	**$1,807**	**$1,593**	**-11.9%**	**-$214**	**43.4%**	**38.3%**	**$0.184**	**$0.162**
usage	$0-$20k	8.34%	5.33	$228	$315	38.1%	$87	1.7%	2.3%	$0.117	$0.162
rank	$20k-$40k	15.07%	9.84	$439	$581	32.5%	$142	5.9%	7.8%	$0.122	$0.162
method	$40k-$60k	19.84%	14.20	$679	$839	23.5%	$160	12.0%	14.9%	$0.131	$0.162
	$60k-$100k	29.89%	19.91	$1,080	$1,176	8.8%	$96	28.9%	31.4%	$0.149	$0.162
	>$100k	26.87%	30.69	$2,143	$1,812	-15.4%	-$331	51.5%	43.5%	$0.191	$0.162
SCE					**Average Annualized Bill**			**Share of**		**Average Price**	
	Income	Share of	Daily Use			Percent	Dollar	**Total Revenue**		**($/KwH)**	
	Range	Customers	(kWh)	*Bench*	*Flat*	Change	Change	*Bench*	*Flat*	*Bench*	*Flat*
random	$0-$20k	9.17%	17.45	$978	$1,029	5.2%	$51	7.6%	8.0%	$0.153	$0.161
rank	$20k-$40k	15.74%	18.24	$1,037	$1,074	3.5%	$36	13.9%	14.4%	$0.156	$0.161
method	$40k-$60k	20.68%	19.28	$1,115	$1,137	2.0%	$22	19.6%	20.0%	$0.158	$0.161
	$60k-$100k	31.09%	20.26	$1,194	$1,194	0.0%	$0	31.6%	31.6%	$0.161	$0.161
	>$100k	23.32%	22.22	$1,373	$1,309	-4.7%	-$64	27.3%	26.0%	$0.169	$0.161
weighted	**$0-$20k**	**9.17%**	**7.92**	**$353**	**$466**	**32.2%**	**$113**	**2.8%**	**3.6%**	**$0.122**	**$0.161**
rank	**$20k-$40k**	**15.74%**	**11.65**	**$550**	**$687**	**24.8%**	**$136**	**7.4%**	**9.2%**	**$0.129**	**$0.161**
method	**$40k-$60k**	**20.68%**	**15.62**	**$798**	**$921**	**15.4%**	**$123**	**14.0%**	**16.2%**	**$0.140**	**$0.161**
w*=0.40	**$60k-$100k**	**31.09%**	**21.81**	**$1,262**	**$1,285**	**1.9%**	**$23**	**33.4%**	**34.0%**	**$0.159**	**$0.161**
	>$100k	**23.32%**	**31.58**	**$2,137**	**$1,861**	**-12.9%**	**-$277**	**42.4%**	**36.9%**	**$0.185**	**$0.161**
usage	$0-$20k	9.17%	6.07	$265	$358	35.3%	$93	2.1%	2.8%	$0.119	$0.161
rank	$20k-$40k	15.74%	10.38	$468	$611	30.7%	$143	6.3%	8.2%	$0.124	$0.161
method	$40k-$60k	20.68%	14.82	$717	$873	21.8%	$156	12.6%	15.4%	$0.133	$0.161
	$60k-$100k	31.09%	21.46	$1,199	$1,265	5.4%	$65	31.7%	33.5%	$0.153	$0.161
	>$100k	23.32%	34.35	$2,383	$2,024	-15.1%	-$359	47.3%	40.2%	$0.190	$0.161
SDG&E					**Average Annualized Bill**			**Share of**		**Average Price**	
	Income	Share of	Daily Use			Percent	Dollar	**Total Revenue**		**($/KwH)**	
	Range	Customers	(kWh)	*Bench*	*Flat*	Change	Change	*Bench*	*Flat*	*Bench*	*Flat*
random	$0-$20k	8.34%	14.83	$843	$871	3.3%	$28	6.8%	7.1%	$0.156	$0.161
rank	$20k-$40k	18.41%	15.76	$903	$923	2.2%	$20	16.2%	16.5%	$0.157	$0.161
method	$40k-$60k	21.59%	16.68	$963	$976	1.4%	$14	20.2%	20.5%	$0.158	$0.161
	$60k-$100k	29.02%	17.91	$1,049	$1,052	0.3%	$3	29.6%	29.7%	$0.160	$0.161
	>$100k	22.64%	20.36	$1,238	$1,195	-3.5%	-$43	27.2%	26.3%	$0.167	$0.161
weighted	**$0-$20k**	**8.34%**	**4.73**	**$226**	**$277**	**22.6%**	**$51**	**1.8%**	**2.2%**	**$0.131**	**$0.161**
rank	**$20k-$40k**	**18.41%**	**8.52**	**$416**	**$500**	**20.2%**	**$84**	**7.4%**	**8.9%**	**$0.134**	**$0.161**
method	**$40k-$60k**	**21.59%**	**12.78**	**$650**	**$749**	**15.4%**	**$100**	**13.6%**	**15.7%**	**$0.139**	**$0.161**
w*=0.00	**$60k-$100k**	**29.02%**	**18.91**	**$1,063**	**$1,109**	**4.3%**	**$46**	**30.0%**	**31.3%**	**$0.154**	**$0.161**
	>$100k	**22.64%**	**32.41**	**$2,142**	**$1,901**	**-11.3%**	**-$241**	**47.1%**	**41.8%**	**$0.181**	**$0.161**
usage	$0-$20k	8.34%	4.73	$226	$277	22.6%	$51	1.8%	2.2%	$0.131	$0.161
rank	$20k-$40k	18.41%	8.52	$416	$500	20.2%	$84	7.4%	8.9%	$0.134	$0.161
method	$40k-$60k	21.59%	12.78	$650	$749	15.4%	$100	13.6%	15.7%	$0.139	$0.161
	$60k-$100k	29.02%	18.91	$1,063	$1,109	4.3%	$46	30.0%	31.3%	$0.154	$0.161
	>$100k	22.64%	32.41	$2,142	$1,901	-11.3%	-$241	47.1%	41.8%	$0.181	$0.161

Table 5A: Average Bill By Income Bracket Under Benchmark and Alternative Flat Tariff Using Random-Rank, Usage-Rank and Weighted-Rank Within-CBG Allocation Methods

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