Redistribution Effects of Electricity Pricing in Korea

Jung S. You and Soyoung Lim
Rice University, Houston, TX, U.S.A.
E-mail: jsyou10@gmail.com

Revised: January 31, 2013

Abstract

Domestic electricity pricing in Korea implements block pricing. The pricing structure is complicated to have 6 segments each of those has usage fee and fixed fee different from other segments. This block pricing is non-convex, and the rate of the lowest usage fee to the highest usage fee is at least 11 times. Prices also depends on whether a household resides in a house supplied with low voltage or with high voltage. Especially rapidly rising usage fee has caused consumers to complain about the block pricing structure and some suggest that an alternative block pricing with three segments with variant fixed fee schemes be considered instead of the current baseline block pricing.

We aim to analyze the impact of alternative electricity pricing on the welfare of consumers, compared to the current block pricing scheme. To do this, we first establish a theoretical model to compute each household's welfare change when it faces non-convex budget set. Our measurement of welfare change is equivalent variation (EV). As we should know the demand schedule and predicted consumption levels at each scenario during the computation of welfare change, we estimate the actual electricity demand function in Korea and compute every household's electricity consumption and expenses. Having actual demand schedule and predicted consumption levels under alternative scenarios, we compute every household's EV, social welfare and social inequality applying Atkinson's inequality aversion indices.

Keywords: ; .

JEL Classification ;

1 Introduction

Domestic electricity pricing in Korea implements block pricing. The pricing structure is complicated to have 6 segments each of those has usage fee and fixed fee different from other segments. This block pricing is non-convex, and the rate of the lowest usage fee to the highest usage fee is at least 11 times. Prices also depends on whether a household resides in a house supplied with low voltage or with high voltage. Especially rapidly rising usage fee has caused consumers to complain about the block pricing structure and some suggest that an alternative block pricing with three segments with variant fixed fee schemes be considered instead of the current baseline block pricing.

We aim to analyze the impact of alternative electricity pricing on the welfare of consumers, compared to the current block pricing scheme. To do this, we first establish a theoretical model to compute each

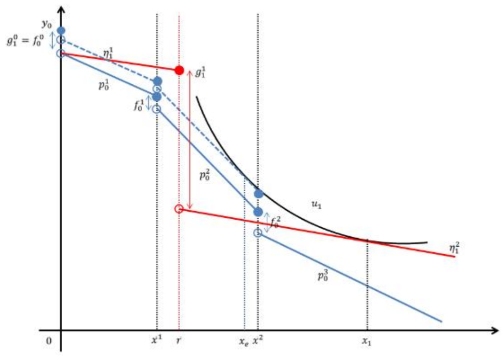

Figure 1: x^e lies on a segment $(\bar{x}^1, \bar{x}^2)$

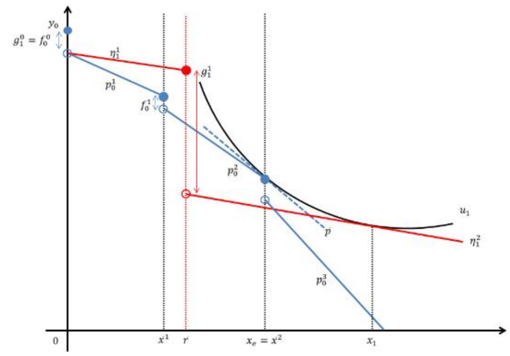

Figure 2: x^e meets a threshold; $x^e = \bar{x}^2$

household's welfare change when it faces non-convex budget set. Our measurement of welfare change is equivalent variation (EV). As we should know the demand schedule and predicted consumption levels at each scenario during the computation of welfare change, we estimate the actual electricity demand function in Korea and compute every household's electricity consumption and expenses. Having actual demand schedule and predicted consumption levels under alternative scenarios, we compute every household's EV, social welfare and social inequality applying Atkinson's inequality aversion indices.

2 Previous studies

3 Model

The current electricity block pricing consists of threshold $\bar{x} = (\bar{x}^0, \cdots, \bar{x}^n)$ where $\bar{x}^0 = 0, \bar{x}^n = \infty$, usage fee $\mathbf{p}_0^b = (p_0^1, \cdots, p_0^n)$, and fixed fee $\mathbf{f}_0^b = (f_0^0, \cdots, f_0^{n-1})$. Let alternative block price consist of $\bar{\mathbf{r}} = (\bar{r}^0, \cdots, \bar{r}^m)$ where $\bar{r}^0 = 0, \bar{r}^m = \infty$, usage fee $\eta_{\mathbf{1}}^{\mathbf{b}} = (\eta_1^1, \cdots, \eta_1^m)$, fixed fee $\mathbf{g}_{\mathbf{1}}^{\mathbf{b}} = (g_1^0, g_1^1, \cdots, g_1^{m-1})$.

4 Regression of Demand Function

Before we proceed to scenario analysis, a demand function should be estimated so as to obtain the change in electricity consumption in response to the change in price. We set up a time series model for demand function as follows.[1] We need a linear demand equation such as

$$x_t = \alpha p_t + \beta y_t + e_t \tag{1}$$

[1]Though it is ideal to estimate a demand function at micro level, regression with household level data was not successful because the variation of price is very limited. The electricity is supplied only by KEPCO in Korea and there is no regional variation in price settings. Moreover, the change in price occurs only once a year. Thus we were not able to control for endogeneity stemmed from the simultaneity of quantity and price though 2SLS method was attempted.

Variable	No. of obs.	Average	Standard deviation	Minimum	Maximum
Usage(kWh)	32	269	145	80	499
Price(Won/kWh)	32	153	48	101	253
GDP per capita (Real,10,000 won)	32	1,024	755	101	2,492
Cooling degree days (HD)	32	722	102	451	946
Heating degree days (CD)	32	2,723	210	2,323	3,103

Table 1: Descriptive Statistics: Aggregate Data

where $E[e_t] = 0$. As x_t, p_t, y_t however are unit-root time series and are not cointegrated, we do not want to estimate equation (1) right away. Rather we estimate differenced series such as

$$\Delta x_t = \alpha \Delta p_t + \beta \Delta y_t + \epsilon_t \tag{2}$$

where ϵ_t is a stationary process with $E[\epsilon_t] = 0$. We can write $p_t = p_{t-1} + u_{1,t}$, $y_t = y_{t-1} + u_{2,t}$ and $e_t = \psi e_{t-1} + \eta_t$ where $u_{1,t}, u_{2,t}$ and η_t are mean zero stationary processes with $E[u_{1,t}\eta_t] = 0$ and $E[u_{2,t}\eta_t] = 0$. Note that the explained and explanatory variables are cointegrated if $|\psi| < 1$, or not otherwise. We would like to check the validity of regression in differences. Equations (1) and (2) let us write

$$\begin{aligned}\Delta x_t &= \alpha \Delta p_t + \beta \Delta y_t + (e_t - e_{t-1}) \\ &= \alpha \Delta p_t + \beta \Delta y_t + (\psi - 1)e_{t-1} + \eta_t \\ &= \alpha \Delta p_t + \beta \Delta y_t + \epsilon_t.\end{aligned}$$

If $\psi = 1$ holds, then $E[\Delta p_t \epsilon_t] = E[u_{1,t}\eta_t] = 0$ and $E[\Delta y_t \epsilon_t] = E[u_{2,t}\eta_t] = 0$. Thus, regressing Δx_t on explanatory variables generates consistent estimators for α and β. If $|\psi| < 1$, $E[\Delta p_t \epsilon_t] = (\psi - 1)E[u_{1,t}e_{t-1}] \neq 0$ and $E[\Delta y_t \epsilon_t] = (\psi - 1)E[u_{2,t}e_{t-1}] \neq 0$ unless $u_{i,t}$ and e_{t-1} are uncorrelated for each $i, i = 1, 2$. OLS in differences will lead to inconsistent estimators in this case. As $e_t = e_0 + \sum_{i=0}^{t} \eta_i$ with $E[\eta_t] = 0$, we rather assume $E[e_0] = 0$ instead of $E[e_t] = 0$.

4.1 Data

The data used for regression of demand equation is aggregate data, which is annually reported by Korea Electric Power Corporation (KEPCO). KEPCO announces its total sales value, number of households who are on contract, and total quantity sold during each year. Using this information, the price of residential electricity is calculated as the total sales value divided by total number of households which purchased electricity. The period covers 1980 through 2011. In demand estimation, real GDP per capita was used as a proxy to household income. Table 1 shows the simple descriptive statistics of yearly data from 1980 through 2011. On average, a household consumes 269 kWh per month and average price is 153 won per kWh. During the sample period, the average real GDP per capita approximately ten million won and it reached 25 million won at the end of sample period. Moreover, weather is an important contributor of consumption of electricity. To take into weather effect account, heating degree days and cooling degree days are considered as well.

4.2 Results

The regression is conducted for models with different specifications, one with only price and income and the other adding weather variables. The results of regression is listed in Table 3. In model 1, the estimate of price coefficient is -0.494 and the estimate of income coefficient is 0.134. The

Variables	Model 1	Model 2
First differenced price	-0.494**	-0.582**
	(0.204)	(0.246)
First differenced real GDP per capita	0.134***	0.125***
	(0.035)	(0.037)
First differenced CD		0.032
		(0.024)
First differenced HD		0.001
		(0.008)
No. of observation	31	31

Note : 1) *, **, *** represent significance at 10% level, 5% level and 1% level, respectively.
2) Parenthesis are standard error.

Table 2: Regression results

model 2 shows that the estimated price coefficient is -0.582 and the income coefficient is estimated at 0.125. Though both models show statistically significant estimates for price coefficient and income coefficient, the estimates from model 1 will be used to calculate price elasticity later on.

Moreover, endogeneity arising between price and consumption might be problematic. Hence, this study run two stage least squares regression using lagged variables by one period and two periods as instruments. Then Hausman test is conducted for endogeneity test. As a result, the null hypothesis of no endogeneity was accepted because chi-squared test statistics is 1.05 and p value is 0.5906.

5 Scenario Analysis

In this section, we set up scenarios as alternative price schedules in order to measure the economic impact of different pricing system. Specifically, bill changes, consumption changes and welfare changes of individual households are to be addressed. Finally, the impact of different pricing systems on social welfare is explored.

5.1 Data

The data collected by Family Budget Survey (FBS) 2011 is used. FBS is conducted by the Statistics Korea (KOSTAT) and it collects information of household income and expenditure during a month. We use yearly data which shows income and expenses of households during a representative month in 2011.[2] This data is advantageous because it is nationally representative and allows us to examine the change in consumption and bills at household level under alternative pricing systems. Total expenditure on electricity is reported, however, the expenses should be converted to electricity usage using price schedule. The data includes 10,543 households surveyed but we omit households whose incomes are lower than 1,000 won because KEPCO charges every household of minimum fee of 1,000 won per month. As a result, the sample used for scenario analysis includes 10,504 households.

Table **??** shows the average electricity consumption and bills across income groups under current rates. Not surprisingly, higher income households have higher usage of electricity and they pay

[2]KOSTAT surveys households on a monthly basis and it announces monthly data, quarterly data and yearly data.

more than lower income households. However, the fraction of electricity bill in household income decreases by household income, which suggests that the economic burden associated with the electricity becomes large among low income households.

5.2 Price elasticities

This study presumes that households respond to the change in price. Thus, the calculation of new consumption level needs price elasticity. Let x^* be the consumption level under the current price system. $p_0^b = (p_0^1, \cdots, p_0^n)$ and $f = (f^0, \cdots, f^{n-1})$ denote the vector of block usage fees and fixed fees of the current price system, respectively. $\bar{x} = (\bar{x}^0, \bar{x}^1, \cdots, \bar{x}^n)$ denotes thresholds for blocks where $\bar{x}^0 = 0$ and $\bar{x}^n = \infty$. When a household consumes electricity at the amount of x^* in block l under the current price system, the marginal price it faces is p_0^l. Using demand function, the consumption x^* can be written as follows:

$$x^* = \alpha p^* + \beta y^* + \gamma z \tag{3}$$

where $\sum_{j=1}^{0} = 0$ and $y^* = y_0 + \sum_{j=1}^{l-1}(p^* - p_0^j)(\bar{x}^j - \bar{x}^{j-1})$ if $l > 1$ and $y^* = y^0$ otherwise. Note that the income y^* includes the actual income y_0 and virtual compensations due to the block pricing to support the marginal price p_0^l. Also, as the actual income y_0 must cover fixed fee, the virtual compensation does not include any fixed fee. The electricity expenses of the household under the price system is:

$$\begin{aligned} R &= \sum_{j=1}^{l-1} p_0^j \bar{x}^j + (x^* - \bar{x}^{l-1}) p_0^l \\ &= \sum_{j=1}^{l-1} p_0^j \bar{x}^j + (\alpha p_0^l + \beta[y_0 + \sum_{j=1}^{l-1}(p_0^{j+1} - p_0^j)\bar{x}^j] - \bar{x}^{l-1}) p_0^l. \end{aligned}$$

If the household's consumption x^* does not occur at any threshold $\bar{x}^i$, $i \in \{0, 1, \cdots, n-1\}$, marginal price p_0^l is the same as the household's marginal willingness to pay for the last unit consumed. If x^* occurs at any $\bar{x}^i$, $i \in \{0, 1, \cdots, n-1\}$, where the price rises from p_0^{i-1} to p_0^i, the marginal price may differ from marginal willingness to pay. We denote the marginal price mp and the consumer's marginal willingness to pay $mwtp$. The total change in consumption can be written as

$$\frac{dx^*}{d(mp)} = \left[\frac{\partial x^*}{\partial(mwtp)} + \frac{\partial x^*}{\partial y} \cdot \frac{d\Delta y}{d(mwtp)}\right] \frac{d(mwtp)}{d(mp)} \tag{4}$$

where $\Delta y = \sum_{j=1}^{l-1}(p_0^{j+1} - p_0^j)\bar{x}^j$. Note that $\frac{\partial x^*}{\partial(mwtp)}$ is the slope of demand and $\frac{\partial x^*}{\partial y}$ is marginal income effect. The term outside the brackets $\frac{d(mwtp)}{d(mp)} = 0$ if $x^* = \bar{x}^i$ for any $i \in \{0, \cdots, n-1\}$ and $\frac{d(mwtp)}{d(mp)} = 1$ otherwise. $\frac{d\Delta y}{d(mwtp)}$ is the change in intra-marginal expenditure. For our liner demand and block price system, (4) takes the simple form as follows:

$$\frac{dx^*}{d(mp)} = \alpha \cdot \mathbf{1}(x^* \neq \bar{x}^i \text{ for all } i \in \{0, 1, \cdots, n-1\}) + \beta \bar{x}^{l-1} \cdot \mathbf{1}(\bar{x}^{l-1} < x^* < \bar{x}^l) \tag{5}$$

where $\mathbf{1}(\cdot)$ is the indicator function. Using (5), price elasticity of a household whose current consumption level is x^* at marginal price p_0^l is

$$\epsilon = \frac{p_0^l}{x^*} \cdot \left[\alpha \cdot \mathbf{1}(x^* \neq \bar{x}^i \text{ for all } i \in \{0, 1, \cdots, n-1\}) + \beta \bar{x}^{l-1} \cdot \mathbf{1}(\bar{x}^{l-1} < x^* < \bar{x}^l)\right] \tag{6}$$

Income brackets	Number of households	Household income (1,000won)	Electricity usage (kWh per month)	Percentage in usage (%)	Electricity bill (won per month)	Fraction of electricity bill in household income (%)
1st	1,051	469	231	7.5	29,730	6.3
2nd	1,050	1,086	264	8.5	36,159	3.3
3rd	1,051	1,670	281	9.1	39,438	2.4
4th	1,050	2,207	292	9.5	41,478	1.9
5th	1,050	2,733	308	10.0	45,079	1.6
6th	1,051	3,245	322	10.5	48,012	1.5
7th	1,050	3,804	329	10.7	49,789	1.3
8th	1,051	4,479	337	10.9	51,556	1.2
9th	1,050	5,469	348	11.3	55,131	1.0
10th	1,050	8,305	372	12.0	60,694	0.7
Total/Average	10,504	3,346	308	100	45,705	1.4

Note: The price schedule applied is as of July 2011.

Table 3: Regression results

Income deciles	1	2	3	4	5	6	7	8	9	10	Total
Price elasticity	-0.337	-0.315	-0.303	-0.301	-0.287	-0.289	-0.283	-0.287	-0.286	-0.283	-0.297

Table 4: Price elasticities

Using parameters estimated from demand function and household data from FBS, price elasticity for individual households are calculated. The average price elasticity is -0.297, which implies that household demand is inelastic in price changes and electricity is a normal good. It is notable that the absolute value of price elasticity becomes smaller when household income increases. Since high income households tend to have more electronic goods and electric goods than low income households so that they have difficulties in changing their consumption in a short period of time.

5.3 Scenarios

Examining the impact of different price schedule on electricity bills, this study sets up nine scenarios as alternatives. The scenarios are built under two principles, revenue neutrality and previous discussions on the change in price schedule. The summary of scenarios is shown in table 5.

Baseline scenario is the existing price schedule in Korea. The residential electricity is separately priced by voltage, low and high. It is a six tier pricing system. Moreover, fees are composed of two parts, fixed fees and usage fees varying by usage blocks. The Korean electricity price system is more complicated than those in other countries because fixed fees increase by usage block as well as usage fees. Thus households pay for different fixed fees depending on their marginal price. For example, a household should pay fixed fee of the fourth usage block if its marginal price is the usage fee of the fourth usage block. As noted earlier, the existing pricing system is very steeply structured.

The following two scenarios, S2 and S3 are constructed under the assumption of flat charges. By removing tiers, we can measure the impact of tier system. Scenarios S4-1 and S4-2 assume three usage blocks cutting at 260kWh and 340kWh, following the consensus made among policy makers and researchers so far. Also, the progressivity of fees is restricted to three such that the fees in highest block is three times the fees in lowest block. Similarly, scenario S5-1 and S5-2 are assumed to have three blocks with cutoff at 150kWh and 300kWh and also have fees with progressivity of three. Lastly, scenario S6-1 and S6-2 are assumed to have three blocks with lower cutoffs than preceding two scenarios and fees with progressivity of three. They will support our finding as a sensitivity check.

5.4 Change in consumption and bills

Table 5.4 shows average consumption per month and electricity bill for each income group under scenarios. The results show that low income households are more negatively affected by rate changes. That is, the bill sharply increases though the consumption of electricity moderately increases among low income households compared to high income households. Applying S1, the fees at lower usage blocks are down from the previous level and the fees at higher usage blocks are lower than current ones. As a result, average consumption of the lowest income households slightly increases to 238 kWh (3.0 percent increase of baseline) but average consumption of the highest income group increases to 404 kWh (8.7 percent increase of baseline). On the other hand, the change in bills differently occurs across income groups. Under scenario S1, average monthly bill increased by 17.6 percent among the lowest income group while the bill increased only by 4.9 percent among the highest income group. This happens because most low income households face price increase while high income households

Usage block(kWh)			∼ 100	101 ∼ 200	201 ∼ 300	301 ∼ 400	401 ∼ 500	501 ∼
Baseline	Low voltage	Fixed	380	840	1,460	3,490	6,540	11,990
		Usage	56.2	116.1	171.6	253.6	373.7	656.2
	High voltage	Fixed	380	680	1,170	2,890	5,470	9,970
		Usage	53.4	91.2	135.1	196.3	294.5	531.9
S1	Low voltage	Fixed	1,493	2,091	2,688	3,285	3,883	4,480
		Usage	89.9	125.8	161.8	197.7	233.7	269.6
	High voltage	Fixed	1,362	1,907	2,452	2,997	3,541	4,086
		Usage	73.3	102.6	131.9	161.2	190.5	219.8

Usage block(kWh)			Flat charge
S2	Low voltage	Fixed	0
		Usage	142
	High voltage	Fixed	0
		Usage	119.7
S3	Low voltage	Fixed	2,933
		Usage	131.9
	High voltage	Fixed	2,888
		Usage	110.9

Usage block(kWh)			∼ 260	261∼ 340	341∼
S4-1	Low voltage	Fixed	2,933		
		Usage	103.7	207.4	311.1
	High voltage	Fixed	2,888		
		Usage	83.3	166.6	249.9
S4-2	Low voltage	Fixed	1,582	3,163	4,745
		Usage	103.7	207.4	311.1
	High voltage	Fixed	1,318	2,636	3,954
		Usage	83.3	166.6	249.9

Usage block(kWh)			∼ 150	151∼ 300	301∼
S5-1	Low voltage	Fixed	2,933		
		Usage	81.7	163.3	245
	High voltage	Fixed	2,888		
		Usage	65.3	130.6	195.9
S5-2	Low voltage	Fixed	1,249	2,499	3,748
		Usage	81.7	163.3	245
	High voltage	Fixed	1,110	2,220	3,330
		Usage	65.3	130.6	195.9

Usage block(kWh)			∼100	101∼200	201∼
S6-1	Low voltage	Fixed	2,933		
		Usage	66	132.1	198.1
	High voltage	Fixed	2,888		
		Usage	53	105.9	158.9
S6-2	Low voltage	Fixed	1,047	2,094	3,142
		Usage	66	132.1	198.1
	High voltage	Fixed	985	1,970	2,954
		Usage	53	105.9	158.9

Table 5: Summary of scenarios

tend to face decrease in price so that the effect of rate change dampens the effect of increasing consumption.

The scenarios S2 and S3 bring out the most drastic change in consumption and bills. The moving from the tier system to flat charge results in drastic change in electricity consumption and electricity bills. Applying S2, the consumption among the lowest income group increases by 4.4 percent but the bill jumps up by 25.9 percent from the baseline. On the other hand, the average consumption of the highest income group rises by 14.4 percent from the baseline while the bill decreases by 0.2 percent. Meanwhile, difference of bill across income groups is widened under S3 though the consumption is not different from the result of S2.[3] This indicates that low income people will be worse off and high income households will be better off under flat charge system in terms of monthly bill that they pay for.

The results also show that reducing six tier system to three tier system brings increases in electricity consumption and bills across all income groups. Applying S4-1 and S4-2, the average consumption does not show a sharp difference in the percentage change across income groups. However, low income groups have bigger increase in their bills than high income groups. Under the remaining scenarios, the average consumption and electricity bills increase across most income groups. However, the magnitude of consumption change is different across income groups. While the percentage change of consumption increases by household income, the percentage change in average electricity bills decreases by household income. This indicates switching from the current price system to three tier system with progressivity of three will lead to a decrease in the difference in electricity bill across income groups. It also appears that low income households will be more negatively affected by the change of price system.

Table 6: Change in usage and bills

Income brackets	Usage (kWh)	Electricity bill (Won)	Income brackets	Usage (kWh)	Electricity bill (Won)
Baseline			S1		
1st	231	29,730	1st	238 (3.0)	34,949 (17.6)
2nd	262	36,159	2nd	275 (4.3)	41,450 (14.6)
3rd	281	39,438	3rd	296 (5.1)	44,913 (13.9)
4th	292	41,478	4th	307 (5.3)	46,786 (12.8)
5th	308	45,079	5th	326 (5.6)	49,973 (10.9)
6th	322	48,012	6th	343 (6.5)	52,734 (9.8)
7th	329	49,790	7th	351 (6.7)	54,440 (9.3)
8th	337	51,556	8th	361 (7.1)	55,942 (8.5)
9th	348	55,131	9th	375 (7.7)	58,684 (6.4)
10th	372	60,694	10th	404 (8.7)	63,649 (4.9)
S2			S3		
1st	243 (4.4)	37,439 (25.9)	1st	247 (6.3)	38,683 (30.1)
2nd	284 (8.1)	43,485 (20.3)	2nd	289 (9.7)	44,272 (22.4)
3rd	308 (9.5)	46,634 (18.2)	3rd	312(11.0)	47,182 (19.6)
4th	321 (9.6)	48,353 (16.6)	4th	325(11.0)	48,753 (17.5)
5th	341(11.1)	51,085 (13.3)	5th	345(12.4)	51,270 (13.7)
6th	360(11.9)	53,135 (10.7)	6th	364(13.2)	53,143 (10.7)
7th	369(11.8)	54,383 (9.2)	7th	373(13.0)	54,297 (9.1)

[3]The change in consumption depends only on the change in usage fees. Therefore, the electricity consumption under scenarios with the same usage fees are the same regardless of fixed fees.

Table 6 – *Continued from previous page*

Income brackets	Usage (kWh)	Electricity bill (Won)	Income brackets	Usage (kWh)	Electricity bill (Won)
8th	380(12.8)	55,526 (7.7)	8th	384(14.0)	55,347 (7.4)
9th	394(13.4)	57,196 (3.7)	9th	398(14.5)	56,877 (3.2)
10th	426(14.4)	60,560 (-0.2)	10th	429(15.4)	59,939 (-1.2)
S4-1			S4-2		
1st	242 (4.0)	34,739 (16.8)	1st	242 (4.0)	33,875 (13.9)
2nd	275 (4.5)	40,166 (11.1)	2nd	275 (4.5)	39,663 (9.7)
3rd	292 (4.0)	43,026 (9.1)	3rd	292 (4.0)	42,716 (8.3)
4th	302 (3.2)	44,391 (7.0)	4th	302 (3.2)	44,224 (6.6)
5th	317 (3.4)	47,206 (4.7)	5th	317 (3.4)	47,244 (4.8)
6th	333 (3.3)	49,953 (4.0)	6th	333 (3.3)	50,109 (4.4)
7th	339 (2.8)	51,621 (3.7)	7th	339 (2.8)	51,889 (4.2)
8th	348 (3.3)	53,147 (3.1)	8th	348 (3.3)	53,482 (3.7)
9th	360 (3.5)	56,419 (2.3)	9th	360 (3.5)	56,837 (3.1)
10th	387 (3.8)	62,098 (2.3)	10th	387 (3.8)	62,746 (3.4)
S5-1			S5-2		
1st	236 (1.2)	33,608 (13.0)	1st	236 (1.2)	33,036 (11.1)
2nd	270 (2.7)	39,899 (10.3)	2nd	270 (2.7)	39,611 (9.5)
3rd	290 (3.2)	43,362 (9.9)	3rd	290 (3.2)	43,205 (9.6)
4th	301 (2.7)	45,033 (8.6)	4th	301 (2.7)	44,984 (8.5)
5th	318 (3.9)	48,363 (7.3)	5th	318 (3.9)	48,398 (7.4)
6th	336 (4.3)	51,135 (6.5)	6th	336 (4.3)	51,262 (6.8)
7th	344 (4.3)	53,028 (6.5)	7th	344 (4.3)	53,175 (6.8)
8th	353 (4.9)	54,382 (5.5)	8th	353 (4.9)	54,609 (5.9)
9th	368 (5.7)	57,426 (4.2)	9th	368 (5.7)	57,656 (4.6)
10th	398 (6.9)	62,859 (3.6)	10th	398 (6.9)	63,168 (4.1)
S6-1			S6-2		
1st	232 (-0.2)	33,195 (11.7)	1st	232 (-0.2)	32,878 (10.6)
2nd	269 (2.5)	39,916 (10.4)	2nd	269 (2.5)	39,799 (10.1)
3rd	291 (3.6)	43,662 (10.7)	3rd	291 (3.6)	43,612 (10.6)
4th	303 (3.6)	45,739 (10.3)	4th	303 (3.6)	45,749 (10.3)
5th	322 (5.1)	49,159 (9.1)	5th	322 (5.1)	49,227 (9.2)
6th	342 (6.1)	51,937 (8.2)	6th	342 (6.1)	52,016 (8.3)
7th	350 (6.2)	53,620 (7.7)	7th	350 (6.2)	53,711 (7.9)
8th	361 (7.3)	55,198 (7.1)	8th	361 (7.3)	55,289 (7.2)
9th	376 (8.2)	57,699 (4.7)	9th	376 (8.2)	57,774 (4.8)
10th	409 (9.8)	62,489 (3.0)	10th	409 (9.8)	62,560 (3.1)

Note: Parenthesis are percentage change in usage and bill from baseline.

5.5 Welfare changes

We first compute the equivalent variation (EV) of every household following the change of electricity block price. Table 7 shows average EV of each income decile. Having each household's EV, we can compute social welfare according to Atkinson. Different ρ indicates the degree of inequality aversion.

Table 8 shows that ranking of each scenario including baseline price in terms of social welfare. At each ρ, the smaller the number is, the greater social welfare a scenario generates. Table 9 shows the ranking of each scenario including baseline in terms of inequality aversion. At each ρ, the smaller number is, the less inequality a scenario generates.

6 Conclusions

References

[Borenstein, 2009] Severin Borenstein, 2009 “To What Electricity price Do Consumers Respond? Residential Demand Elasticity Under Increasing-Block Pricing.” Working paper

[Borenstein, 2011] Severin Borenstein, 2011 “Regional and Income Distribution Effects of Alternative Retail Electricity Tariffs.” Energy Institute At Haas,

[Borenstein, 2012] Severin Borenstein, 2012 “The Redistributional Impact of Nonlinear Electricity Pricing.” *American Economic Journal: Economic Policy*, Vol. 4, No. 3, pp. 56 90

[Choi et al., 2008] Choi, Chi-Young, Ling Hu, and Masao Ogaki. 2008. “Robust estimation for structural spurious regressions and a Hausman-type cointegration test.” *Journal of Econometrics*, Vol. 142, pp.327-351.

[Reiss and White, 2005] Peter C. Reiss and Mattew W. White, 2005 “Household Electricity Demand, Revisited.” *The Review of Economic Studies* Vol. 72, No. 3, pp. 853883

[Ruijs, 2009] Arjan Ruijs, 2009 “Welfare and Distribution Effects of Water Pricing Policies.” *Environ Resource Econ*, Vol. 43, pp. 161 182,

Income	S1	S2	S3	S4-1	S4-2	S5-1	S5-2	S6-1	S6-2
468056.22	2783.40	-1866.38	-1769.34	1782.03	1782.03	996.31	996.31	1646.10	1646.10
1084807.36	424.50	-3738.60	-2679.79	-1272.70	-1272.70	-2891.55	-2891.55	-2354.35	-2354.35
1668489.46	-2703.99	-4534.58	-2471.0	-6298.50	-6298.50	-7602.61	-7602.61	-6386.22	-6386.22
2205302.06	-3815.46	-2329.13	357.56	-8880.12	-8880.12	-9536.77	-9536.77	-7636.09	-7636.09
2730061.26	7401.91	12839.39	16703.75	-1674.32	-1674.32	-1482.67	-1482.67	2763.89	2763.89
3242167.21	-10306.07	-1906.63	2748.18	-21834.53	-21834.53	-19755.72	-19755.72	-13890.21	-13890.21
3800280.41	29293.17	42754.67	47893.69	14070.94	14070.94	18235.15	18235.15	25391.59	25391.59
4475195.34	-12664.79	9170.13	16812.50	-36089.56	-36089.56	-29764.14	-29764.14	-15921.06	-15921.06
5463410.01	167743.35	197898.60	206037.96	140002.20	140002.20	151603.51	151603.51	167923.47	167923.47
8288155.13	335102.52	398118.29	410554.06	286194.80	286194.80	315250.30	315250.30	350046.45	350046.45
average	51388.67	64718.50	69501.83	36646.72	36646.72	41557.76	41557.76	50220.60	50220.60

Table 7: EV of income deciles

	Baseline	S1	S2	S3	S4-1	S4-2	S5-1	S5-2	S6-1	S6-2
ρ=0	7	3	2	1	6	6	5	5	4	4
ρ=0.5	7	3	2	1	6	6	5	5	4	4
ρ=1	7	3	2	1	6	6	5	5	4	4
ρ=1.5	3	1	2	2	1	1	1	1	1	1
ρ=2	5	1	3	4	2	2	2	2	1	1
ρ=10	7	2	4	6	3	3	5	5	1	1

Table 8: Ranking of scenarios in terms of social welfare

	Baseline	S1	S2	S3	S4-1	S4-2	S5-1	S5-2	S6-1	S6-2
ρ=0	1	1	2	1	2	2	2	2	1	1
ρ=0.5	1	3	6	7	2	2	4	4	5	5
ρ=1	1	3	6	7	2	2	4	4	5	5
ρ=1.5	5	1	7	8	2	2	4	4	3	3
ρ=2	7	1	5	6	4	4	3	3	2	2
ρ=10	6	2	4	4	3	3	5	5	1	1

Table 9: Ranking of scenarios in terms of inequality aversion