Does Increasing Block Pricing Decrease Energy Use? Evidence from the Residential Electricity Market

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Abstract

Many electric utilities in the US have replaced flat pricing schedules with increasing block prices (IBPs) in an effort to decrease aggregate energy use without imposing costs on low-income households. IBPs are step functions where the price per kilowatt-hour increases as a household uses more electricity. It is not clear, however, in theory or in practice, whether IBPs decrease aggregate energy use and protect low-income households relative to a revenue-neutral flat rate. I use detailed monthly billing records combined with demographic data for 11,745 California households and price differences over time across utility climate zones to estimate price elasticities of energy demand by income. I find that that wealthier households are more price elastic. I use these elasticities to show that IBPs increase total electricity use relative to a revenue-neutral flat price, therefore failing to achieve their goal of conservation. Last, I find that IBPs decrease electricity bills for low-income households while pushing costs to high-income households.

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1 Introduction

Increasing Block Prices (IBPs), introduced for residential electricity customers in the 1980s, have the dual goals of decreasing total electricity use and protecting low-income households from increasing electricity prices. Under these tiered IBPs, the price per kilowatt-hour (kWh) increases step-wise with electricity use: households that use more electricity pay more per kWh. However, it is not clear that IBPs meet their conservation or distributional goals. For a change from flat electricity prices to IBPs, low-consumption households experience a decrease in price and high-consumption households an increase. This makes the effect of replacing flat prices with IBPs on total electricity demand theoretically ambiguous because it depends on the relative elasticities of electricity demand for households experiencing price increases and decreases, the distribution of the households across the pricing schedule, and whether consumers respond to marginal or average price.

Even if IBPs meet the goal of decreasing total electricity use, whether IBPs help low-income households depends on the relationship between electricity use and income, the effect of a reduced-rate program for low-income households, and the effect of charging households different prices based on where they live. This paper resolves these ambiguities empirically by asking: (1) Do IBPs decrease total electricity use relative to a revenue-neutral flat price? and (2) Do IBPs help low-income households?

A central issue for all nonlinear prices is whether consumers respond to marginal or average price. This problem is particularly relevant for electricity because consumers may not know their electricity price. Under IBPs, average prices are less than or equal to marginal prices, which means that if consumers respond to average price they have a lower incentive to conserve. In this paper, I evaluate the outcomes for conservation and redistribution under both marginal and average price response assumptions.

Whether IBPs decrease total electricity use or help low-income households depends critically on price elasticities of electricity demand by income. To estimate those elasticities, I use data from the Residential Appliance Saturation Study (RASS) for California, which contains household-level monthly electricity use and demographics. I estimate demand elasticities for both marginal and average price response assumptions. Both estimates are important because, in theory, households
respond to marginal prices, but current empirical evidence suggests that consumers optimize with respect to average price (Ito, 2014; Wichman, 2014). This paper is the first to estimate price elasticities by income assuming that households respond to average price.

The main challenge in estimating price elasticities is that electricity prices are endogenous. There are two sources of that endogeneity. The first is the common simultaneity problem: price and quantity are jointly determined by the equilibrium of electricity supply and demand. When electricity demand is high, the utility company charges high prices. The second source, which is also a simultaneity problem, results from the nature of IBP schedules themselves: per-unit prices increase with electricity use. Any unexpected or unobservable factors that increase electricity use could move a household onto a higher pricing tier. Both of these simultaneity problems result in a positive correlation between electricity prices and use.

To address the two endogeneity problems, I use two sources of exogenous price variation: temporal and cross-sectional. Temporal variation results from occasional updates to prices that utilities make over time. Cross-sectional variation results from geographically differentiated electricity prices within the same utility. While these intra-utility pricing regions have been used to estimate policy outcomes, such as energy savings from building codes, this paper is the first to use them to estimate price elasticities of electricity demand.¹

To solve these endogeneity problems and estimate price elasticities, I borrow an approach from the taxation literature called a simulated instrument. That approach, which has been recently applied to the electricity literature, predicts a household’s current electricity price using historical electricity use (Ito, 2014). My analysis focuses on the sample of households that live within 10 kilometers of borders where electricity prices change discontinuously. If households respond to average price, price elasticities of demand range from -0.155 for households with income from $0-34,999 to -0.226 for households with incomes greater than $150,000. If households respond to marginal price, households are less elastic. Elasticities range from -0.136 for households with income from $0-34,999 to -0.155 for households with incomes greater than $150,000.

To answer the question of whether IBPs decrease total electricity use, I apply these elasticities to estimate counterfactual flat electricity prices that would raise the same revenue as the existing IBPs. I compare observed electricity use under IBPs to counterfactual electricity use under the

¹ See Levinson (2016) and Bruegge, Deryugina, and Myers (2018) for further discussion.
revenue-neutral flat prices. If consumers respond to average price, IBPs would increase electricity use by 1.01 percent compared to the flat price. The average price response effect dominates because higher use households misperceive their electricity prices to be lower than the marginal prices and consume more electricity. If instead, consumers respond to marginal prices, a switch from flat to block prices would decrease demand by 1.18 percent. In both cases, I find similar results using previously estimated demand elasticities.

Using both marginal and average price response assumptions establishes bounds on the effect of IBPs on total electricity use. Because evidence shows that households respond to average price, IBPs are likely increasing total electricity consumption, failing to achieve their goal of conservation (Ito, 2014; Wichman, 2014).

To answer whether IBPs meet their goal of helping low-income households, I compare changes in electricity bills across income groups. The correlation between monthly electricity use and income is small, suggesting that IBPs do little to protect low-income households from high electricity bills. To test this, I compare electricity bills across alternative pricing schedules, finding that IBPs save low-income households a small amount of money on their electricity bills by pushing costs onto higher-income households. Borenstein (2012) poses the same question using household-level electricity consumption data and a range of elasticities, finding that IBPs help low-income households but at significant efficiency losses. One advantage of my analysis is that I observe income at the household level in the RASS, which allows me to study the effects of IBPs and the low-income subsidy rate at the household level. I find that the low-income subsidy rate is more effective at protecting low-income households than IBPs.

In sum, IBPs do not meet their stated goal of decreasing aggregate electricity demand if households respond to average price. I find that households would increase their electricity consumption under three different sets of price elasticity estimates, demonstrating that this finding is robust to a range of price elasticity estimates. I also find that IBPs help low-income households, but that the primary mechanism for redistributing income among rate-payers is a subsidized low-income electricity rate.
2 Empirical Setting

2.1 California’s IBPs and Data

This study focuses on households served by two of the three major investor-owned utilities in California: San Diego Gas and Electric (SDG&E) and Pacific Gas and Electric (PG&E). SDG&E and PG&E are two of the largest utilities in the US. In 2003, one of the years in this study, SDG&E served 1.1 million households and PG&E served 4.3 million households.

Each household’s electricity price depends on the month, the location, and how much electricity it consumes. Each location-specific IBP has a different kWh threshold for the first tier, called a “baseline,” and subsequent rate increases occur at 130 percent, 200 percent, and 300 percent of that baseline. The baseline is set by historical average monthly electricity use by households within region with the same climate, known as a climate zone.²

Figure 1 depicts an example for June 2009 for PG&E’s climate zone T. This IBP has five tiers, ranging from 11 cents per kWh to 44 cents per kWh. The height of each tier represents the price per kWh a household pays; these are the same within a utility. The width of each tier depends on the baseline tier one threshold at which prices increase; these vary within a utility. In the example in Figure 1, the baseline allocation is 235 kWh. Households pay 11 cents per kWh for electricity use up to 253 kWh (the baseline), 13 cents from 253 to 329 kWh (130 percent of 253), 26 cents from 329 to 506 kWh (200 percent of 253), 38 cents from 506 to 759 (300 percent of 253), and 44 cents above 759 kWh.

Figure 1 also shows the average price the household pays as a function of its electricity consumption, represented by the dashed line. The average price is the same as the IBP for the first tier, and then increases more slowly than the IBP for higher tiers. For example, a household using 436 kWh per month, which was average electricity use in PG&E Zone T in June 2009, would pay 26 cents for the 437th kWh. The average price across all 437 kWh would be 15.3 cents per kWh. The total monthly electricity bill would be $66.91.

More generally, each utility has a set of tiered rates. Each utility has multiple climate zones with different baseline electricity allocations, determining where the prices jump from one tier to the next. SDG&E has four zones and PG&E has ten. Baselines are generally lower in coastal

² The CPUC, together with the utility companies, determines these climate zones.
Most California households face prices like the one in Figure 1. The main exception are households in the CARE program. CARE offers low-income households 25 to 30 percent discounts on their electricity prices. In all empirical estimates in this study, I account for household CARE eligibility based on income thresholds. Around 1.4 million PG&E customers were eligible for CARE in 2015. CARE prices are lower than IBP rates and have two tiers rather than the standard five. In PG&E in June 2009, for example, CARE households paid 8 cents per kWh up to the baseline allocation and 10 cents per kWh for all electricity use above the baseline allocation.

2.2 Household Electricity Use Data

Household electricity data come from the RASS. The RASS, funded by the California Energy Commission, surveyed the electricity use of a representative sample of California households in 2003 and 2009. The survey contains information on household demographics, physical characteristics of the house, monthly electricity use, and monthly gas use for an average of 16 months for each household in each survey round. Across both surveys, the sample consists of 46,490 households and of those, 18,231 are served by SDG&E or PG&E and therefore are part of this study. Each of those households is paired with monthly electricity use data from the utilities.

I focus on single-family homes and exclude the top and bottom one percent of electricity users and households with missing data for income or the year their home was built. The final data set includes 11,745 households and 191,851 monthly electricity use observations. Each household can be matched to its monthly IBP using the household’s climate zone designation. I use the household-specific electricity consumption data combined with location-specific electricity prices to calculate total monthly bills, marginal electricity prices, and average electricity prices for each household for each month. This combined dataset not only contains monthly electricity use, which is standard in the literature, but also detailed demographic information. That detailed information is key to determining whether IBPs meet their goals of conserving electricity.

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3. This difference reflects the fact that baselines are set to charge roughly the same bills to households in different climate zones. Households living further inland experience warmer weather and therefore use more electricity on average as a result of air conditioner use.


5. For a more detailed description of the data see Appendix A.1.
and helping low-income households.\footnote{6. Many studies use utility-level panel data: see Ito (2014), Borenstein (2009), and Wichman (2017). Similarly, surveys that contain detailed demographic information do not report monthly electricity use. See Reiss and White (2005) and Alberini, Gans, and Velez-Lopez (2011).}

The average household in the sample used 590 kWh per month in 2003 and 617 kWh per month in 2009. The houses are, on average, 1,900 square feet and 35 years old. Appendix Table B.1 shows additional descriptive statistics for the households in the sample.\footnote{7. Levinson (2016) confirms that the RASS is a representative sample of California households by comparing the RASS to the American Housing Survey and the Residential Energy Consumption Survey.}

### 2.2.1 Low-Income Rates

While IBPs are intended to help low-income households, the CPUC mandates a low-income bill assistance program: “California Alternative Rates for Energy (CARE).” Any utility with more than 100,000 customers must provide 20-35 percent discounts on gas and electricity bills for eligible households.\footnote{8. See \url{https://www.cpuc.ca.gov/General.aspx?id=976}. Accessed 5/20/19.}

The CPUC determines income thresholds for CARE eligibility based on household income and size. If a household’s income is below the threshold for its family size, it can enroll in CARE.\footnote{9. Not all households that are eligible for CARE enroll in the program. In 2015, PG&E estimated that roughly 200,000 households of 1.4 million eligible households did not sign up for the program. Source: \url{https://www.pge.com/en/about/newsroom/newsdetails/index.page?title=20151012_thousands_of_energy_customers_could_receive_more_than_30_percent_in_energy_savings_through_pge_care_program} Accessed 2/20/2018.}

I observe both household income and size in the RASS and therefore can determine whether each household is eligible for CARE rates. I use this information to match all CARE-eligible households in my sample to the special CARE electricity prices.\footnote{10. Using both CARE and non-CARE rates is key to determining whether IBPs help low-income households. Borenstein (2012) finds that the presence of CARE decreases the redistribution from IBPs by more than 50 percent.}

### 2.3 Empirical Challenge

There are two primary problems with estimating elasticities using a simple first differences specification of log-differences in electricity use on log-differences in household electricity prices. The first is the standard simultaneity problem: equilibrium electricity prices and demand are determined jointly. And the second is related to the structure of IBPs: under IBPs a household’s electricity price is determined by the quantity of electricity it uses. So, there is a positive correlation between electricity use and electricity prices. One additional problem introduced by first differencing is
that the independent variable, $\Delta\ln(kWh_{it})$, represents the growth-rate in electricity use between two months. If high- and low-electricity users have different growth rates in electricity use, the price-elasticity estimate will be biased.

I estimate price elasticities using a naive first differences strategy controlling for changes in weather and household-by-month fixed effects. Those estimates are reported in Appendix Table B.2 for both marginal and average prices. Using either marginal or average price suggests that demand curves are upward sloping—consumers use more electricity as prices increase. This positive relationship, however, is a result of the two simultaneity problems. For example, these estimates suggest that for a one percent change in average price, electricity use would increase by 1.76 percent. Similarly, for a one percent change in marginal price, electricity use would increase by 0.77 percent.

2.4 Estimating Price Elasticities Using Climate Zones

To address the two simultaneity problems present in the naive first-differences specification, I use an instrumental variables approach by combining cross-sectional and temporal variation in electricity prices. Cross-sectional variation arises from utilities charging different households different prices based on the household’s location. Temporal variation arises from utilities’ changing electricity prices over time.

Households using the same amount of electricity but living in different climate regions pay different electricity prices. For example, two of PG&E’s largest climate zones are Zones T and X. Zone T runs along the coast from Mendocino to San Luis Obispo while Zone X is the same length, but inland. In June 2009 the baseline allocation in Zone X was 369 kWh per month, which is warmer, and the baseline allocation in Zone T was 253 kWh per month. The lower baseline allocation in Zone T corresponds to higher electricity prices for households in Zone T. These higher prices are a result of the fact that the IBP increases more quickly for Zone T households because the baseline allocation is lower.

Suppose there were two households that used 650 kWh in June 2009, one in Zone T and the other in Zone X. For an additional kWh, the Zone T household would have paid 38 cents (on the fourth tier) and the Zone X household would have paid 26 cents (on the third tier). The average price per kWh in Zone T would have been 21 cents versus 16 cents in Zone X. These differences in price would correspond to a $140 electricity bill in Zone T and a $101 electricity bill in Zone X.
Temporal price variation results from electric utilities updating both the utility-wide prices and the baseline allocations. Electricity prices fluctuate seasonally and are increasing over time for both utilities. The changes in baseline allocations primarily reflect seasonal changes: baseline allocations are higher in summer than in winter. The immediate implication of pricing by climate zone is that, for the same electricity use, households living on opposite sides of the climate border pay different prices that change differentially over time.

I use this cross-sectional and temporal variation in a two-stage least squares strategy to identify the price elasticity of electricity demand. I use a price instrument proposed by Auten and Carroll (1999) and used in Ito (2014). The price instrument is: $\Delta \ln(\tilde{P}_{it}) \equiv \ln(P_t(kWh_{i0})) - \ln(P_{t-12}(kWh_{i0}))$, where kWh$_{i0}$ represents the kWh consumed in the first month the household is in the sample and $P_{t-12}$ is the pricing schedule from 12 months prior to month $t$. This represents the change in price a household $i$ would have experienced for energy use kWh$_{i0}$ from month $t - 12$ to month $t$ if it had used the same amount of electricity in both months (Auten and Carroll, 1999).

I estimate the price elasticity of electricity demand via two-stage least squares. The first stage estimates changes in electricity household prices as a function of exogenous, utility-driven, changes in electricity prices.

First Stage:

$$\Delta \ln(P_{it}) = \pi_0 + \pi_1 \Delta \ln(\tilde{P}_{it}) + \sum_{j=1}^{10} D_{itj} + \pi_2 \Delta X_{it} + \nu_{it}$$

The second stage estimates changes in electricity use as a function of the predicted changes in electricity price from the first stage estimation.

Second Stage:

$$\Delta \ln(kWh_{it}) = \beta_0 + \delta \Delta \ln(P_{it}) + \sum_{j=1}^{10} D_{itj} + \beta_1 \Delta X_{it} + \eta_{it}$$

where $\Delta \ln(P_{it})$ is the predicted log-change in price from the first stage regression based on the

11. There are alternative choices for the constant level of electricity consumption to generate alternative instruments. The first is electricity use from a period in the middle. For example, if we are measuring the change in price from January of 2000 to January of 2001, we would use consumption in June of 2000. Another alternative would be to use mean electricity consumption. Using the mean helps lessen the impact of transitory shocks and mean reversion in electricity use. See Blomquist and Selin (2010), Saez, Slemrod, and Giertz (2012), and Ito (2014) for further discussion of these alternative instruments. Using any one of these three instruments requires different assumptions on the structure of the error term.
simulated instrument $\Delta \ln(\tilde{P}_{it})$. In the first stage regression, $\pi_1$ represents the relationship between the instrument, $\Delta \ln(\tilde{P}_{it})$, and the observed log-change in electricity prices over twelve months. As in Ito (2014), I add a dummy variable equal to 1 if electricity use is in decile $j$, $D_{itj}$, to control for differences in the growth rate of electricity consumption between high- and low-users. Identification of this dummy variable comes from different households using the same amount of electricity, but paying different prices based on where they live. $\Delta X_{it} = X_{it} - X_{it12}$ is the difference in weather from $t$ to month $t - 12$, $\tau_t$ a month-of-sample fixed effect, and $\eta_{it} = \epsilon_{it} - \epsilon_{it12}$. The coefficient, $\delta$, is the estimated price elasticity of electricity demand.

I estimate the instrumental variables regression on two different sub-samples of data. The first is a limited geographic sample of households that live within 10 km of the closest climate border. This method relies on the assumption that households living nearby are similar and are not sorting across the climate border based on electricity prices. Bruegge, Deryugina, and Myers (2018) show that households living close to California Energy Commission climate borders use similar amounts of electricity. Balance tests for household characteristics across climate zones can be seen in Appendix Table B.6.

The second method of identifying the effect of prices on electricity demand is simple one-to-one matching on observable household characteristics. Using this alternative sample serves as a robustness check to using households immediately across the border. The wealth of information in the RASS allows me to compare similar households living throughout the climate zones, rather than only across the border. Balance tests for household characteristics in the matched sample in Appendix Table B.7.

Within each sample, I estimate heterogeneous price elasticities for four different income groups. Rather than estimating elasticities by electricity use, this paper estimates elasticities by income. Because IBPs were intended to protect low-income households, understanding how price sensitivity varies by income group is a key parameter of interest.
3 Results

3.1 Price Elasticities

Appendix Table B.3 reports the estimates of $\pi_1$ from the first-stage regression, equation (1), for both marginal and average price. These estimates are using the geographically limited climate-bored sample. For the regression on average price, a one percent increase in the log-difference in the “simulated” average price results in a 0.89 percent increase in the log-difference in the actual average price. I split the sample into the four income groups and estimate the first-stage regression again separately for each group. The correlation between the price instrument and the actual change in price remains strong and positive.

For marginal price, a one percent increase in the simulated marginal price results in a 0.69 percent increase in the log-difference in the actual marginal price. All F-statistics are greater than 10, suggesting a strong first-stage relationship. The correlation is stronger for the average price instrument because the average prices generated by IBPs do not have the big jumps in price that the marginal prices do.

Table 1 reports the estimates of price elasticies of demand using the geographically limited sample and the instrument based on the first period of consumption $kWh_{i0}$.\textsuperscript{12} The first column reports the estimates for price elasticities of demand if households respond to average price. In the full sample, a one percent increase in the average electricity price causes households to decrease their electricity consumption by -0.090 percent. This estimate mirrors the estimate of -0.088 found by Ito (2014).

Next, I split the sample into four different income groups and estimate price elasticities separately by income. I find that low-income households are slightly less price elastic than high-income households. The price elasticities of demand reported in Table 1 range from -0.16 for households with income from $0 to $34,999 to -0.23 for households with income greater than $150,000. Wealthier households have more price elastic than lower-income households.

A one percent increase in marginal price causes a -0.075 percent decrease in electricity consumption, if households respond to marginal price. Again, higher-income households are more price elastic than lower-income households. Price elasticities of demand range from -0.14 for house-

\textsuperscript{12} Robustness checks for five kms and 20 kms can be seen in Appendix Tables B.10 and B.11.
holds with income from $0 to $34,999 to -0.16 for households with income greater than $150,000. Elasticities estimated by previous studies range from 0 to -0.6 (Reiss and White, 2005). The estimates in Table 1 are within this range.\textsuperscript{13}

In all estimates in Table 1 the price-elasticities for lower-income households are not statistically significant. Many of these households qualify for California’s low-income pricing program, CARE. As previously mentioned, CARE provides 25 to 30 percent discounts on electricity prices both by charging lower per-unit prices and by using a two-tier IBP rather than a five-tier IBP. These CARE households do not experience many changes in electricity prices over time. So, the variation in prices for these households is smaller, which decreases the statistical precision of my estimates.\textsuperscript{14}

3.2 Finding the Counterfactual Flat Price

To determine whether IBPs decrease total electricity use, I compare actual electricity under the existing IBP to electricity use under a flat price that raises the same revenue as that IBP. As previously mentioned, utility companies are rate of return regulated, so any price changes must raise the same revenue as the price schedule they are replacing. Thus, electricity use must be compared under two alternative pricing schedules that raise the same revenue. The procedure that follows is similar to a strategy frequently used in the public finance literature to compare outcomes under revenue neutral tax changes.

The equation below takes price elasticities estimates from Table 1 into account to hold revenue neutral between both pricing scenarios. The following approximation calculates a flat price, $\bar{p}$, that

\begin{equation}
\eta_{it} = \epsilon_{it} - \epsilon_{t0} \quad (Ito, 2014).
\end{equation}

This correlation could arise from mean-reversion in electricity consumption: if a household has a positive use shock in their first month in the sample, typically their electricity use will drift back down over time, leading to correlation between errors over time. Other simulated instruments based on average electricity use, $kW_{hi}$, and the month in the middle, $kW_{h_{it6}}$, have been suggested (Blomquist and Selin, 2010 and Saez, Slemrod, and Giertz, 2012). Table B.12 reports estimates of price elasticities using the household’s average monthly electricity use, $kW_{hi}$. And Table B.13 reports estimates of price elasticities using the month in the middle of the two end months, $kW_{h_{it6}}$. The month in the middle, for example, would be June 2009 if the log-difference is for December 2008 to December 2009. The elasticity estimates reported in tables B.12 and B.13 show a similar pattern to the main elasticity estimates in Table 1.

13. It is still possible that the first period of electricity consumption, $kW_{i0}$, is correlated with the error term $\eta_{it} = \epsilon_{it} - \epsilon_{t0}$ (Ito, 2014). This correlation could arise from mean-reversion in electricity consumption: if a household has a positive use shock in their first month in the sample, typically their electricity use will drift back down over time, leading to correlation between errors over time. Other simulated instruments based on average electricity use, $kW_{hi}$, and the month in the middle, $kW_{h_{it6}}$, have been suggested (Blomquist and Selin, 2010 and Saez, Slemrod, and Giertz, 2012). Table B.12 reports estimates of price elasticites using the household’s average monthly electricity use, $kW_{hi}$. And Table B.13 reports estimates of price elastiticies using the month in the middle of the two end months, $kW_{h_{it6}}$. The month in the middle, for example, would be June 2009 if the log-difference is for December 2008 to December 2009. The elasticity estimates reported in tables B.12 and B.13 show a similar pattern to the main elasticity estimates in Table 1.

14. These elasticity estimates are also robust to using the alternative matched sample. The matched sample is generated by matching households between climate zones using simple one-to-one nearest neighbor matching. Appendix Table B.14 reports the main estimates using the matched sample for both average and marginal price. Appendix Table B.15 reports the elasticity estimates using the matched sample and the average electricity use instrument, $kW_{hi}$. And Appendix Table B.16 reports the elasticity estimates using the matched sample and the price instrument based on electricity use in the middle month, $kW_{h_{it6}}$. The price-elasticity estimates using the matched sample and different versions of the price instrument yield qualitatively similar results.
raises the same revenue, \( R \), as the block price, \( s(p_i) \):

\[
R = \sum_{i}^{N} D_i(\bar{p}) \ast \bar{p} = \sum_{i}^{N} \left[ D_i(s(p_i)) + (\bar{p} - s(p_i))\delta_j \frac{D_i(s(p_i))}{s(p_i)} \right] \ast \bar{p}
\]  

(3)

where \( R \) is utility revenue, \( i \) is a consumer index, \( \bar{p} \) is the revenue-neutral flat price, \( D_i(\bar{p}) \) is electricity demand under the flat rate, \( D_i(s(p_i)) \) is electricity demand under the current multi-tier rate \( s(p_i) \), and \( \delta_j \) is the price elasticity of electricity demand for the income group \( j \).

Equation (3) is a Taylor series representation of utility revenue from individual consumer demand under the counterfactual flat price \( \bar{p} \). The first line of the equation represents the revenue raised by electricity use under the flat price. In the second line the term in brackets represents electricity demand under the flat price, \( \bar{p} \), using the observed electricity demand under the existing IBP, \( D_i(s(p_i)) \). In my data, I observe \( R \), \( s(p_i) \), and \( D_i(s(p_i)) \). I estimate the price elasticities \( \delta_j \) and then I can rearrange equation (3) to solve for \( \bar{p} \). This expression allows me to assume households respond either to marginal or average price, represented by \( p_i \). Equation (3) is used to calculate a separate flat price in each climate zone in each month.

If households respond to the average price, the revenue-neutral flat price is about 15 cents per kWh, on average over all households in all months. This flat price, \( \bar{p} \), ranges from 11 cents to 21 cents based on the climate zone. The lowest tier one price in the sample is 8.3 cents (a CARE price) and the highest is 44 cents depending on the month and climate region. So, on the lowest end, the flat price is only slightly higher than the cheapest electricity price and on the highest end the flat price is half as much as the highest price.

I also calculate equation (3) separately for CARE-eligible and CARE-ineligible households. This allows my analysis to incorporate a separate flat price for low-income households. The average CARE flat price is 9.6 cents per kWh and the average non-CARE flat price is 16 cents per kWh. The CARE households receive a 40 percent discount on their electricity use under the flat price relative to the higher-income households. This discount roughly corresponds to the average discount on electricity use for CARE households under IBPs.
3.3 Do IBPs Decrease Total Electricity Use?

With the revenue neutral flat price, $\bar{p}$, I can calculate each household’s counterfactual electricity use to compare total electricity use under the flat price, $D(\bar{p})$, to total electricity use under the IBP, $D(s(p_i))$. Household $i$’s consumption under the flat price, $D_i(\bar{p})$ is given by:

$$D_i(\bar{p}) = D_i(s(p_i)) + (\bar{p} - s(p_i))\delta_j \frac{D_i(s(p_i))}{s(p_i)}$$

(4)

where $D_i(\bar{p})$ is household consumption under the hypothetical flat price, $D(s(p_i))$ is consumption under the current block pricing regime, and $p_i$ is household average (or marginal) price. Then, I aggregate across households within each climate zone to calculate the percentage change in total consumption under the hypothetical flat price, $D(\bar{p})$, from observed total consumption under the IBP, $D(s(p_i))$.

Figure 3 is a representative example of the steps necessary to determine the change in electricity use for a switch from flat prices to IBPs. The solid step function shows the IBP schedule in PG&E’s Zone T in June 2009. The solid distribution represents actual electricity consumption under the existing IBP. The dashed line shows the flat price that would have raised the same revenue in Zone T in June 2009, calculated to be 17 cents per kWh using Equation (3). The dashed distribution depicts the estimated electricity use under the counterfactual flat price of 17 cents per kWh, calculated using Equation (4). The solid distribution (IBP) is a rightward shift of the dashed distribution (flat), which shows that average electricity use would have increased in Zone T in June 2009 for a switch from a flat prices to an IBP. I complete this exercise in every zone in every month to determine whether, in aggregate, a hypothetical switch from flat prices to IBPs decreases total electricity use.

Table 2 reports the total percentage changes in electricity demand for a change from flat prices to IBPs for each climate zone. The bottom row reports the average change across climate zones for total electricity use. Total electricity consumption would have increased by 0.70 percent in 2003 and by 1.36 percent in 2009 if households responded to average electricity prices. Total electricity consumption would have decreased by 1.01 percent in 2003 and by 1.38 percent in 2009 if households responded to marginal electricity prices.\footnote{Appendix Table B.22 reports the same estimates using the flat price with a low-income rate. These results}

15. Appendix Table B.22 reports the same estimates using the flat price with a low-income rate. These results
prices, meaning the results in Table 2 demonstrate that IBPs increase total electricity use relative to a flat price (Ito, 2014 and Wichman, 2014 Shaffer, 2019).

In 2003 and 2009, if households respond to average price, IBPs increase demand relative to a flat price. But, if households respond to marginal price, IBPs decrease demand relative to a flat price. The difference in total electricity use under average versus marginal price response assumptions is due to two factors: first, I estimate smaller price sensitivities for households responding to marginal price, and second, marginal prices are higher than average prices. So, if households are responding to marginal price, then the price signal to decrease electricity use is stronger because marginal prices are higher than average prices. These high prices lead households to cut back on their electricity consumption. Despite the fact that some households still experience a decrease in price and increase their consumption, more households experience an increase in price and decrease their consumption.

There is some heterogeneity in the effect of IBPs on electricity use between climate regions. This is because there are different distributions of income, price elasticities, and electricity use between climate zones. For one extreme example of the heterogeneous demand response between climate zones, consider the difference in 2009 between PG&E’s Zone R, which is an inland region covering part of California’s Central Valley, and SDG&E’s Coastal Zone. In Zone R, households would have increased their electricity use by 2.83 percent if prices changed from flat to block, while in the Coastal Zone, households would have increased their use by only 0.46 percent. In both zones, around 30 percent of households experience a decrease in their electricity prices for a switch from flat to block prices. But, the average decrease in price in Zone R is larger (19 percent) relative to the average decrease in price in the Coastal Zone (13 percent). So, while the same proportion of households experience a price decrease, because the price decrease is bigger in the Central Valley, these households increase their electricity use by relatively more than households in the Coastal Zone. The differences in total electricity use between these zones demonstrate that the effect of IBPs depends on the type of consumers served by the utility company.

show small to little change in total electricity consumption if households respond to average price and decreases in electricity use if households respond to marginal price.
3.4 IBPs, Electricity Use, and Alternative Elasticity Estimates

To test the sensitivity of the finding that IBPs increase total electricity use, I repeat the calculations in equations (3) and (4) using two often cited papers (Reiss and White, 2005 and Ito, 2014). Table 3 shows the changes in electricity demand using these alternate elasticities. Reiss and White (2005) find elasticity estimates ranging from -0.49 for the lowest income households to -0.29 for the highest income households. They estimate these elasticities using a discrete continuous choice model, assuming marginal price response. I use these estimated elasticities for $\delta_j$ and both marginal and average price for $p_i$ in equations (3) and (4). Under Reiss and White’s elasticity estimates, changes in total electricity use range from a 5.56 percent increase for average price response to a 4.87 percent decrease for marginal price response.

The estimated change in demand is greater under Reiss and White’s estimated elasticities than under my estimates for two reasons. The first is that they find that lower-income households are more price elastic than higher-income households. Since lower-income households use slightly less electricity than higher-income households, they are the most likely to experience a price decrease when switching from a flat price to an IBP. Thus, the households who experience the decrease in price are the ones who are the most price elastic. Second, they find elasticities that are larger in magnitude than my estimates, which magnifies their effects compared to my estimates.

In a more recent study of price elasticities of electricity demand, Ito (2014) estimates a price elasticity of -0.088. He does so using a simulated price instrument for households along the Southern California Edison (SCE) and SDG&E service border in San Diego. He also calculates the change in electricity use from a revenue-neutral flat price instead of IBPs. He finds that IBPs would increase aggregate demand by 0.27 percent if consumers respond to average price but would decrease aggregate demand by 2.33 percent if consumers respond to marginal price.

Table 3 shows the percentage change in total electricity use using Ito’s elasticity estimate of 0.088. Demand would have increased by 0.77 percent if households respond to average price but would have decreased 1.33 percent if households respond to marginal price. Because Ito finds that consumers are relatively price inelastic, the magnitude of the demand response is small, but still demonstrates that IBPs do not meet the goal of decreasing total electricity use. My results differ from Ito’s because (1) I calculate a different revenue-neutral flat price in each month while he
uses the long-run average electricity price, (2) my sample of households differs from his, and (3) I calculate price elasticities of demand by income group and use these in my calculations.

Table 3 summarizes these outcomes, where my estimates align more with the estimates using Ito’s elasticities than Reiss and White’s. These differences reflect the fact that I find price elasticities that are closer in magnitude to Ito’s. Ito, however, estimates only one elasticity while both my estimates and Reiss and White’s allow for heterogeneity between households with different incomes.

4 Do IBPs Help Low-Income Households?

IBPs introduce a classic trade-off between equity and efficiency. IBPs are socially inefficient because different households pay different marginal prices for the same good (Borenstein, 2012). Rather than using IBPs, utility companies could charge marginal prices that are reflective of the social cost of electricity generation, and give a cash transfer to low-income households. This type of price schedule could be preferred to IBPs because (1) all households would pay the same per unit price and (2) cash transfers are typically more efficient than in-kind transfers (Thurow, 1974). A scheme where low-income households receive a cash transfer is currently infeasible because it requires utility companies knowing the income of each household they serve.16

Under IBPs, Households’ electricity bills increase as their electricity use increases under IBPs. So, electricity bills are higher for high-use households than for low-use households. These differences in bills between high and low users are intended to protect low-income households from high electricity bills. But, whether IBPs help low-income households in practice depends on three key components. First, relief from high bills depends on the correlation between income and electricity use. Low-income households will only be on the low pricing tiers if they are low-electricity users. Second, relief from high bills depends on CARE. CARE targets household income directly, so whether IBPs help any further depends on how much help is already being provided by CARE. And third, the relief depends on the effect of utilities’ climate zone pricing. Low-income households tend to live in warmer areas of California, so they live in climate zones where prices are lower, on average. I characterize the effects of these three components to determine whether IBPs protect low-income households from high electricity bills.

16. The most notable exception is CARE. However, the utility company only knows that these households qualify for lower rates, not their explicit incomes.
IBPs will decrease electricity bills for low-income households only if monthly electricity use is closely related to income. To test whether monthly electricity use and income are closely related, I test the correlation between the two. That correlation is 0.222 in the RASS. Figure 2 shows the distribution of electricity use by income group. High-income households use more electricity than low-income households. But, each distribution has a long right tail in electricity use—some households in each income group use large amounts of electricity. IBPs are an imperfect instrument for redistribution because monthly electricity use may not be a good proxy for income.

Differences in appliance portfolios between high and low-income households could be one possible reason for the weak correlation between monthly electricity use and income. Low-income houses are smaller, and have fewer air conditioners and televisions than high-income households. But, their houses are older, have older refrigerators and heaters, and are located in warmer climates. Whether high- or low-income households use more electricity is not immediately apparent from their characteristics.

I calculate electricity use per square foot for each household to measure of electricity use intensity. The higher that number, the more electricity a house uses per square foot. Electricity use intensity decreases monotonically as income increases in my sample. The correlation between electricity use intensity and income is -0.099. That negative relationship suggests that high-income households use less electricity per square foot than low-income households. High-income households use less electricity per square foot than low-income households despite living in bigger homes. The negative relationship between electricity use per square foot and income further weakens the correlation between monthly electricity use and income.17

California’s CARE program is designed to protect low-income households from high bills. So, IBPs may not offer these low-income households any additional assistance. If the lowest-income households are on CARE pricing schedules, IBPs only have the potential to help CARE-ineligible households. CARE directly targets low-income households while IBPs use monthly electricity use as a proxy for income. Any bill protection offered by IBPs will be in addition to any protection offered by CARE.

In my sample, 16.6 percent of households meet CARE income eligibility requirements; most

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17 I also calculate electricity use per household member. I find a negative relationship between monthly electricity use per person and income, with a correlation of -0.0031. This negative correlation suggests that each household member uses less electricity in higher-income households than lower-income households.
of these households are in the two lowest income bins. CARE prices are lower than the standard IBPs and only have two tiers rather than five. Because many low-income households are already enrolled in CARE, IBPs have limited opportunities to offer assistance to low-income households.

Third, utility companies in California charge electricity prices that vary by climate zone. Electricity prices in warmer climates are lower than cooler climates. In my sample, lower-income households tend to live in warmer areas than higher-income households, which means that they pay lower electricity prices. I take pricing by climate zone into account by estimating climate-zone-specific flat prices.

The next three sections examine the effect of IBPs on consumer welfare. First, I compare bills between three different pricing schedules: the existing IBPs with CARE, flat prices with CARE, and flat prices without CARE. All three pricing schedules raise the same revenue. Second, I calculate changes in consumer surplus from a hypothetical switch from the flat prices to the existing IBPs.

4.1 Winners and Losers from IBPs

I compare bills between three different pricing schedules that raise the same revenue: the existing IBPs with CARE, flat prices with CARE, and flat prices without CARE. Equation (3) is used to calculate the alternative flat prices and Equation (4) is used to calculate electricity use under those alternative prices. These changes in electricity bills determine whether IBPs protect low-income households from high electricity bills.

Table 4 shows electricity bills under the existing IBPs and flat prices with and without CARE assuming all eligible households are enrolled in CARE. The average flat price across all months and all climate zones is 15 cents per kWh. These estimates combine the effect of IBPs and CARE. IBPs with CARE lower electricity bills for the lower income households from $69.94 under the flat price to $53.58 under the IBP. IBPs combined with CARE save households with income from 0 to $34,999 $16.16 on average each month. Households with income from $35,000-74,999 save $1.05 each month, those with income from $75,000-149,000 pay $5.04 more, and those with income greater than $150,000 pay $14.85 more, under IBPs relative to a flat price without CARE rates. In terms of percentages, these changes in electricity bills represent a large share of the total bills of low-income households. IBPs, in conjunction with CARE, save these households around 23 percent on their electricity bills. Middle and high-income households pay more under IBPs than they do under flat prices.
electricity prices. Thus, IBPs and CARE protect low-income households from high electricity bills by pushing costs onto higher-income households.

The flat monthly bills in Table 4 do not take CARE pricing into account. Thus, low-income households would be switching from a flat price without a low-income subsidy to a tiered price with a subsidy. The stark differences in bills for the lowest income households are likely being driven by the presence of CARE.

Table 5 shows the exact same changes in electricity bills, but for a flat price with a low-income rate. That flat CARE price is 9.6 cents per kWh, on average, and the flat price for non-CARE households is 16 cents per kWh, on average. This calculation ensures revenue neutrality within each of the two groups (CARE and non-CARE), and reflects what a flat price might look like in California.

Electricity bills for the lowest income households under IBPs with CARE again are $53.78. Bills under the flat price, including a low-income rate, are $55.45. Thus, a switch from a flat price with a low-income program to an IBP with a low-income program would only save the lowest income households an additional $1.66 on their electricity bills. A low-income subsidy for electricity bills is the important component for protecting low-income households from high bills. Households with income from $35,000-74,999 save $3.39 each month, those with income from $75,000-149,000 pay $0.02 more, and those with income greater than $150,000 pay $10.04 more, relative to a flat price with a low-income rate. The differences in bills are much larger without providing a low-income flat rate, suggesting that CARE is responsible for helping low-income households more than IBPs.

4.2 Changes in Consumer Surplus from IBPs

IBPs charge different marginal prices to different households based on their electricity use. These differences in marginal price distort consumption relative to a flat price where all households pay the same marginal price. These changes in consumer surplus from introducing flat prices have three key implications. First, per unit electricity prices fall for the first units of electricity use. These price decreases get passed through to the consumer in the form of lower electricity bills. But, beyond any threshold where prices are higher than the initial flat price, households pay higher

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18. Again, assuming that all CARE-eligible households are enrolled in the program.
19. The average prices represent the average prices in a given year-month across all climate zones.
per unit prices. These higher prices are passed through to the household in the form of higher electricity bills. Whether a household’s electricity bill falls for a change from flat to block prices depends on what share of their electricity use falls above and below the original flat electricity price.

In addition to changing household per-unit electricity prices, IBPs also introduce deadweight loss. Households consuming in the part of the block pricing schedule that is above the flat price under-consume relative to what they would have used under the flat price. Households in the part of the block pricing schedule with lower per unit prices over-consume relative to what they would have used under the flat price.

Figure 4 represents a stylized version of the changes in consumer surplus the previous two paragraphs described. This figure shows a high-use household with a hypothetical demand curve, \( D \). The flat price, \( \bar{p} \), lies between a hypothetical two-tier IBP such that \( p_1 < \bar{p} < p_2 \). Under the flat price, \( \bar{p} \), and the household’s demand curve, \( D \), the household uses \( \bar{q}_i \) kWh month. When the pricing schedule changes to the block price from the IBP, the household now faces the second tier of the block pricing schedule \( p_2 \). Correspondingly, electricity use falls from \( \bar{q}_i \) to \( q_i \).

There are three labeled regions in Figure 4. The first, region A, represents the increase in consumer surplus from paying a lower per unit price, \( p_1 \) for each kWh up to the threshold where the block price increases. The second, region B, represents a decrease in consumer surplus from paying more per kWh for every kWh consumed above the threshold where the block price increases above the original flat price. The third, region C, represents the deadweight loss from under-consumption relative to the original flat price.

This example demonstrates how IBPs could affect consumer surplus. Whether consumer surplus increases or decreases depends on the share of a household’s consumption at prices above and below the original flat price. This example represents a two-tier IBP, but also extends to IBPs with more than two tiers. It also extends to low-use households.

I calculate the change in consumer surplus for all households in my sample by assuming linear demand.\(^{20}\) Table 6 shows the changes in consumer surplus from switching to an IBP from flat prices without a low-income rate. The lowest income households experience a $19.41 increase in consumer

\(^{20}\) This assumption of linear demand is not realistic, but it illustrates the changes in consumer surplus that the households experience.
surplus, which is 36 percent of their electricity bills. The highest income households experience a $22.25 decrease in consumer surplus, which is 17 percent of their electricity bills.\footnote{This analysis assumes that households respond to marginal price, which is contrary to the evidence in Ito (2014) and Wichman (2014). Average price response has different implications for changes in consumer welfare because price misperception must also be taken into account. Wichman (2017) develops a model to quantify the effect of misperceiving prices on changes in consumer surplus in the context of a natural experiment.}

5 Conclusion

In this paper, I demonstrate that if households respond to average prices, IBPs increase total electricity consumption in California, which is contrary to their stated goal. This outcome depends on the relative price elasticities of households along the pricing schedule. I also find that IBPs redistribute income relative to a flat pricing schedule, but that the important factor in this redistribution is the presence of CARE, the subsidized low-income electricity rate.

If households respond to average price, I find that the deadweight loss from using IBPs instead of a socially optimal flat price is smaller than if households respond to marginal price. This outcome is due to the fact that electricity prices in California are higher than the social marginal cost of electricity use. Because IBPs charge users low prices for the first units of electricity, these lower prices are closer to the socially optimal price.

As the United States works to confront climate change, the electricity sector is the first frontier—in 2016, the electricity sector generated 28 percent of total greenhouse gas emissions (Environmental Protection Agency, 2016). Economists argue that electricity prices should reflect the social marginal cost of electricity generation, and IBPs are one approach to decreasing emissions while protecting low-energy users, who are assumed to be low income (Borenstein, 2012; Levinson and Silva, 2018). IBPs are a climate change mitigation tool used around the world. For example, China introduced IBPs for electricity in 2012 (Zhang, Cai, and Feng, 2017).

It is important to understand whether IBPs meet their dual goals because more and more utilities are considering introducing them. While IBPs are becoming increasingly common in electricity markets, nonlinear prices are pervasive. Examples of other nonlinear prices include increasing marginal tax rates and water rates, and decreasing nonlinear rates for cellphone data plans. While these pricing policies often have salutary policy goals, the results in this paper demonstrate that their effectiveness in meeting those goals depends on how, or whether, consumers respond to them.
For instance, increasing marginal tax rates, intended to raise revenue, may have the unintended consequence of decreasing hours worked, relative to a flat tax (Saez, 2010; Kucko, Rinz, and Solow, 2018; Mortenson and Whitten, 2018). This is especially true if the increases in marginal tax rates are salient to consumers. Evidence shows that consumers respond better to salient prices, but it is often very difficult for households to know the price they are paying under complex nonlinear pricing schedules (Chetty, Looney, and Kroft, 2009; Finkelstein, 2009; Jessoe and Rapson, 2014). Price salience can either help or hinder these policies in meeting their goals. More research on consumer price response is needed to evaluate the efficacy of policy outcomes where non-linear pricing schedules are the driving mechanism.

References


6 Figures and Tables

6.1 Figures

Figure 1: PG&E IBP Schedule June 2009

![IBP Schedule](https://www.pge.com/tariffs/electric.shtml) Access 9/15/17

Note: This graph shows the IBP schedule for PG&E customers living in Zone T in June, 2009. The solid line shows a five-tier IBP with prices ranging from 11 cents per kWh to 44 cents per kWh. The dashed line shows the average prices generated by the IBP schedule. Source: [https://www.pge.com/tariffs/electric.shtml](https://www.pge.com/tariffs/electric.shtml) Accessed 9/15/17
Figure 2: Distribution of Consumption by Income Group

Note: This figure shows four different distributions of electricity use by income group. As income increases, the mass of the distribution shifts to the right, but all distributions are overlapping. Source: RASS

Figure 3: PG&E Zone T: June 2009

Note: This figure shows the IBP and average price households living in Zone T paid for their electricity consumption in June 2009. The solid density represents the distribution of electricity use under that pricing schedule. The flat dashed line is the revenue-neutral price that I calculated using equation (3). The dashed distribution represents electricity use that I calculated under that flat price using equation (4). Sources: https://www.pge.com/tariffs/electric.shtml Accessed 9/15/17; RASS
Figure 4: Welfare Change from Flat to IBP

Note: This graph represents the change in consumer surplus from switching from a flat price to an IBP schedule. This is a stylized example with a two-tier IBP.
### 6.2 Tables

Table 1: Geographic Sample: Price Elasticities of Demand

<table>
<thead>
<tr>
<th>Income Group</th>
<th>Avg Price Elasticity</th>
<th>Marginal Price Elasticity</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Sample</td>
<td>−0.0901*</td>
<td>−0.0748*</td>
<td>32,530</td>
</tr>
<tr>
<td></td>
<td>(0.0404)</td>
<td>(0.0260)</td>
<td></td>
</tr>
<tr>
<td>$0-34,999</td>
<td>−0.155</td>
<td>−0.136</td>
<td>6,110</td>
</tr>
<tr>
<td></td>
<td>(0.237)</td>
<td>(0.124)</td>
<td></td>
</tr>
<tr>
<td>$35,000-74,999</td>
<td>−0.0188</td>
<td>−0.0325</td>
<td>10,352</td>
</tr>
<tr>
<td></td>
<td>(0.0843)</td>
<td>(0.0452)</td>
<td></td>
</tr>
<tr>
<td>$75,000-149,999</td>
<td>−0.0908</td>
<td>−0.0885*</td>
<td>11,462</td>
</tr>
<tr>
<td></td>
<td>(0.0573)</td>
<td>(0.0417)</td>
<td></td>
</tr>
<tr>
<td>$&gt;150,000</td>
<td>−0.226*</td>
<td>−0.155*</td>
<td>4,606</td>
</tr>
<tr>
<td></td>
<td>(0.0816)</td>
<td>(0.0583)</td>
<td></td>
</tr>
</tbody>
</table>

*Note:* Standard errors in parentheses are clustered at the household level to adjust for serial correlation in electricity consumption, *p*<0.05. This table reports the 2SLS results for households living within 10km of a climate border using the simulated instrument based on $kWh_{i0}$. All regressions control for weather and a dummy for the decile of electricity consumption. Omitted covariates for the regression on average price can be seen in Table B.8 and for marginal price in Table B.9. Robustness checks for 5km and 10km can be seen in Appendix tables B.10 and B.11 respectively.
Table 2: Geographic Sample: Percent Change in Aggregate Consumption

<table>
<thead>
<tr>
<th></th>
<th>2003 Average</th>
<th>2003 Marginal</th>
<th>2009 Average</th>
<th>2009 Marginal</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PG&amp;E</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R</td>
<td>1.23%</td>
<td>−0.53%</td>
<td>2.83%</td>
<td>0.31%</td>
</tr>
<tr>
<td>S</td>
<td>0.83%</td>
<td>−0.98%</td>
<td>1.81%</td>
<td>−0.84%</td>
</tr>
<tr>
<td>T</td>
<td>0.77%</td>
<td>−1.16%</td>
<td>1.93%</td>
<td>−0.97%</td>
</tr>
<tr>
<td>X</td>
<td>0.52%</td>
<td>−1.45%</td>
<td>1.62%</td>
<td>−1.45%</td>
</tr>
<tr>
<td><strong>SDG&amp;E</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coastal</td>
<td>0.59%</td>
<td>−0.35%</td>
<td>0.46%</td>
<td>−2.07%</td>
</tr>
<tr>
<td>Mountain</td>
<td>1.82%</td>
<td>0.90%</td>
<td>0.71%</td>
<td>−1.90%</td>
</tr>
<tr>
<td>Desert</td>
<td>1.90%</td>
<td>1.01%</td>
<td>1.35%</td>
<td>−1.94%</td>
</tr>
<tr>
<td>Inland</td>
<td>0.56%</td>
<td>−0.36%</td>
<td>0.60%</td>
<td>−1.86%</td>
</tr>
<tr>
<td>Weighted Average</td>
<td>0.70%</td>
<td>−1.01%</td>
<td>1.36%</td>
<td>−1.38%</td>
</tr>
</tbody>
</table>

*Note:* This table reports the total changes in electricity use for moving from a revenue-neutral flat price to the existing IBPs. Positive numbers indicate IBPs increase electricity use relative to a flat price and negative numbers indicate that IBPs decrease electricity use. The average is weighted by the number of household-month observations in the RASS.

Table 3: Aggregate Changes Using Other Price Elasticities

<table>
<thead>
<tr>
<th>Year</th>
<th>Brolinson Average</th>
<th>Marginal</th>
<th>Reiss and White (2005) Average</th>
<th>Marginal</th>
<th>Ito (2014) Average</th>
<th>Marginal</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td>0.70%</td>
<td>−1.01%</td>
<td>3.25%</td>
<td>−4.74%</td>
<td>0.51%</td>
<td>−1.19%</td>
</tr>
<tr>
<td>2009</td>
<td>1.36%</td>
<td>−1.38%</td>
<td>8.25%</td>
<td>−5.01%</td>
<td>1.08%</td>
<td>−1.49%</td>
</tr>
<tr>
<td>Weighted Average</td>
<td>1.01%</td>
<td>−1.18%</td>
<td>5.56%</td>
<td>−4.87%</td>
<td>0.77%</td>
<td>−1.33%</td>
</tr>
</tbody>
</table>

*Note:* This table reports the percentage changes in average electricity use under three different sets of elasticity estimates. The averages are weighted by the number of household-month observations in the RASS. Note that Reiss and White (2005) only estimate price elasticities assuming that households respond to average price, which I apply universally under both sets of calculations. Similarly, Ito (2014) only estimates price elasticities assuming that households respond to average price.
Table 4: Changes in Electricity Bills in $

<table>
<thead>
<tr>
<th>Income</th>
<th>Monthly Bill (IBP)</th>
<th>Monthly Bill (Flat)</th>
<th>Change</th>
<th>Percent</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>$0-34,999</td>
<td>53.78</td>
<td>69.94</td>
<td>16.16</td>
<td>23.11%</td>
<td>39,408</td>
</tr>
<tr>
<td>$35,000-74,999</td>
<td>83.58</td>
<td>84.63</td>
<td>1.05</td>
<td>1.24%</td>
<td>60,438</td>
</tr>
<tr>
<td>$75,000-149,999</td>
<td>101.97</td>
<td>96.93</td>
<td>-5.04</td>
<td>-5.20%</td>
<td>63,343</td>
</tr>
<tr>
<td>$&gt;150,000</td>
<td>132.25</td>
<td>117.67</td>
<td>-14.58</td>
<td>-12.39%</td>
<td>26,771</td>
</tr>
</tbody>
</table>

Note: This table presents the changes in electricity bills by income for switching from flat to block prices. A positive number for “Change” indicates that a household’s electricity bills increase under a flat price. Each row is weighted by the number of household-month observations in that income category.

Table 5: Changes in Electricity Bills with a Flat CARE rate

<table>
<thead>
<tr>
<th>Income</th>
<th>Monthly Bill (IBP)</th>
<th>Monthly Bill (Flat with CARE Rate)</th>
<th>Change ($)</th>
<th>Percent</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>$0-34,999</td>
<td>53.78</td>
<td>55.45</td>
<td>1.66</td>
<td>2.99%</td>
<td>39,408</td>
</tr>
<tr>
<td>$35,000-74,999</td>
<td>83.58</td>
<td>86.97</td>
<td>3.39</td>
<td>3.90%</td>
<td>60,438</td>
</tr>
<tr>
<td>$75,000-149,999</td>
<td>101.97</td>
<td>101.95</td>
<td>-0.02</td>
<td>-0.02%</td>
<td>63,343</td>
</tr>
<tr>
<td>$&gt;150,000</td>
<td>132.25</td>
<td>122.21</td>
<td>-10.04</td>
<td>-8.22%</td>
<td>26,771</td>
</tr>
</tbody>
</table>

Note: This table presents the changes in electricity bills by income for switching from flat to block prices where the flat price includes a reduced CARE rate. A positive number for “Change” indicates that a household’s electricity bills increase under a flat price. Each row is weighted by the number of household-month observations in that income category.

Table 6: Changes in Consumer Surplus from Flat to Block By Income

<table>
<thead>
<tr>
<th>Income</th>
<th>Monthly Bill ($)</th>
<th>Change in CS ($)</th>
<th>Percent</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>$0-34,999</td>
<td>53.78</td>
<td>19.41</td>
<td>36.09%</td>
<td>39,540</td>
</tr>
<tr>
<td>$35,000-74,999</td>
<td>83.58</td>
<td>-0.99</td>
<td>-1.19%</td>
<td>60,446</td>
</tr>
<tr>
<td>$75,000-149,999</td>
<td>101.97</td>
<td>-8.37</td>
<td>-8.20%</td>
<td>63,343</td>
</tr>
<tr>
<td>$&gt;150,000</td>
<td>132.25</td>
<td>-22.25</td>
<td>-16.82%</td>
<td>26,771</td>
</tr>
</tbody>
</table>

Note: This table presents the changes in consumer surplus by income for switching from flat to block prices. A positive number for “Change” indicates that a household’s surplus increases under a flat price. Each row is weighted by the number of household-month observations in that income category.