Electricity Demand in Chinese Households: Findings from China Residential Energy Consumption Survey

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ABSTRACT

China's residential electricity demand has grown at an annual average rate of 11.9% from 1990 to now and continued growth is expected. In 2012, the tiered pricing for household electricity (TPHE) was implemented nationwide. This paper describes a demand analysis of residential electricity consumption which is important for projections, policy design and evaluation. It describes Chinese residential electricity consumption characteristics and patterns and estimates price and income elasticities of residential electricity demand, along with the effects of related socio-economic variables, using a unique household surveyed dataset in 2012. We find that overall residential electricity demand is price- and income- inelastic, with the estimated value of -0.507 and 0.145, respectively. But a unity price elasticity is estimated in households that consumed basic amount of electricity, with the value of -1.013. More specifically, a lower price elasticity is detected in higher electricity consumption households compared with that of the lower level, richer families compared with that of the poor, and in North China compared with that of the South. The evaluation of TPHE implies that it has contributed to moderating residential electricity demand growth but is insufficient to motivate energy efficiency behaviors. More measures, such as China Energy Label system and information feedback service, are needed.

Introduction

With rapid economic growth and the acceleration of industrialization and urbanization, residential electricity consumption in China has increased tremendously from 1990 to now at an annual average growth rate of 11.9% (NBS, 2015). This rapid recent increase of electricity demand suggests that great appliance ownership and usage will become key drivers in the coming years, as household income grows. For residential electricity consumption, the largest end-uses of appliances and lighting would consume 643 TWh of electricity in 2030 under a baseline scenario in (Khanna et al., 2014)'s projections. However, its current share of 12.7% of national total electricity consumption is much lower than other developed countries, e.g. the average of 29.6% in 28 European Union countries and 35.9% in U.S. (Eurostat, 2015; EIA, 2015; NBS, 2015). Given the expected continuous increase in residential electricity demand, its management is extremely important to the national energy conservation and emission reduction strategies and targets in China.

As a supplement to supply-side policies, another strategy for moderating electricity growth is to promote shifts in electricity consumption behavior through demand side management (DSM). Price policy has been taking increasingly important role in controlling electricity demand. The National Development and Reform Commission (NDRC) in China announced the implementation of tiered pricing for household electricity use (TPHE) effective

July, 2012. The TPHE has a particular role to play in affecting consumption behavior to improve energy conservation and energy efficiency (Du et al., 2015). Two other important DSM tools are energy information labeling for household appliances and information feedback mechanisms. These information tools have been adopted in numerous countries around the world, and both aim to overcome key information barriers to energy efficiency and conservation by increasing consumers' understanding and knowledge of cost-saving energy efficiency opportunities and behaviors. For China, however, all types of DSM tools are relatively new and their actual effectiveness on slowing residential electricity demand has not been proven. Therefore, both the effects of policy, and design depend greatly on residential electricity demand analysis.

We add to the existing research by providing an empirical study of elasticity estimation of Chinese residential electricity demand across heterogeneous social groups using a unique dataset from the China Residential Energy Consumption Survey (CRECS) which covered 27 provinces and collected 1450 total observations in 2012. This study can overcome information gaps by collecting detailed information on household electricity consumption, socio-economic, demographic and geographical characteristics. These estimation results can contribute to the ongoing debate of how China's electricity market reform will affect different social groups and help design the new pricing scheme.

The rest of the paper is organized as follows. The CRECS and survey results are described in Section 2. In Section 3, we build a classical residential electricity demand model. Results and discussions are presented in Section 4. We evaluate the effects of TPHE in Section 5, and offer some related policy implications in the last section.

CRECS and Survey Results

The CRECS questionnaire covered six main areas with 324 questions in total: household demographics, dwelling characteristics, household appliances, space heating and cooling, patterns of private transportation, and electricity billing, metering, and pricing options. To provide a clear picture of household energy mix, we collected detailed energy relevant information, such as appliance type, frequency and duration of appliance use, different types of energy costs, and electricity bill information in each section of the survey. More details about this survey are presented in Zheng et al. (2014).

The survey results found that the annual average energy consumption of a surveyed household is 1426 kilograms of coal equivalent (kgce[1])/household/year. District heating accounts for 45.4% of total energy use, followed by natural gas (17.8%) and electricity (15.4%). Other types of energy fuel include firewood (11.7%), LPG (6.0%), solar (2.6%) and coal (1.1%). The electricity is used for the most diverse purposes, such as powering household appliances (including lighting), cooking, cooling, and water heating. The composition of household electricity consumption by end-use is presented in Fig.1. Electricity is primarily used for household appliances, which accounts for 46.6% of total electricity end use, followed by cooking, space cooling and water heating. Only 5.0% of total electricity is used for space heating.

There is a notable gap in residential electricity consumption between urban and rural areas. The electricity consumption of urban households is about 1.4 times that of rural households, with absolute value of 1888 kWh/household/year and 1371 kWh/household/year,

[1] Million metric tons of coal equivalent is the standard unit of energy in China. 1 Mtce = 109 kgce = 29.27 million GJ

respectively. Household appliances still consume most of the electricity used by both urban and rural households, with shares of 46.2% and 48.7%, respectively. This is followed by cooking, which has a higher share of 33.2% of total electricity consumption in rural households. Electricity used in water heating, space heating and space cooling are very different across urban and rural households. Electricity used for water heating and space cooling in urban households are more than twice that of rural households, which tend to rely more on LPG and solar. Since district heating is not accessible in most rural regions, electricity used for space heating in rural households is 7.9% of total electricity consumed, which is much higher than in urban regions.

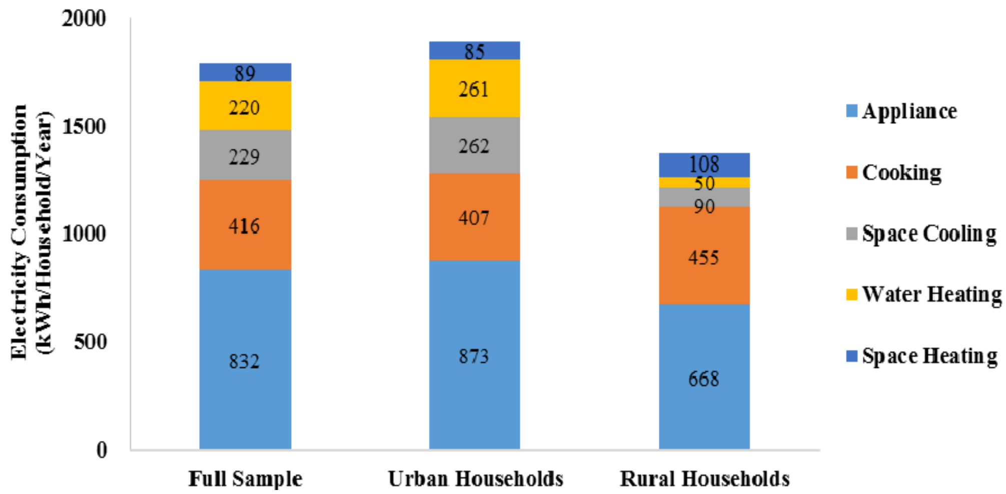

Figure 1. Composition of household electricity consumption

This gap is driven by ownership of household appliances to some extent. The ratio of ownership of some household appliances exceed 100%, including the highest ownership rate of 179.2% for air conditioners (AC). Ownership of household appliances per 100 households are higher in urban regions, e.g., for televisions, personal computers and ACs, with ownership rates of 123.2 sets, 133.6 sets and 186.1 sets per 100 households, respectively.

Table 1. Ownership of surveyed household appliances per 100 households (2012)

Item (Unit)	Full sample	Urban	Rural
Refrigerator	101.10	101.14	100.92
Washing machine	102.17	102.23	101.90
TV	122.32	123.16	118.86
PC	131.02	133.60	106.74
AC	179.23	186.06	128.83
Water heater	109.71	110.71	102.90

Three patterns of Chinese residential electricity demand can be observed from national statistics and CRECS survey data: (i) Household appliances are the most important end-use purpose, in both urban and rural households. (ii) Household appliances ownership will increase as income grows, which will increase electricity consumption. (iii) There is a big gap in electricity consumption between urban and rural households, suggesting that urbanization will continue to sustain residential electricity demand growth.

Residential Electricity Demand Model

Following Alberini and Filippini (2011), we build a classical electricity demand function in log-log form.

$$\ln(Ele_i) = \alpha + \beta_1 \ln(income_i) + \beta_2 \ln(price\_ele_i) + \beta_3 \ln(price\_gas_i) + \gamma X_i + \varepsilon_i$$

where dependent variable $ln(Ele_i)$ is the household electricity consumption measured in kWh. There are two categories of independent variables. (i) The household's socio-economic characteristics include disposable income ($ln(income_i)$), electricity price ($ln(price\_ele_i)$) and gas price ($ln(price\_gas_i)$). (ii) The demographic and geographical characteristics of household in matrix X_i. The following variables are taken into account, family size ($ln(fm\_size_i)$), dwelling area ($ln(dw\_area_i)$), education level of household's head ($ln(edu\_year_i)$), urbanization ($Urban_i$) and weather condition (heating degree days (HDD_i) and cooling degree days (CDD_i)[2]. The descriptive statistics characteristics of variables and expected impacts on electricity demand are summarized in Table 2.

Table 2. The descriptive statistics characteristics and expected impacts of variables

Variable	Unit	Obs.	Mean	S.D.	Min.	Max.	Ex. Impacts
Ele	kWh/household/year	1402	1794.52	1385.22	26.28	16539.96	--
Income	10,000 yuan/year	1402	9.89	15.88	0.50	350	Positive
Price_ele	Yuan/kWh	1402	0.53	0.06	0.32	0.80	Negative
Price_gas	Yuan/m^3	1402	2.52	0.96	1.37	5.93	Positive
Fm_size	Person/household	1402	2.66	1.07	1.00	8.00	Positive
Dw_area	m^2	1402	104.62	48.71	21.00	250.00	Positive
Edu_year	Year	1402	11.35	3.79	0.00	22.00	Uncertain
Urban	Dummy	1398	0.80	0.40	0.00	1.00	Positive
HDD	Day/year	1402	177.64	46.46	30.00	366.00	Positive
CDD	Day/year	1402	36.15	30.65	0.00	144.00	Positive

Results and Discussion

For cross-section data, we mainly apply Ordinary Least Squares (OLS) with robust standard error method to estimate, and then a Quantile Regression (QR) method is used to analyze quantity effects of electricity demand. The basic electricity demand model (Model I), quantity effects by electricity consumption quantile (Model II-IV), income effects by disposable income level (Model V), and regional comparison between North and South China (Model VI) on residential electricity demand are presented in Table 3.

[2] HDD and CDD represent the number of days on which the temperature is respectively below and above the predetermined thresholds of cooling and heating, and by how many degrees. The threshold is a "temperature-barrier" over or under which the heating or cooling appliances will be switched on. Refer to IAQS (GB/T 18883-2014), the standard temperature with space heating in winter is 16℃-24℃. The standard temperature with air conditioner cooling in summer is 22℃-28℃. We identify the heating and cooling threshold temperature as the lowest temperature in winter 16℃ and the highest temperature in summer 28℃. The daily average outdoor temperature from NOAA is a proxy variable to indoor standard temperature.

Table 3. Regression results for economic analysis

Electricity consumption	Basic Model I	Quantity Model II (Q10)	Model III (Q50)	Model IV (Q90)	Income Model V	Region Model VI
Ln(income)	0.145***	0.195***	0.136***	0.179***	0.0229	0.121***
	(0.0227)	(0.0394)	(0.0245)	(0.0366)	(0.0405)	(0.0281)
Ln(price_ele)	-0.507***	-1.013***	-0.475**	-0.496*	-0.797***	-0.904***
	(0.169)	(0.302)	(0.188)	(0.281)	(0.253)	(0.278)
Ln(price_gas)	0.146**	0.0977	0.130*	0.117	0.142**	-0.0136
	(0.0639)	(0.114)	(0.0709)	(0.106)	(0.0638)	(0.0674)
Ln(fm_size)	0.177***	0.142*	0.170***	0.0847	0.173***	0.189***
	(0.0447)	(0.0812)	(0.0506)	(0.0755)	(0.0448)	(0.0447)
Ln(dw_area)	0.132***	0.161**	0.0990**	0.153**	0.136***	0.138***
	(0.0431)	(0.0754)	(0.0470)	(0.0702)	(0.0427)	(0.0426)
Ln(edu_year)	0.237***	0.146	0.164***	0.279***	0.232***	0.223***
	(0.0485)	(0.0890)	(0.0554)	(0.0828)	(0.0480)	(0.0473)
Urban	0.155***	0.112	0.166***	0.0634	0.144***	0.178***
	(0.0540)	(0.0925)	(0.0576)	(0.0861)	(0.0535)	(0.0538)
HDD	-0.000365	-0.000276	-0.000404	-0.000686	-0.000272	0.000535
	(0.000722)	(0.00116)	(0.000720)	(0.00108)	(0.000712)	(0.000699)
CDD	0.00224**	0.00103	0.00239**	0.00307*	0.00251**	-0.000771
	(0.00102)	(0.00176)	(0.00109)	(0.00163)	(0.00101)	(0.00113)
Middle					0.446**	
					(0.226)	
*Ln(price_ele)*Middle*					0.381	
					(0.346)	
Rich					0.803***	
					(0.276)	
*Ln(price_ele)*Rich*					0.749*	
					(0.391)	
North						-0.0575
						(0.245)
*Ln(income)*North*						0.0490
						(0.0399)
*Ln(price_ele)*North*						0.672*
						(0.366)
Constant	5.090***	4.132***	5.497***	5.794***	4.970***	5.156***
	(0.326)	(0.568)	(0.354)	(0.529)	(0.337)	(0.359)
Observations	1386	1386	1386	1386	1386	1386
R-squared	0.145				0.157	0.180
Pseudo R-squared		0.076	0.078	0.099		

Note: the robust standard errors are in parentheses. ***, **, * are 1%, 5%, 10% significance level.

Basic Model

Overall, in Model I, the residential electricity demand is income and price-inelastic. The income elasticity of electricity demand is 0.145, which is statistically significant at the 1% level. This suggests that a 1% increase in household's disposable income would result in only a 0.145% increase in electricity demand (ceteris paribus). The own price elasticity is estimated to be -0.507, which is also statistically significant at the 1% level. This suggests that a 1% increase in residential electricity price would result in a 0.507% decline in electricity demand (ceteris paribus). However, since income and price elasticities are well below unity, price increase and income growth result in a much less than proportional change in electricity consumption. The result implies that households are less responsive to electricity price change or income growth.

This finding is consistent with our expectation and most of the existing literature. Based on different samples and methods, the price elasticity of residential electricity demand in China is estimated to range from -0.57 to -0.35, and the income or expenditure elasticity is estimated to range from 0.14 to 0.90 (Cao, Ho and Liang, 2016; Sun and Ouyang, 2016; Zhou and Teng, 2013). From a dynamic perspective, the majority of studies estimated the short-run price elasticity in U.S. which ranges from -0.39 to -0.14. And the long-run price elasticity is more wide, which ranges from -0.94 to -0.17 (Alberini and Filippini, 2011; Alberini, Gans and Velez-Lopez, 2011). Another issue is that how residents respond to price change. Ito (2014) suggested that consumers are likely to respond to the average price rather than the marginal price because of its incomprehensible price-setting and information barriers. Also, households are more sensitive to the lagged average price since their current and future consumption behaviors are affected by the past information they obtained. Such kind of lagged response would weaken the expected effects of electricity pricing reform.

For other variables, the estimated coefficient on the price of natural gas is 0.146 and statistically significant. The result implies that there is a substitutive relationship between electricity and natural gas, which suggests that electricity and natural gas can be switched to some extent. The characteristics of dwelling and household demographics also affect the electricity demand of the household as expected. Taking weather conditions into consideration, *HDD* does not have a significant impact on residential electricity demand as expected. In our surveyed sample, only 389 households (27.8%) chose electricity for distributed heating and the share of electricity consumption in total distributed heating is 23.6%. More widely, the share of electricity used for space heating in total electricity consumption is only 5.0%. This implies a very low usage of electricity for space heating in China. However, space cooling depends on air conditioners and fans and one day increase in *CDD* would lead to a 0.002 kWh/household/year increase in electricity demand (ceteris paribus), which is statistically significant at the 1% level. This suggests that Chinese residents do rely heavily on electricity for cooling during the summer.

Finally, there is a big electricity consumption gap in households located in urban and rural area. The coefficient of the dummy variable, *Urban*, is 0.155, and statistically significant at the 1% level. It suggests a significantly higher electricity consumption in urban compared with rural area. Besides income effects discussed later, household appliances directly contribute to household electricity consumption (Krishnamurthy and Kriström, 2015; Zhou and Teng, 2013).

Quantity Effects

In Model II-IV, we examine the impact factors of electricity demand by three levels, 10%, 50% and 90% quantile of residential electricity consumption using the quantile regression method. The electricity demand is income inelastic in all three groups, which ranges from 0.136 to 0.195, all below unity. There is a significant difference in the price elasticity of electricity demand among the three groups. In the lowest electricity consumption level (Model II), the price elasticity is estimated to be -1.013, which is statistically significant at the 1% level and above unity. This suggests that a 1% increase in residential electricity price would result in a nearly 1% decline in household electricity demand (ceteris paribus). However, in the median and highest electricity demand groups (Model III and IV), the electricity demand is price inelastic. The coefficients are -0.475 and -0.496, both below unity and marginally significant. The estimated coefficients of other variables in this panel remain stable compared with the basic model.

These results imply that income elasticity of electricity demand is mostly constant, while customers' sensitivities to price are weaker at the higher demand quantile. Raising the average or overall electricity price will be more detrimental to families who need the basic amount of electricity[3] and cannot further reduce their electricity demand. Therefore, the expected effect of TPHE on encouraging electricity conservation in households who consume more will be weaken, which is proofed later.

Income Effects

We add two dummy variables that represent middle income and high income households and associated interaction terms to control for the effect of income difference on electricity demand. We separate the whole sample into three groups - poor family, middle income family and rich family - according to the disposable income level[4]. The dummy variables, *Middle* and *Rich*, are equal to 1 for families with middle income and high income, otherwise, are equal to 0.

In Model V, the poor family is regarded as a baseline. The coefficients of dummy variables, *Middle* and *Rich*, are 0.446 and 0.803 respectively, both statistically significant at the 1% level. Compared with poor households, the middle income class consume more electricity, and the high income class consume much more than the middle income class. This means electricity demand will increase with disposable income growth. The estimated coefficients of the interaction terms *ln(price_ele)*Middle* and *ln(price_ele)*Rich* can be interpreted as the difference in price responsiveness of electricity demand by different income levels. The price elasticity of poor household is -0.797, and statistically significant at the 1% level. It implies that a 1% increase in residential electricity price would result in a 0.797% decline in electricity demand for poor family (ceteris paribus). The coefficient of *ln(price_ele)*Middle* is 0.381, and statistically insignificant, which means that the middle income family and the poor family respond similarly to electricity price changes. The estimated coefficient of *ln(price_ele)*Rich* is 0.749, and statistically significant at the 10% level, which means that the rich family are much less responsive to electricity price changes. The coefficient of *ln(income)* is statistically insignificant after we control the variance in income by dummy variables. The estimated coefficients of other variables in Model V remain stable compared with the basic model.

It is important to note that there is a decreasing trend of own price elasticity of electricity demand with disposable income growth. One reason is that income growth also stimulates the potential energy consuming capacity. The higher the income level, the higher absolute cost, but the lower proportion of energy-related expenditure in total expenditure. This energy-related

[3] 10% quantile of residential electricity consumption is less than 612 kWh/household/year.
[4] Poor ≤50,000 yuan/year, 545 households (38.87%). Middle income (50,000, 120,000] yuan/year, 553 households (39.44%). Rich >120,000 yuan/year, 304 households (21.68%).

expenditure pattern would result in an increase in energy demand and decrease in response to price change with income growth. An important policy message from this result is that raising electricity price will be more detrimental to low income families.

Regional Comparison

In Model VI, we add a dummy variable (*North*) that represents whether the resident lives in North or South China, and the associated interaction terms controlling for the effect of living location on electricity demand. We divide north and south regions by district heating line based on Qinling Mountain_Huaihe River. There are 689 (49.1%) and 713 (50.9%) households that live in South China and North China, respectively. The value of *North* is 1 if the household locates in North China, otherwise the value is 0.

The income and price elasticity for Southern households are 0.121 and -0.904, both statistically significant at the 1% level and below unity. Compared with Southern households, the Northern family responds similarly in electricity consumption to rising disposable income. The Northern own price elasticity is -0.232, which is much smaller than that in Southern households but still below unity. The lower sensitivity of Northern households to electricity price change is due to their lower reliance on electricity use (most space heating needs are met by district heating) and less expenditure on electricity use. In our surveyed sample, the electricity consumption is 2048 kWh/household/year in South China and 1550 kWh/household/year in North China. The expenditure on electricity is 1055 Yuan/household/year in South China and 803 Yuan/household/year in North China.

Taking the difference of marginal electricity consumption change between Southern and Northern China into consideration, there is no significant gap of income elasticity between them, but the price elasticity of Northern family is much smaller than that of Southern family. Given the expectation of increasing disposable income level and rising electricity price, which would lead to a rise and a decline respectively in electricity consumption. Since they have almost the same income elasticity, Northern and Southern families would increase their electricity consumption in a similar degree. However, with a much smaller price elasticity, the Northern family may cut less electricity consumption to response to price increase. Finally, the difference of marginal electricity consumption between Northern and Southern households is small due to income effect (income elasticity) and substitution effect (price elasticity).

TPHE Evaluation

In China, provincial governments were authorized to set up electricity-price tiers according to local conditions such as local income levels and climate conditions. We used a rate structure of TPHE according to Beijing for our analysis, where electricity demand level is the highest amongst all regions for every block[5]. In our surveyed sample, there are 948 urban households (85.3%), 110 urban households (9.9%) and 53 urban households (4.8%) in the first, second and third electricity consumption blocks, respectively[6].

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[5] The surveyed average per capita residential electricity consumption in 2012 was 674.6 kWh, which is higher than the officially statistically reported national average of 460.4 kWh.

[6] Electricity consumption level: Block 1 ≤ 2800 kWh/household/year. Block 2 (2800, 4800] kWh/households/year. Block 3 > 4800 kWh/households/year.

We classify households into two groups using the surveyed dummy variable of *know about the implemented TPHE or not*. The results of two-sample t-test in each block are presented in Table 4. We first use the traditional t test to examine whether there is a significant difference in electricity consumption between the affected (*Tiered*) and non-affected (*Others*) groups. Our null hypothesis assumes that the two groups have the same mean value, which fits both unpaired and paired data. This test produces a t value of 5.3221, which suggests that the null hypothesis can be rejected at the 0.1% significance level in the Block 1. But the differences in Block 2 and Block 3 are not significant. Furthermore, we conduct two nonparametric tests, the Kolmogorov–Smirnov test and Wilcoxon-Mann-Whitney test, to find out whether the two groups are drawn from the same population distribution. The null hypothesis here is that there is no difference in the distributions. The Kolmogorov-Smirnov test and Wilcoxon-Mann-Whitney test report that the two samples are not drawn from the same distribution in Block 1 but there is no difference in the distributions between the tiered and non-tiered groups in Block 2 and Block 3[7]. These results suggest that the TPHE does not have a statistically significant relationship with lowered residential electricity consumption.

Table 4. Two-sample T-test for TPHE's effects

Block 1				
Group	Observations	Mean	S.E.	S.D.
Tiered	356	1571.20	33.39	630.01
Others	592	1346.82	25.80	627.76
Difference		224.38*** (5.3221)	42.16	
Block 2				
Group	Observations	Mean	S.E.	S.D.
Tiered	56	3636.98	70.98	531.16
Others	54	3497.68	68.10	500.47
Difference		139.30 (1.4146)	98.48	
Block 3				
Group	Observations	Mean	S.E.	S.D.
Tiered	36	6883.24	387.57	2325.42
Others	17	6115.86	415.11	1711.52
Difference		767.38 (1.2119)	633.22	

Note: t-values are in parentheses. ***, **, * are 0.1%, 1%, 5% significance level, respectively.

These results are somewhat surprising given that we expect effective incentives for electricity conservation and reduced distortion of cross-subsidies in electricity tariffs under the current TPHE scheme and suggest that additional research is needed to tease out the differences in findings. We believe there may be three possible explanations for the different findings: (i) we confirmed that the own price elasticity of electricity demand decreases with the electricity

[7] Block 1: Kolmogorov-Smirnov test reports a distance value of 0.1807 and zero p-value. Wilcoxon-Mann-Whitney test reports a variance value of 16666970 and zero p-value.
Block 2: Kolmogorov-Smirnov test reports a distance value of 0.2262 and 0.120 p-value. Wilcoxon-Mann-Whitney test reports a variance value of 27972 and 0.1350 p-value.
Block 3: Kolmogorov-Smirnov test reports a distance value of 0.3301 and 0.161 p-value. Wilcoxon-Mann-Whitney test reports a variance value of 2754 and 0.1585 p-value.

consumption growth. This implies that end users are less sensitive to price change if they consume more and supports previous findings that the increase in electricity consumption by lower tier households offsets reductions by households in higher tiers under TPHE. (ii) There is no effective sharing of price information with consumers. The availability of comprehensive information on the prices and tiers is very important to consumers' abilities to respond to price signals. (iii) Our survey began in the winter 2012, only six months after the implementation of the TPHE when many consumers were still unaware of the new tier structure. This is evidenced by the low awareness rate of only 31% among our surveyed residents. This mandatory electricity tariff was not well publicized because the power utilities lack incentives to notify residents of the new tier structure because their revenue (profit) is directly linked to total electricity sales. As mentioned before, the lagged response from residents also weaken the effects of TPHE.

Therefore, the incentives for consumers to reduce electricity consumption under TPHEs may not be reflected at the time our survey data was collected and under China's current power sector structure.

Conclusions

This paper estimates the elasticity of residential electricity demand using micro-level data from the China Residential Energy Consumption Survey (CRECS) which covered 26 provinces and collected 1450 total observations in 2012. The key research findings and related policy implications are summarized below.

Residential electricity consumption is price- and income- inelastic with the value of -0.507 and 0.145, respectively. The result implies that price change and income growth would result in a much less than proportional change in electricity consumption. A substitutive relationship between electricity and natural gas is identified, with the coefficient value of 0.146. Besides, the demographic and geographical characteristics of household do affect its electricity demand as expected. It is also noted that there is a significantly higher electricity consumption in urban compared with rural area.

In more detail, elasticity of residential electricity consumption is estimated by electricity consumption level, by income level and across North and South China. (i) The income elasticity of residential electricity demand is mostly constant in different quantile, while the own price elasticity of electricity demand declines with the increase of residential electricity demand, with the estimated value ranging from -1.013 to -0.475. The more electricity a household consumes, the less sensitive it is to price change. (ii) There is a decreased trend of own price elasticity of electricity demand with disposable income growth, with the estimated value ranging from -0.797 to -0.048. In other words, a richer family is less responsive to price change than a poorer family. (iii) The Northern and Southern families' response to income growth is similar but the own price elasticity of northern family is much smaller than that in Southern household, with the estimated value of -0.904 and -0.232, respectively.

Better understanding and quantification of China's income and price elasticities of residential electricity demand can help improve energy demand projections and outlooks, which can then help inform policy design and development. The low price elasticity of residential electricity demand, in addition to its negative relationship to urbanization, electricity consumption increase and income growth suggests that electricity price reform would be less effective in reducing electricity consumption. However, there is an opportunity to carry out TPHE with high-level tiered pricing designs by provincial governments. First, the residential electricity price in China is lower than many other countries, with a small ratio of water, electricity and fuels expenditures to the total consumption expenditures in rich families. Higher level tiered pricing would stimulate residents in higher tiers to reduce their consumption while at the same time, the lower-tier residents still benefit from price subsidies and can consume more. Second, the differing electricity consumption potential, cost and usage patterns across regions suggest that it is more effective to implement TPHE at the provincial level to account for differing volume of electricity that result from different local conditions.

With the continuing rise in household income, great ownership and usage of appliances are expected to drive residential electricity demand. Household income growth also stimulates the potential consuming capacity, which is reflected by the share of energy cost in total household consumption expenditure. Though these income effects are very small due to low income elasticity, the potential rise of appliances' ownership and energy consumption capacity suggest policies and measures such as the China Energy Label for efficient appliances and consumption information feedback are needed to help enhance resident's perception and behavior towards energy conservation.

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