Residential Electricity Pricing in China

QIAOYUAN LIN, MARIAN RIZOV, AND MARIE WONG
Department of Economics and International development, Middlesex University

Abstract: *The paper aims to evaluate the implications of the new residential pricing system in China by examining price and income elasticity of demand by different household types. We use pre-reform annual panel data for 29 provinces over a fourteen year period, from 1998 to 2011, applying feasible generalize least squares models. The price and income elasticities for household sector are -0.412, and 1.476 at nation level, -0.300 and 1.550 in urban areas and -0.522 and 1.093 in rural areas respectively. With regional effects, the price and income elasticities are -0.146 and 1.286 for urban households in coastal provinces and -0.772 and 1.259 for urban households in inland provinces respectively. The empirical results reveal that there is important heterogeneity in the responsiveness to electricity price changes according to household income level and location.*

The proposal for restructuring the electricity pricing system in the household sector had sparked hot debates in the Chinese society since October 2010. These debates mainly concerned two questions. First, was the effect of the proposed rise in retail electricity price different across residents? Second, was the proposed pricing system fair for households with different income levels? The government believed that the proposed rise in electricity prices was necessary, and the increase was reasonable. So it would not have a negative impact on residents' daily life. In contrast, many residents argued the pricing scheme did not appropriately address income inequality across regions and households, and if carried out as planned it would increase the burden on some households. After receiving a wide range of opinions and suggestions, the proposal was modified and announced by the government as 'Multistep Electricity Price' in July 2012. This study attempts to evaluate the reform in the pricing system by providing robust empirical evidence by investigating the pre-reform price and income elasticity of household demand for electricity across regions and income levels in China.

Existing literature on the issue is limited and primarily focuses on the impact of electricity demand on economic growth at aggregate country level. Such information is inappropriate for judging the effect of the current residential pricing on the demand for electricity in China. One reason is that aggregate estimates are not suitable to explain consumption of electricity of different groups of

---

Qiaoyuan Lin is a Ph.D. candidate in the Department of Economics at Middlesex University Business School, The Burroughs, London UK, NW4 4BT. Telephone number: +44(0)20 8411 4982; Fax: +44(0)20 8411 6607; E-mail: Q.Lin@mdx.ac.uk. Dr. Marian Rizov is a reader in the Department of Economics at Middlesex University Business School. Dr. Marie Wong is a senior lecturer in the Department of Economics at Middlesex University Business School.

The authors thank Dr. Ali Tasiran for his advice on data analysis, Dr. Ricardo Gottschalk for his suggestion, and anonymous referees for their helpful comments.

households. From a social and economic perspective, electricity sector provides for the daily necessity of 1.3 billion people in China. Financial returns should not be the only consideration for electricity pricing, household's ability to cope with the cost of living should also be considered. Even though the Chinese economic growth has been impressive in the past three decades, the inequality of income distribution has also widened significantly. A second reason challenging previous results is that comparing with developed countries, supply of electricity is less reliable in developing countries, including China. This is due mainly to the problem of supply shortages, grid performance, wiring deficiencies and other technical issues. Previous studies on the electricity pricing in China all assumed that supply of electricity was sufficient and reliable which is unrealistic, despite the improvements made in recent years. Hence there is a need to control for the supply reliability in the analysis.

Given the debates in the society and lack of appropriate studies in the literature, this paper aims to investigate the price and income elasticity of household demand for electricity by multidimensional household average income levels in China. The paper assesses residents' responsiveness to changes in electricity price and their income while controlling for several other factors affecting demand commonly used in the literature. These are the price of residential pipeline natural gas, weather, and electricity supply reliability. The main contribution of the paper is two-fold. First, we provide robust empirical evidence for China by employing good quality panel data for 29 provinces over a fourteen year period, from 1998 to 2011 and applying feasible generalized least squares estimator. Second, we explicitly incorporate the electricity supply reliability effect into the analysis.

The results, on the whole, provide evidence of highly statistically significant residential electricity price elasticities of less than one and income elasticities of demand larger than one. The empirical results reveal that disposable income substantially impacts on demand, and there is important heterogeneity in the responsiveness to electricity price changes according to household income levels. Poorer households are more sensitive to changes in electricity prices than richer urban households. We, therefore, argue that the current electricity pricing system might have underestimated the impact of changes in electricity price on some households, especially in low-income inland provinces.

Next, in the paper, the residential electricity market and its pricing system are discussed, followed by a review of the literature. We then discuss theoretical considerations, data and estimation methodology. Empirical results are reported, and policy implications of the findings are discussed followed by a conclusion.

Residential electricity pricing system in China

Evolution of residential electricity prices

In the 1950s, each electricity supply company in China had its own right of independent pricing. There were many different electricity pricing forms. Even the National Planning Commission (NPC) was not able to discover and control the whole situation. Some regions allowed using grain in exchange for electricity. For example, per unit residential electricity usage was measured by 1 kilogram of millet in Baotou region in 1950. In the following year, the usage of grain was replaced by currency, and it was approximately equated to 0.22 RMB (Renminbi) per unit (kilowatt hour, kWh)[1].

Table 1

Province Official Residential Electricity Prices and Retail Residential Prices of Pipeline Natural Gas in 2011

Province	REP	GP	Province	REP	GP
Anhui	0.558	2.114	Jiangxi	0.600	4.048
Beijing	0.481	1.830	Jilin	0.520	2.054
Chongqing	0.515	1.536	Liaoning	0.495	2.083
Fujian	0.518	3.404	Ningxia	0.449	1.280
Gansu	0.510	1.295	Qinghai	0.443	1.161
Guangdong	0.610	3.698	Sanxi (陕西)	0.498	1.786
Guangxi	0.526	4.503	Shandong	0.493	2.003
Guizhou	0.451	3.304	Shanghai	0.615	2.232
Hainan	0.598	2.321	Shanxi	0.462	1.446
Hebei	0.495	2.161	Sichuan	0.520	1.516
Heilongjiang	0.505	1.682	Tianjin	0.485	1.964
Henan	0.503	1.696	Xinjiang	0.474	1.390
Hubei	0.567	2.088	Yunman	0.421	4.563
Hunan	0.581	2.304	Zhejiang	0.553	2.920
Jiangsu	0.523	1.964	*Average*	*0.516*	*2.288*

Notes: REP denotes residential electricity price taken from electricity supply enterprises at province level. RMB per unit (kWh). GP denotes the price of pipeline natural gas taken from the China Price Information network. RMB per cubic meter. 1 cubic meter of natural gas is approximately equivalent to 11 kWh.

In 1960, the central government introduced a unified management principle for electricity prices and the state started regulating them. The NPC and the Ministry of Water Resources and Electric Power jointly issued the national electricity prices catalogue[2]. This is the first time that China had electricity prices catalogue[3] for different regions. Electricity enterprises had to implement these retail prices to residents and to the industrial and commercial sectors. For instance, residential electricity price was approximately 0.29 RMB per unit in Guangxi province in 1960[4] while it was 0.22 RMB per unit[5] in Hubei province. The retail electricity prices were highly centralized and fairly stable in many areas until the 1990s. Most of the prices were between 0.20 RMB to 0.30 RMB per unit.

Residential electricity prices underwent numerous adjustments and increases from 1997 until 2005. Subsequently, the retail prices have not changed much.

Table 1 shows retail residential electricity price in 2011. The highest price is 0.615 RMB per unit in Shanghai while the lowest is in Yunman, 0.421 RMB per unit. The average price in the country is 0.516 RMB per unit. Despite the massive investment in the electricity industry and the rapid increase of income, the level of the official residential electricity prices seems to have remained at a fairly low level. Considering pipeline natural gas as a substitute energy source, its prices at the provincial and national levels look higher than electricity prices, but 1.00 RMB per cubic meter of natural gas is approximately equivalent to 0.091 RMB per kWh of electric power. Compared with other countries, the average residential electricity price in China also appears low, but as a proportion of income it is one of the highest (see Table 2).

Table 2

Comparison of International Average Residential Electricity Prices in 2011

Country	Price (cents per kWh)	Income per capita (U.S dollar)	Ratio of price and income (per 1000 kWh)
China	8.3	5,417	1.534
Germany	32.5	44,111	0.737
France	17.7	44,007	0.402
Italy	25.8	36,267	0.711
Japan	17.6	45,870	0.383
Poland	18.9	13,469	1.403
Romania	13.9	8,875	1.566
South Korea	8.9	22,424	0.397
Turkey	15.7	10,363	1.515
United Kingdom	18.4	38,811	0.474
United State	11.9	48,387	0.245

Source: Eurostat (2011). U.S. Energy Information Administration (2011). International Monetary Fund (2010-2011). The prices for Japan and South Korea are for 2008.

Urban and rural residential electricity prices

According to the pricing policy in China, there has been no distinction between urban and rural residential prices, but one price for all residents. In practice, however, the price for rural residents was much higher than for those urban residents in the 1990s. This was mainly due to arbitrary charges to rural residents. It was common that the average price charged to rural end-users was much higher than that to urban users. According to Dang (2000), the actual residential electricity price was 1.50 RMB per unit in most rural areas; in few places it was even 5.00 RMB per unit. The average residential price in urban areas was only approximately 0.40 RMB per unit in 1998.

In order to reduce the burden on farmers and rural end-users, the National Development and Planning Commission (NDPC) and the State Grid Corporation of China (SGCC) issued two urgent telegrams to electricity supply sector in 1998[6]. Since then, the arbitrary charges were gradually ameliorated. At the same time, arguably, the Asian financial crisis led to electricity surplus. This crisis opened up an opportunity to address the problems. In the same year, the State Council (document 134, 1998) formulated six large-scale infrastructure projects to expand domestic demand and stimulate economic growth. Rural electricity network development and improvement was one of these projects. The project aimed to reform management system and standardize management, to develop and improve rural distribution network and to facilitate power supply cost reduction and alleviate end-users' burdens. The expected outcomes were ultimately to merge urban and rural distribution networks and to achieve uniform residential electricity price for all urban and rural areas. This project was popularly called "Two Changes and One Price". According to the NDPC[7], the majority of provinces had achieved one price for urban and rural areas by 2003.

Residential electricity pricing system reform

In recent decades, the electricity sector in China has been through several key stages of reforms aiming at the creation of competitive power markets. One critical step was the dismantlement of the State Power Corporation in 2002 into five state-owned power groups (the Big Five) and the State Grid Corporation as the central government aimed to end the monopoly in the power generation industry. These six organizations and numerous province branch companies together manage power supply market. The pricing is influenced by bargaining process between the industry oligarchs and the administrative control represented by the National Development and Planning Commission (NDPC).

Along with the reform in 2002, the State Council also launched "Electricity Pricing System Reform Scheme" (document 62, 2003) in the following year, and the price reform was a key component of the power sector reform. The ultimate aim of the scheme was to allow end-users a free choice of electricity supplier and to enjoy an equilibrium price in the electricity market.

Even though, the price reform was meant to be a core issue of the whole power sector reform, there were complications and difficulties. The scheme, in fact, had not been fully implemented. The residential electricity pricing system remained largely unchanged since then. However, fuel market prices increased rapidly since the early 2000s and power enterprises strongly criticized the inadequate residential pricing system. The reason for the criticism was that residential sector had been adopting a single electricity pricing policy. The single pricing policy means that a household is charged a single electricity price regardless of the total amount of electricity usage. In addition, the enterprises insisted on increasing residential electricity prices because they were much lower than the prices in the industrial sector and the average electricity price in the country. Furthermore, residential electricity prices had been lagging behind coal and gas prices. It was, therefore, not possible for the electricity industry to cover its costs. Hence, electricity pricing reform for the residential sector had been on the top of the agenda since late 2000s.

On the basis of domestic and international situation, the NDRC announced a draft proposal for implementing a new pricing system to replace the single price system for residential customers on 9th October 2010. The draft proposal aimed at introducing an increasing block tariff. The proposed increasing block tariff envisaged that monthly electricity consumption to be divided into three categories and charges on electricity consumption to be progressively increasing based on the amount of electricity usage. The NDRC believed that the new tariff would improve the whole pricing system. It was also expected to address the problem of electricity shortage and high fuel prices. Furthermore, it was planned gradually to align the pre-reform (low) single residential electricity price to a rational and reasonable pricing system. The tariff was also expected to encourage reduction in electricity consumption and the associated pollution.

However, the benefits of the new tariff had not been convincing for many households and had attracted widespread repercussion, criticism and fears amongst residential customers which are mainly subject to income disparity[8]. Despite the public disapproval according to the NDRC statistics from a total of 21,794 comments 61% showed support while only 34.5% - opposition. It was also argued that the draft proposal did not envisage a significant increase in electricity price and for 70% to 80% of households' electricity bill would remain unchanged. In July 2012, the NDRC has modified the draft by increasing the rate of unaffected consumers from the initial 70%-80% to 80%-90% across provinces and regions.

Literature review

In the consumer behavior theory, a measure of household's demand sensitivity is its responsiveness to changes in prices, holding other factors constant. Households react to changes in the electricity price by adjusting their electricity demand. As price hikes, households reduce the quantity used while as price falls the household response is the opposite. This responsiveness of households to price changes is characterized by "price elasticity of demand" in the consumer behavior theory. In demand elasticity context, the theory not only suggests how sensitive demand for electricity is to changes in the price of electricity, but also to changes in the prices of related energy sources and to changes in income. A number of previous studies adopt this basic economic framework to conduct their analysis.

The gap in the domestic literature

Several early studies investigate the relationship between Chinese electricity consumption, prices and output within macroeconomic or regional frameworks.

Lin (2003) discusses the variation of electricity prices across the country and concludes that the available electricity prices are not adequate to examine the relationship between electricity consumption and economic output at national level. Therefore, the study adopts time series data from 1978 to 2001 for the price of coal as a proxy for the electricity prices. The estimated price elasticity is unusually low, only 0.016. A study by Lam (2004) concludes that the average electricity prices are below the average total costs and highly subsidized as the author investigates the determinants of the average electricity price for 26 provinces with cross-section data for 1998. Xu and Chen (2006) point out that one of the most serious problems with electricity prices is that it does not reflect the true relationship between supply and demand. Similarly, Zhang and Heller (2007) describe that the electricity demand and supply relationship is based on planned allocation by the government, and conclude that tariffs have a little relation with the real cost of supplying power or demand.

He et al. (2011) examine the demand price elasticity for several sectors: residential, agricultural, industrial, and commercial. The study adopts computable general equilibrium model with cross-section data for 2007. In terms of the residential sector, the study concludes that the price elasticity is only -0.3 which indicates that residents are not sensitive to change in electricity prices across the nation. However, one underlying assumption of He et al.'s (2011) study is that there are no constraints to the electricity power supply which is unlikely the case in China. Zhao et al. (2012) conduct an investigation on the impact of electricity policies on electricity generation efficiency with regional data and pooled regressions. The study considers average price effect measured as the ratio of revenue and quantity of electricity sold over the period 1993-2007.

There are two concerns regarding previous studies. First, it may be true that the average electricity price is low given the massive and ongoing investment in the electricity industry. However, the existing studies are not adequate to reveal the effect of prices and the proposed alternative electricity pricing system on the demand for electricity in the household sector. The primary reason is that national-level information is not suitable for explaining consumption of electricity by different groups of households. Furthermore, from an econometric point of view shortcomings stem from problems with data used for analysis, the specifications selected for the estimating equations, or sometimes from the variables used. Apart from these aspects, previous studies also do not focus on the consequences of varying household income levels even though it is generally accepted that there are large income disparities between regions and rural and urban areas. Therefore, the existing econometric estimates do not provide sufficient information about the pricing reform effects on households. Besides, although the generation and supply of electricity in China has significantly improved, the reliability of supply is still in doubt. According to the Electricity Power Reliability Management Center, the average of interruption hours per customer (AIHC-1) is 7.01 hours per household across the nation in 2011. The rural supply system performance is much poorer than the urban one; the AIHC-1 is 18.43 hours per rural household in 2011. With this in mind, there is thus a need to control for the reliability factor when examining price elasticity of electricity demand.

The international literature

Many theoretical and empirical studies on the price and income elasticity of residential electricity demand have been carried out in an international context. Early studies are conducted by Houthakker (1951) and Fisher and Kaysen (1962)[9]. These studies obtain varying results depending on the variables used. Houthakker (1951) carries out a pioneering cross-sectoral study of electricity demand in the UK. He assumes the presence of stable demand function and shows the demand for electricity is quite sensitive to both changes in prices and income. Fisher and Kaysen (1962) use time series data from 1946 to 1957 for 47 states in the United States. They add extra non-economic variables such as utilization rates of appliance stocks. In the short run, the findings of Fisher and Kaysen (1962) agree with Houthakker's (1951) study – the demand of residential electricity mainly depends on price and income. In the long run, Fisher and Kaysen conclude that non-economic variables are the primary determinants of residential electricity demand while electricity price has a lesser impact on demand.

However, the measurement of appliance stocks is difficult; Fisher and Kaysen (1962) point out that the quality of their data ranged "…from somewhat below the sublime to a bit above the ridiculous…" and that "…no results can be better than the data on which they are based (p.27)". Wills (1977) states that lack of adequate data for these stocks have usually precluded their use in empirical work while he examines a cross-section data of 77 cities in the USA. Subsequently, Wills (1977) reveals that a high quality of measurement on the stocks is necessary otherwise the long run analysis is hampered. Although the appliance stock is a determinant of the demand for electricity, to obtain a high quality data is still problematic until now. Therefore, recent studies exclude appliance stock from analysis[10]. Given data limitation, some studies use income as a proxy for appliance stock.

Recently, the interest in empirical studies of residential electricity demand has increased. It is mainly due to the tendency of global electricity sectors becoming more competitive and deregulated. Furthermore, knowledge of the determinants of residential electricity demand and its accurate forecasting are relevant for assessing proposals to revise electricity rates and for predicting the residential electricity demand. Larsen and Nesbakken (2004) and Narayan and Smyth (2005) investigate the determinants of the demand for residential electricity. Their economic model states that residential electricity demand is a function of its own price, the price of substitute sources of energy, real income, prices of household appliances as well as other variables, which might influence household preferences.

Table 3 illustrates the most recent studies that have estimated the income and price effects on residential electricity demand with various econometric techniques in different countries. On the whole, the results for income and price elasticity are consistent with the theory. Income elasticities are positive, and own-price elasticities are negative. In terms of variables used, all studies use residential electricity consumption as an indicator for electricity demand. The most popular independent variables are mainly economic factors such as electricity price, substitute energy price(s) and household income. Features of dwellings appear in several studies such as the size of dwelling, stock of appliances and the outdoor temperature, among them, the outdoor temperature is the most frequently used in recent studies.

A study by Nakajima (2010) for Japan shows that own price elasticity is greater than 1 – demand in Japan is price elastic. Similarly, Narayan et al. (2007) provide panel data results for G7 developed economies that indicate in the long-run residential demand for electricity is price elastic, 1.45; and income inelastic, 0.31. Overall, existing studies demonstrate that in developed economies, electricity demand is generally price elastic in the long run as the estimates are above 1. In contrast, in developing countries such as India, Turkey, Sri Lanka, Taiwan and South Korea demand is own-price inelastic in the long run. These price elasticities of demand are from 0.15 to 0.39. In terms of income elasticity, only Taiwan and South Korea show elasticities greater than 1.

Three issues arise in the literature based on the findings of the international empirical studies. First, the conventional wisdom is that those households with higher income are less sensitive to energy prices than households with medium to low incomes. Accordingly, household in developed economies should react less to the changes of electricity prices than households in developing countries. However, there is opposite evidence in the literature for the long run. The reason is likely that developing countries tightly regulate their markets leading to artificially low price electricity in residential sectors.

Table 3
International Studies of Residential Electricity Demand

Country	Data period	Variables	Income elasticity	Own price elasticity	Estimation technique or framework	Author
Indian	Survey data: 1993-1994 Monthly 3000 households	REC; Electricity price; Kerosene price; LPG price; Personal income; Covered area of the welling square feet.	0.60-0.64 across all three seasons	-0.42 winter -0.29 summer	Cross-section data techniques	Filippini and Pachauri 2004
Turkey	Time-series: 1968-2000	Per capita REC; The real income; The real residential electricity price; The urbanization rate.	Long-run: 0.70	Long-run: -0.52	The bounds testing procedure to cointegration (Pesaran et al., 2001)	Halicioglu 2007
South Korean	Time-series: 1973-2007	Household disposable income; The real electricity prices; Structural factors.	Long-run: 1.33	Long-run: -0.23	Structural time series model (Harvey, 1989)	Sa'ad, 2009
The United States	Panel data: 48 states 1993 -2008	REC; The real person income; The real price of electricity; HDD and CDD.	48 states: 0.38 (1993-2000) 0.85 (2001-2008)	Long-run: -0.33 (93-2000) -0.14 (2001-2008)	Panel cointegration test (Pedroni, 1999)	Nakajima and Hamori 2010
Australia	Time-series: 1969-2000	Per capita REC; The real income; HDD+CDD; The real price of gas; The real electricity price.	Long-run: 0.323-0.408 Short-run: 0.0121-0.0415	Long-run: -0.541 Short-run: -0.263	The bounds testing procedure to cointegration (Pesaran et al., 2001)	Narayan and Smyth 2005
The United States	Time-series: 1965-2006	Per capita REC; The real capita income; The real average residential price of electricity; HDD+CDD; The	Long-run: 0.273 Short-run: 0.101	Long-run: -1.0652 Short-run: -0.386	The ARDL bounds testing procedure to cointegration (Pesaran and Pesaran, 1997)	Dergiades and Tsoulfidis 2008

		average price of oil; The stock of housing.				
Sri Lanka	Time-series: 1960-2007	Per capita REC; The real per capita GDP; The average real price of electricity; The average real prices of kerosene oil; The average real prices of LP gas.	Long-run: 0.78 Short-run: 0.32	Long-run: -0.62 Short-run: -0.16	Cointegration and error-models developed by Engle-Granger (1987)	Athukorala and Wilson 2009
Japan	Panel data: 46 prefectures 1975-2000	The per household REC; The real disposable income per household; The real unit price of the residential electricity.	Long-run: 0.602	Long-run: -1.127	Panel unit root tests (Levin et al., 2002); Panel cointegration tests (Pedroni, 1999); Johansen-Fisher-type cointegration test (Maddala and Wu, 1999)	Nakajima 2010
Taiwan	Time-series: 1955-1995	Per capita REC; The real electricity price; The percentage of the population living in cities; The real disposable per capita income; The real world oil price; HDD and CDD.	Long-run: 1.04 Short-run: 0.23	Long-run: -0.16 Short-run: -0.15	The general-to-specific modelling approach (Hendry, 1986 and Hendry and Juseliue, 2000, 2001) Engle and Granger method (1987)	Holtedahl and Joutz 2004
G7:	Panel data: 1978 -2003	Per capita REC; The real income per capita; The real price of natural gas; The real residential electricity	Long-run: 0.3119 Short-run: Insignificant	Long-run: -1.4502 Short-run: Insignificant	Panel OLS; Panel DOLS Panel unit root test (Breitung, 2000); Panel cointegration (Pedroni,2004)	Narayan, Smyth and Prasad 2007

	price.

Second, regarding the stock of appliances, demand for electricity is derived from the flow of services provided by the household's durable energy-using appliances. The use of these household appliances is related to construction features of dwellings, for example, space heating and cooling, lighting, the number of people in the household as well as the outdoor temperature. However, it is likely that there is a high correlation between stock of appliances and income in developing countries since households will purchase more appliances when they have higher income in order to improve the quality of living. The high correlation makes difficult to estimate accurately the effect of each variable on the demand for residential electricity. Therefore, there is an argument that the stock of appliances should be omitted from specifications in developing countries or instrumented with appliance prices.

Third, there has not been much work done on the effect of electricity supply reliability in developing countries where intermittent interruptions to supply are common place. It is thus indispensable to capture the effect in examining electricity pricing. One of the contributions of this study is to extend the existing literature on the Chinese residential electricity issues by introducing a technical index of electricity supply reliability as a controlling factor.

Theoretical considerations, data and estimation methodology

The demand model

As discussed in the literature review, the majority of previous empirical studies relies on the consumer behavior theory and develops empirical demand models for analyzing the residential electricity consumption. A standard model represents residential electricity demand as a function of own price, the prices of substitute sources of energy, income, prices of household appliances, stock of housing and temperature.[11] In setting up our model, we point to the fact that electricity utilities are typically natural monopolies in all different contexts so that the standard residential electricity demand model developed for Western economies is largely applicable to developing countries as well (see also Table 3). Even if, we accepted that the market structure differs in terms of the degrees of competition between developed and developing countries, the relatively higher degree of competition in the West would permit end-customers to have more choices for their electric power suppliers. This, in turn, means lower prices and better services from suppliers. Yet, the majority of end-customers have less/or no choices in developing countries, but they often benefit from monopoly or oligopoly in these countries due to the strict regulation and control of utilities by governments. That is the reason why electricity retail prices are often artificially low despite high generation and distribution costs in developing countries. In this respect, the role of market players may not be particularly significant, but rather common factors in the standard model. For example, Kirschen (2003) points out that the introduction of competition in the electricity retail market has not been very successful even in California.

Many studies fall well short of the ideal empirical specification because of data constraints. Therefore, Narayan and Smyth (2005) suggest a parsimonious demand model including own price, prices of substitute energy, income, and temperature. This suggestion implicitly assumes non-binding supply of electricity which is appropriate in developed economies. However, sufficient and consistent supply of electricity is not the case in developing countries like China. Therefore, we extend the general model in the panel setting as follows.

$$D_{it} = f(EP_{it}, GP_{it}, Y_{it}, R_{it}, W_{it}, A_{it}), \; i = 1 \ldots N, \; t = 1 \ldots T, \qquad (1)$$

where D denotes the residential electricity consumption per capita (kWh), i denotes cross-sectional unit and t stands for time period. *EP* represents the real retail residential electricity price (RMB per kWh). *GP* denotes the real price of natural gas (RMB per cubic meter). Y is the real annual household disposable income per capita (RMB) that is also used as a proxy for the household electric appliances and household characteristics. Income is calculated for three groups of households: average national income (*YA*), urban household income (*YU*) and rural household income (*YR*). R denotes electricity supply reliability and its corresponding indicator is the average interruption hours per customer (AIHC-1). W captures weather conditions and is calculated as a sum of the total number of heating degree days and cooling degree days. A depicts a set of unobservable factors in a panel data setting.

Equation (1) can be further modified following Beenstock et al. (1999) by expressing it in a relative price form. This is the most common specification in the literature (Narayan and Smyth, 2005):

$$D_{it} = f(EP_{it}/GP_{it}, Y_{it}, R_{it}, W_{it}, A_{it}), \quad i = 1 \ldots N, \; t = 1 \ldots T. \qquad (2)$$

Data and variables

Residential electricity demand

Residential electricity consumption (REC) has been sharply increasing in the past three decades in China. For instance, REC was 480.8 billion kWh in 1990 while total REC increased to 4,396.1 billion kWh in 2008 (*China Statistical Yearbook*, 2010), which is a nine times increase. The REC share of total electricity consumption was approximately 12% which is much lower than industrial electricity consumption (80%) in 2008. Nevertheless, REC represents the second largest share of total electricity consumption and it directly affects more than a billion people living standards in China. We use annual REC per capita as demand indicator. Data are mainly from the *China Energy Statistical Yearbook* from 1999 to 2012. Figure 1 shows that the residential electricity consumption per capita increases over the period and that the spread of electricity consumption varies substantially across coastal and inland provinces. Richer provinces consistently consume more electric power than poorer provinces.

Figure 1
Residential Electricity Consumption Per Capita, 1998-2011

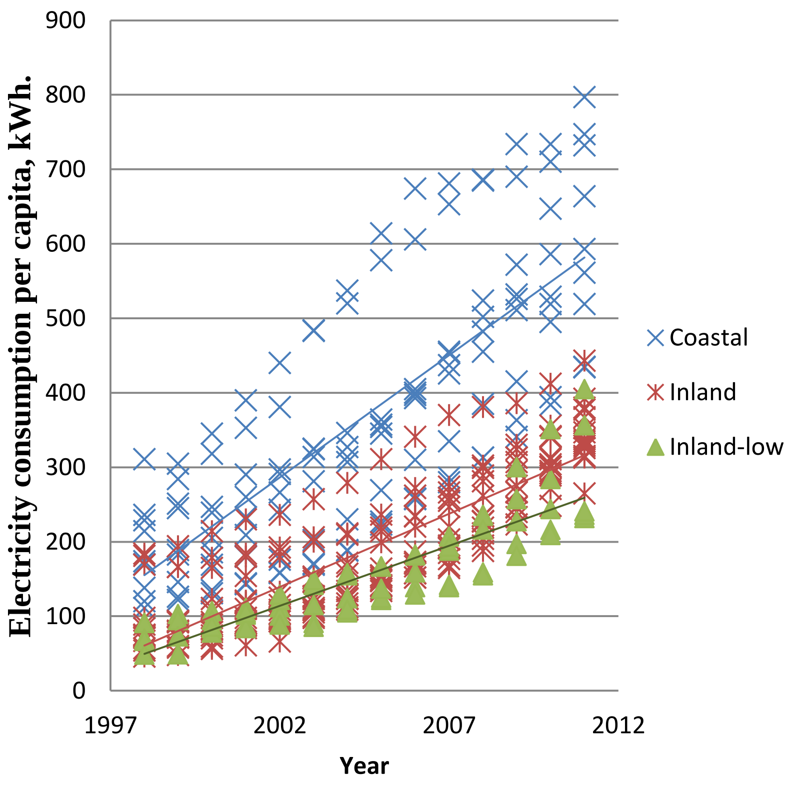


Figure 2
The Real Household Dispoable Income Per Capita, 1998-2011

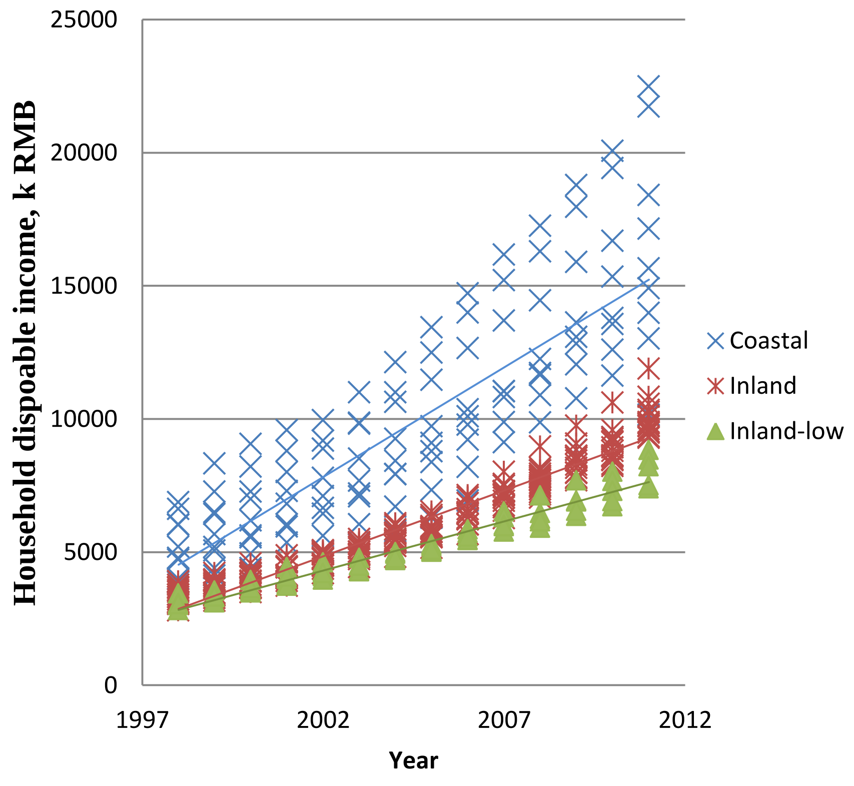


Table 4
Summary of Variables

Variable	Description	Unit	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
EC	Residential electricity consumption	kWh per capita	46	124	201	238.3	312.5	797
EP	The real residential electricity prices	RMB per k kWh	280.1	439.5	488.6	499.6	552.4	929.6
GP	The real price of the pipeline natural gas	RMB per cubic meter	871	1,683	2,167	2,433	2,955	7,310
R	The electricity supply reliability	Minute per household	49.8	355.7	581.9	788.4	946.3	6,492
W	The sum of heating degree day and cooling degree day	Degree	2,512	4,667	5,543	5,910	6,844	11,487
YA	The real average household disposable income	Thousand RMB per capita	2,815	4,671	6,304	7,112	8,582	22,491
YU	The real average urban household disposable income	Thousand RMB per capita	4,196	7,039	9,505	10,468	12,645	31,170
YR	The real average rural household disposable income	Thousand RMB per capita	1,399	2,290	3,141	3,756	4,493	13,811
Coastal	Coastal provinces	Thousand RMB per capita	3,868	6,675	9,116	9,882	12,439	22,491
Inland	Inland provinces	Thousand RMB per capita	2,815	4,342	5,685	6,078	7,698	11,889
Inland-low	The bottom five of low income inland provinces	Thousand RMB per capita	2,826	3,982	5,010	5,228	6,353	8,837

Notes: Coastal provinces (9): Beijing, Shanghai, Zhejiang, Guangdong, Jiangsu, Tianjin, Shandong, Fujian and Hebei. The bottom five Inland-low provinces (5): Xinjiang, Guizhou, Gansu, Ningxia, and Qinghai. Inland provinces (15): the rest. 1st Qu and 3rd Qu stand for the first and the third quantile respectively.

Household income

Increase in income and its impact on living standards is an important driving force of electricity consumption in China. As household income increases, residents tend to buy a bigger size of dwelling and use more electric appliances resulting in higher consumption of electricity for cooking, heating, lighting and entertaining. Figure 1 and Figure 2 show that the trends of electricity consumption and income closely increase. The majority of previous studies show that income is a significant determinant of demand for electricity. We employ the real household disposable income per capita as an indicator for household income. It is taken from the *Chinese Statistic Yearbook* from 1999 to 2012.

Figure 2 displays the income differences across all 29 provinces, classified into coastal, inland and the bottom five (low-income) inland provinces. In 2011, the coastal province with the highest average income (22,491 RMB per capita) was Shanghai, in the east of China. In contrast, the lowest average income (7,396 RMB per capita) inland province was Gansu, in the northwest of China. The household incomes in both provinces have doubled over the fourteen year period. Nevertheless, the growth in incomes has also led to the widening of income disparities. The coastal provinces (Shanghai, Beijing, Zhejiang, Guangdong, Jiangsu, Tianjin, Shandong, Fujian and Hebei) grew the most and were far ahead of others. The bottom five inland provinces are Gansu, Shanxi, Guizhou, Xinjiang and Qinghai.

Table 4 provides information about the disparity in incomes between urban and rural households. It is clear that urban household income is much higher than the rural one. On average, urban household income is approximately 10,468 RMB per capita while rural household income is around 3,756 RMB per capita. This level of the rural household income is similar to the income of households living in urban areas with minimum income of 2,815 RMB per capita. It is likely that these households will be more sensitive to changes in electricity price than rich urban households given the single pricing policy for residential electricity.

Own-price effects

As with the household income, real electricity price is another decisive factor affecting household demand. Generally, most residential electricity prices at province level have three classes according to capacity of power cables: less than 1 kW; between 1 kW and 10 kW and great than 10 kW. The residential electricity price series represent in general average prices based on the first two classes, which are more common than the third class. The source of official retail price information is taken from each electricity supply enterprise at province level.

Figure 3

The Real Residential Electricity Pirce in Different Areas, 1998-2011

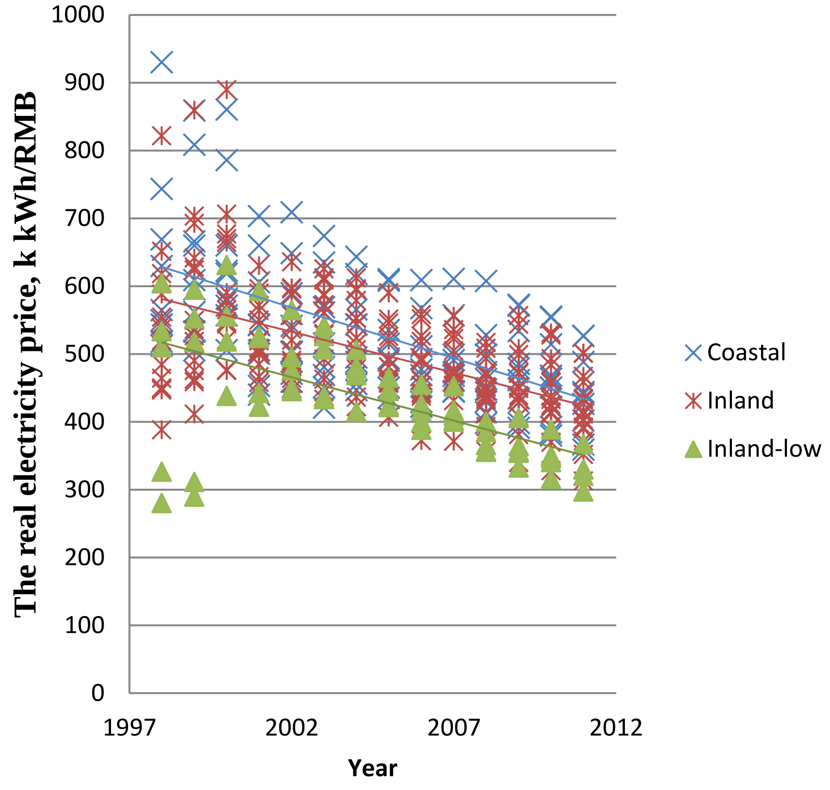
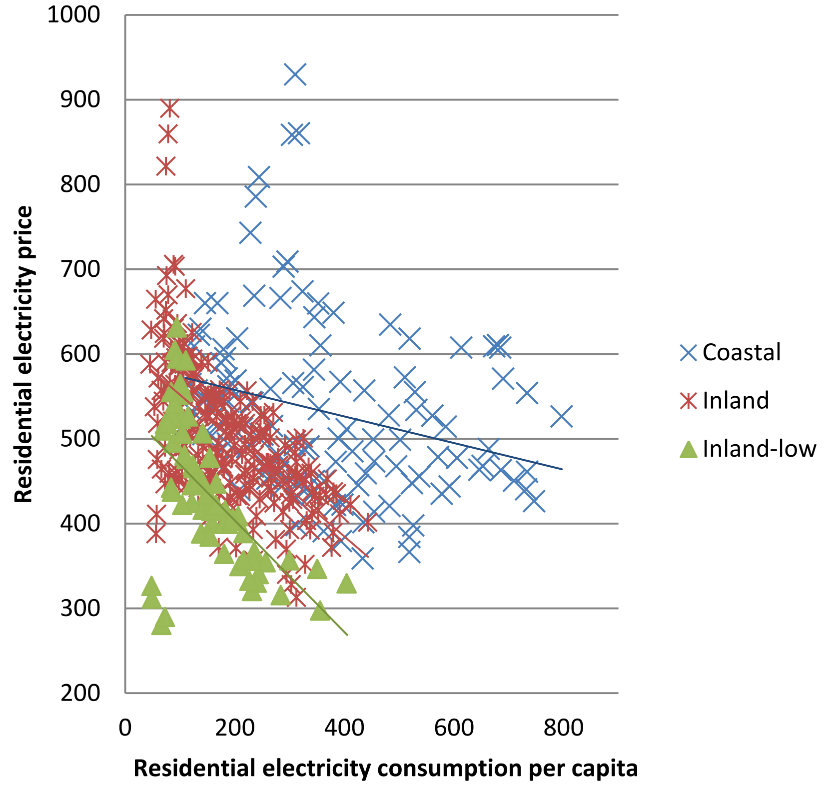


Figure 4

Residential Electricity Consumption and Real Retial Price, 1998-2011



Expected reaction of households to high electricity prices is to reduce electricity demand. Households use more electricity with low electricity price than with high price. Accordingly, it is expected that there is a negative relationship between electricity price and households' electricity consumption. Urban residents and high-income households, in general, may be less price-sensitive because the nominal electricity price has not changed very much over the period of analysis and the real electricity price has even decreased. In other words, urban and high-income households may be less responsive to own-price change. Meanwhile, residents in rural areas and low-income households are likely to be more sensitive to changes in the electricity prices

Figure 3 shows the differences of residential electricity prices across coastal, inland and low-income inland provinces. Straight lines indicate that the average residential electricity price correspond to the order of regional income level. The price distribution exhibits weak association with levels of income. Two high-income provinces have fairly low electricity prices (Beijing and Fujian). In contrast, some low-middle income provinces have relatively high electricity prices. Nevertheless, according to the amount of electricity consumed, the price distribution seems to be fairly reasonable across the three levels of provinces. Figure 4 indicates that coastal provinces use the most electric power, and charged with higher prices, while the opposite is for the low-income inland provinces.

Cross-price effects

Generally, in the short run, increase in the price of electricity will increase the demand for substitute forms of energy such as natural gas, providing that appropriate appliances are already available. In the long run, an increase in the price of electricity will tend to increase stock of appliances that use other fuels. This will cause an outward shift in the demand curve for alternative fuels, with corresponding increases in the quantity consumed. However, traditionally the shift can be limited (Jan et al., 1976). The reason is that households do not have the stock of appliances that permits them to switch between types of energy, in particular, in the short run. As a result, the shift is limited to the income effect until an adjustment in appliance stocks can occur.

In the case of China, although the substitute energy equivalent price is lower than electricity price (see Table 4), the shift from electricity to the pipeline natural gas is restricted. Particularly, the infrastructure for the pipeline natural gas is limited in some urban areas and most rural areas in China. Consequently, the effect of the substitute energy will have little or no impact on these households responsiveness to changes in electricity own-price[12]. However, this shift may be more pronounced for some urban households, especially the Chinese government has increased efforts to boost urban infrastructure development. Therefore, cross-price effect might be significant for the demand of electricity in some urban areas.

We use pipeline natural gas as a substitute fuel for electricity, because it has been a commonly used substitute fuel for electricity in urban areas in recent years. The natural gas price is taken from the China Price Information Network[13] for the period 1999 – 2012. The price is mainly based on information for urban residents in every province. Price of natural gas for rural residents is not available. As a result, the estimations for the cross-price effect for rural household are likely to be much lower (and less reliable) than for urban residents. In general, the cross-price effect should be positive.

Electricity supply reliability and weather

To measure electricity supply reliability we employ total annually average interruption hours per customer (AIHC-1) as an indicator controlling for the effect of electricity supply. The source of this variable is the Electricity Power Reliability Management Center which annually publishes a technical index based (only) on 10 kW urban power supply system; other supply systems are not covered. Due to data availability we only can use the AIHC-1 as a proxy for all households. The expected effect of the interruption in supply is negative.

The information on weather conditions is obtained from the Weather Underground[13]. We use for every provincial capital city the sum of heating degree days (HDD) and cooling degree days (CDD) as a proxy for the weather conditions at province level because information is not available for every city and county within a province. Both HDD and CDD are indexes with reference to temperature of 65^0F. The higher the HDD and CDD the more electricity households consume. Thus, the expected effect of temperature on demand is positive.

Estimation methodology

In the discussion on the main factors affecting electricity demand, we noted that there are differences across provinces and time. The estimation strategy contains two processes. First, we identify an appropriate estimator(s) for the models which include pooled ordinary least squares (POLS), robust methods, and feasible generalised least squares (FGLS) estimators with fixed effects panels. Second, based on the verified estimator(s), we examine the differences of the price and income elasticity of demand given the regional income effects and the price of substitute energy. The general fixed effects specifications are[14]:

$$lnD_{it} = \beta_1 + \delta_t + \beta_2 lnEP_{it} + \beta_3 lnGP_{it} + \beta_4 lnY_{it} + +\beta_5 lnR_{it} + \beta_6 lnW_{it} + e_{it} \quad (3)$$

$$lnD_{it} = \beta_1 + \alpha_i + \beta_2 lnEP_{it} + \beta_3 lnGP_{it} + \beta_4 lnY_{it} + \beta_5 lnR_{it} + \beta_6 lnW_{it} + e_{it} \quad (4)$$

where α_i and δ_t are the unobserved "individual" and time effects which represent the joint impact of the latent variables on the dependent variable D_{it}. Since energy consumption and the regressors are in logarithms, the coefficients are directly interpreted as demand elasticities.

In the literature, previous studies correct for a bias associated with the endogeneity of electricity price in Equation (3) and Equation (4) (Blazquez et al., 2012, Alberini and Filippini, 2011, and Matsukawa, 2004). The reason is that many countries have been adopting increasing block pricing systems which are nonlinear in terms of price and quantity. As we discussed, the pre-reform pricing system was a single fixed price for each province in China; hence we treat electricity price as exogenous in our estimation.

However, the dependent variable and the random error are suspected of heteroskedasticity since the variances for all observations are clearly not the same. If this is the case, this problem could be overcome by first using robust estimators and further applying FGLS estimator if necessary. The tests for the estimations include poolability by a standard F-test, the comparison of fixed and random effects models by Hausman (1978) test, serial correlation test by Wooldridge (2002) and cross-sectional dependence by Pesaran (2004).

The next step is to test the null hypothesis if the electricity consumption behavior is the same across regions. To achieve this objective, we apply both intercept dummy and slope dummy variables for each additional explanatory variable in the verified equation, and then jointly test the significance of the dummy variable coefficients using the Chow test (Hill et al., 2008). Furthermore, we assume that regional income affects the parameters of prices and income. Supposing that time effect is detected in the first step then the specified model for each region is as in Equation (5):

$$
\begin{aligned}
lnD_{it} = \beta_1 + \delta_t + \beta_2 lnEP_{it} + \beta_3 lnGP_{it} + \beta_4 lnY_{it} + \beta_5 lnR_{it} + \beta_6 lnW_{it} + \varphi Region \\
+ \theta_1(lnY_{it} * Region) + \theta_2(lnEP_{it} * Region) + \theta_3(lnGP_{it} * Region) \\
+ \theta_4(lnR_{it} * Region) + \theta_5(lnW_{it} * Region) + e_{it} \qquad (5)
\end{aligned}
$$

where *Region* includes three levels: coastal, inland and the bottom five (low income) provinces, as “the bottom five” is the reference group. If the F-statistics for testing the joint null hypothesis of equal parameters is less than a critical value, we will reject the null in favor of the alternative that at least one $\theta_i \neq 0$.

The final step of our estimation strategy is to model the relative price based on the price of electricity substitute as in Equation (2). Presuming a verified fixed time effects model with an appropriate estimator, the estimating equation is defined as follows:

$$
\begin{aligned}
lnD_{it} = \beta_1 + \delta_t + \beta_2 lnRP_{it} + \beta_3 lnY_{it} + \beta_4 lnW_{it} + \beta_5 lnR_{it} + \varphi Region \\
+ \theta_1(lnRP_{it} * Region) + \theta_2(lnY_{it} * Region) + \theta_4(lnW_{it} * Region) \\
+ \theta_5(lnR_{it} * Region) + e_{it} \qquad (6)
\end{aligned}
$$

where *lnRP* is the log of the ratio of the real price of electricity to the real price of natural gas. The relative price variable is expected to be negatively related to electricity consumption and urban areas should have a higher parameter than the one at national level.

Results

Model selection

The coefficients estimated with fixed effect models are reported in Table 5 and Table 6 which summarize estimation results for three groups of households – national, urban and rural. The estimators include pooled OLS, fixed time effects with robust standard errors, fixed individual effects with robust standard errors, and FGLS with time and individual effects.

With regard to the national level and the urban sample (Table 5), poolability by F-statistics indicates that all time fixed effects models are significant at 10% and often at 1% level or better which implies that the electricity consumption functions shift over time. The time effect may be due to factors such as the rapid acceleration of Chinese economic growth that results in fast household income increasing from one year to the next. Similarly, the individual fixed effects are highly significant which reflects the substantial differences among provinces in terms of residential electricity consumption. Therefore, the POLS models are rejected. Second, the significant Hausman tests suggesting that fixed time effects are more favorable than random effects, which is consistent with our expectation. Third, Wooldridge's tests for serial correlation in fixed effects panels are only in favor of FGLS estimator with time effects at national level and urban areas. Furthermore, Pesaran tests for cross sectional dependence of the FGLS estimator with time effects are insignificant at 5% level. Hence, the evidence suggests that the FGLS with time fixed effects is valid models to assess residential electricity consumption for the national level and the urban samples.

In terms of rural areas (Table 6), poolability tests suggest the need to control for either time or individual effects so that POLS is not appropriate. However, the rest of the models have the problem of serial correlation since the Wooldridge’s tests are insignificant. Such issue may be caused by omitted variables of other energy prices capturing effects of other conventional energy sources in rural area such as coal and wood[15]. Yet, the insignificant Pesaran test shows that there is not cross sectional dependence in fixed time effects regressions with robust standard errors, which may suggest that the estimates remain unbiased but inconsistent (Sarafidis and Wansbeek, 2012; Pesaran, 2004; Cerrato and Srantis, 2002).

Price and income elasticities without regional effects

The coefficients of main interests of income, own-price and cross-price effects are statistically significant and are in line with the expectations of the consumer behavior theory (See Table 5 and Table 6).

Table 5

National and Urban Income Models

Income level			National income					Urban income		
Model	Pooled	FE *t*	FE *i*	FGLS *t*	FGLS *i*	Pooled	FE *t*	FE *i*	FGLS *t*	FGLS *i*
Variable	Coef.(S.E)	Coef.(S.E)	Coef.(S.E)	Coef.(S.E)	Coef.(S.E)	Coef.(S.E)	Coef.(S.E)	Coef.(S.E)	Coef.(S.E)	Coef.(S.E)
Intercept	-8.034***					-10.288***				
	0.672					0.769				
EP	-0.231**	-0.413***	-0.077	-0.412***	-0.079	-0.111	-0.306**	-0.135	-0.300***	-0.127**
	0.071	0.094	0.101	0.004	0.047	0.078	0.101	0.106	0.010	0.047
GP	0.118***	0.107**	0.092*	0.107***	0.022	0.165***	0.148***	0.115*	0.142***	0.033
	0.033	0.034	0.046	0.002	0.031	0.036	0.036	0.048	0.008	0.031
YA	1.318***	1.474***	1.303***	1.476***	1.097					
	0.028	0.048	0.042	0.006	0.052					
YU						1.319***	1.548***	1.229***	1.550***	1.039***
						0.031	0.057	0.043	0.010	0.049
W	0.286***	0.299***	-0.0334	0.296***	0.008	0.378***	0.410***	-0.005	0.401***	0.020
	0.038	0.039	0.096	0.002	0.027	0.042	0.042	0.099	0.006	0.026
R	-0.030*	-0.022	0.010	-0.022***	0.001	-0.057***	-0.048**	0.004	-0.047***	-0.001
	0.014	0.016	0.011	0.0002	0.005	0.015	0.017	0.012	0.001	0.005
SSE	18.645	17.745	8.811	17.745	10.171	22.083	20.425	9.363	20.429	10.625
Adj.R^2	0.866	0.741	0.818	0.885	0.934	0.844	0.709	0.812	0.868	0.931
Pooltest		F=1.521 P=0.109	F=14.829 P<-2.2e-16				F=2.416 P=0.004	F=18.050 P<-2.2e-16		
Hausman Test		Chisq = 48.30 P = 3.08e-09	Chisq = 11.68 P=0.039				Chisq = 50.10 P = 1.3e-09	Chisq= 66.00 P = 6.9e-13		
Wooldridge's test		Chisq = 1650.3 P < 2.2e-16	Chisq = 520.45 P < 2.2e-16	Chisq= 0.056 P=0.814	Chisq= 801.4 P<2.2e-16		Chisq = 1690 P < 2.2e-16	Chisq = 655 P < 2.2e-16	Chisq= 0.269 P=0.604	Chisq= 812.9 P<2.2e-16
Pesaran CD test		Z=-1.389 P=0.165	Z=1.220 P=0.222	Z=-1.930 P=0.054	Z=9.066 P<2.2e-16		Z=-1.522 P=0.128	Z=4.205 P=2.6e-05	Z=-1.418 P=0.156	Z=10.351 P<2.2e-16

Notes: ***, ** and * denote statistical significance at 1% level, 5% level and 10% level, respectively.

Table 6
Rural Income Models

Model Variable	Pooled Coef.(S.E)	FE *t* Coef.(S.E)	FE *i* Coef.(S.E)	FGLS *t* Coef.(S.E)	FGLS *i* Coef.(S.E)
Intercept	-0.532				
	0.621				
EP	-0.623***	-0.522***	-0.024	-0.517***	-0.033
	0.073	0.098	0.108	0.005	0.050
GP	-0.005	0.027	-0.047	0.024***	-0.068**
	0.035	0.035	0.049	0.005	0.031
YR	1.174***	1.093***	1.404***	1.097***	1.212***
	0.026	0.037	0.049	0.007	0.048
W	0.016	0.031	-0.071	0.034***	-0.004
	0.040	0.041	0.103	0.007	0.030
R	0.010	-0.006	0.024*	-0.006***	0.007
	0.015	0.017	0.012	0.001	0.005
SSE	20.57	19.106	10.09	19.108	11.14
Adj.R^2	0.854	0.725	0.804	0.876	0.928
Pool test		F= 2.280	F= 13.80		
		P=0.007	P<2.2e-16		
Hausman test		Chisq=42.86	Chisq=21.66		
		P =3.9e-08	P=6e-04		
Wooldridge test		Chisq= 1966	Chisq= 328	Chisq=15.624	Chisq=736.6
		P<2.2e-16	P<2.2e-16	P=7.7e-05	P<2.2e-16
Pesaran CD test		Z=-1.327	Z=6.924	Z=-2.357	Z=14.518
		P=0.185	P=4.4e-12	P=0.018	P<2.2e-16

Notes: ***, ** and * denote statistical significance at 1% level, 5% level and 10% level, respectively.

The electricity price shows a consistently negative effect on the quantity of electricity demanded when holding other factors constant. The elasticity is less than 1 suggesting that the electricity demand is price inelastic. National, urban and rural samples show different estimates for the response of households to changes in residential electricity prices, -0.412, -0.300 and -0.522 respectively. The results reveal that (poorer) rural income households are more sensitive to changes in electricity prices than (richer) urban households.

The household income variable is also consistently, significantly and positively related to electricity consumption for each income group, with elasticity above 1 when holding other factors fixed. Income elasticities suggest that the higher the household income the higher is the electricity demand in China. In other words, urban households demand more electricity than average income and rural households in China as the income elasticity is 1.550 greater than 1.480 at national level and 1.093 in rural areas. The results are consistent with the expectations of the consumer behavior theory.

The cross-price elasticities also are as expected, all positive and significant at the national level and for the urban households. Generally, the cross-price elasticity of urban households is higher than at national level. However, both elasticities are small, which suggests that there may not be a strong substitution relationship between the residential electricity and the alternative - residential natural gas during the period of analysis. Alternative specifications confirm that natural gas is a substitute source of energy for electricity at national level, and in the urban areas - the relative price variable has the expected negative sign and is significant.

Our estimates of own-price elasticity are close to the study by He et al. (2011) estimate of -0.300 for household electricity demand with cross-section data in 2007; our results differ from the study by Lin (2003) who finds an average electricity price elasticity of 0.016 at national level. The latter paper uses time-series data, which does not take the province effect into account. The estimated elasticity close to zero seems unreasonable for the household sector. Considering pervious international studies, our findings also agree with price inelastic estimates for the USA, Australia, Taiwan and Sri Lanka (Table 3).

Supply reliability and weather effects

The electricity supply reliability significantly affects electricity consumption both for national and urban households as demonstrated in Table 5. The findings indicate that the electricity reliability is a key factor affecting residential electricity consumption in spite of electricity supplying enterprises having made efforts to improve the electricity supply reliability in China.

Weather condition is also a highly significant factor influencing residential electricity consumption at national level and in the urban areas. These findings are consistent with previous studies on residential electricity consumption (Alberini and Filippini, 2011; Dergiades and Tsoulfidis, 2008; Holtedahl and Joutz, 2004; Nakajima and Hamori, 2010; Narayan and Smyth, 2005).

Table 7

Testing for The Equivalence of Income Levels and Regional Income Effects

Variable	National Coef.	S.E.	Urban Coef.	S.E.	Rural Coef.	S.E.
EP	0.277***	0.015	0.261***	0.024	0.311***	0.021
GP	-0.450***	0.010	-0.441***	0.015	-0.445***	0.019
YA	1.452***	0.028				
YU			1.363***	0.039		
YR					0.955***	0.032
W	-0.451***	0.012	-0.362***	0.018	-0.614***	0.016
R	0.071***	0.005	0.056***	0.007	0.116***	0.006
Inland	-3.569***	0.463	-4.589***	0.603	-1.277***	0.366
Coastal	-5.703***	0.390	-5.610***	0.511	-11.262***	0.408
EP : Inland	-1.138***	0.030	-1.033***	0.045	-1.350***	0.038
EP: Coastal	-0.588***	0.023	-0.407***	0.034	-0.442***	0.030
GP: Inland	0.545***	0.024	0.547***	0.026	0.504***	0.025
GP: Coastal	0.722***	0.019	0.616***	0.022	0.861***	0.021
YA: Inland	-0.111***	0.025				
YA: Coastal	-0.111***	0.024				
YU: Inland			-0.104**	0.034		
YU: Coastal			-0.077*	0.032		
YR: Inland					-0.099***	0.016
YR: Coastal					0.134***	0.025
W: Inland	0.925***	0.021	0.966***	0.026	0.838***	0.017
W: Coastal	0.604***	0.021	0.536***	0.025	0.793***	0.025
R: Inland	-0.085***	0.006	-0.075***	0.008	-0.114***	0.007
R: Coastal	-0.059***	0.005	-0.043***	0.008	-0.095***	0.006
SSE	12.823		14.006		13.524	
Adj.R^2	0.917		0.909		0.912	
Wooldridge's test	chisq = 2.158, p-value = 0.142		chisq = 1.373, p-value = 0.242		chisq = 13.82, p-value =2.0e-04	
Pesaran CD test	z = -0.711, p-value = 0.477		z = -0.125, p-value = 0.900		z = -1.898, p-value = 0.058	
The Chow test	F=28.010		F=33.453		F=30.129	

Notes: Results are based on FGLS time effects estimators. The 1% critical value of the F distribution for the Chow test is $F_{(0.99,6,437)}$= 2.834. ***, ** and * denote statistical significance at 1% level, 5% level, and 10% level, respectively.

Table 8
Testing For The Price of A Substitute

Variable	National Coef.	S.E.	Urban Coef.	S.E.	Rural Coef.	S.E.
RP	0.390***	0.013	0.412***	0.021	0.417***	0.026
YA	1.425***	0.021				
YU			1.387***	0.045		
YR					0.800***	0.025
W	-0.455***	0.011	-0.374***	0.025	-0.572***	0.028
R	0.057***	0.003	0.058***	0.010	0.089***	0.006
Inland	-8.224***	0.197	-8.361***	0.407	-6.857***	0.358
Coastal	-4.387***	0.210	-3.274***	0.389	-5.472***	0.353
RP: Inland	-0.427***	0.014	-0.468***	0.025	-0.410***	0.027
RP: Coastal	-0.634***	0.012	-0.544***	0.021	-0.646***	0.026
YA: Inland	0.039*	0.018				
YA: Coastal	-0.126***	0.024				
YU: Inland			0.021	0.032		
YU: Coastal			-0.127**	0.041		
YR: Inland					0.086***	0.012
YR: Coastal					0.107***	0.023
W: Inland	0.909***	0.013	0.948***	0.035	0.730***	0.035
W: Coastal	0.570***	0.011	0.483***	0.025	0.487***	0.030
R: Inland	-0.093***	0.003	-0.095***	0.009	-0.121***	0.005
R: Coastal	-0.051***	0.003	-0.050***	0.010	-0.074***	0.006
SSE	14.901		15.680		17.668	
Adj.R^2	0.904		0.899		0.885	
Wooldridge's test	chisq = 0.345, p-value = 0.557		chisq = 0.882, p-value = 0.348		chisq = 1.173, p-value = 0.279	
Pesaran CD test	z = -0.656, p-value = 0.5121		z = -0.094, p-value = 0.925		z = -1.813, p-value = 0.070	

Notes: Results are based on FGLS time effects estimators. ***, ** and * denote statistical significance at 1% level, 5% level, and 10% level, respectively.

Regional income effects

The results reported in Table 7 represent tests of the regional income level impact on the price and income elasticities. Our findings are twofold. First, there are important differences across the three categories of regions since all the Chow tests are significant at 1% level ($F_{(0.99,6,437)}$= 2.834). We, therefore, reject the null hypothesis that the electricity consumption function is uniform and conclude that there are significant differences in consumption behavior according to regional income levels.

Second, regional variation affects the price and income elasticities. The estimates for each of the three regional categories are as follows.

Coastal provinces:

National: $\widehat{D}$= –0.311EP+0.272GP+1.341YA+0.153W+0.012R–5.703Coastal

Urban: $\widehat{D}$= –0.146EP+0.175GP+1.286YU+0.174W+0.013R–5.610Coastal
Rural: $\widehat{D}$= –0.131EP+0.416GP+1.089YR+0.179W+0.021R–11.262Coastal

Inland provinces:

National: $\widehat{D}$= –0.861EP+0.095GP+1.341YA+0.474W–0.014R–3.569Inland
Urban: $\widehat{D}$= –0.772EP+0.106GP+1.259YU+0.604W–0.019R–4.489Inland
Rural: $\widehat{D}$= –1.039EP+0.059GP+0.856YR+0.224W+0.002R–1.277Inland

The majority of electricity price elasticities are less than 1 and show that the lower the income level the higher the own price elasticity of demand. Particularly, households in inland provinces are much more sensitive to changes in electricity prices than households living in coastal provinces. In addition, their income elasticities of demand are consistently higher than 1. Interestingly, the own price elasticity is slightly greater than 1 for rural households in inland province, which also show low income elasticity of demand. The high price elasticities may imply that although the proportion of electricity expenditure in total household consumption is not as substantial as food expenditure, the income effects are still large.

Price elasticity of substitute energy

The parameters of the relative price of electricity to pipeline natural gas are reported in Table 8. They have the expected negative sign (except for rural households in inland provinces) and are highly significant, at the 1% level. The coefficients are -0.037, -0.056 and 0.007 for national, urban and rural income levels for the inland provinces, and -0.244, -0.132 and -0.229 respectively for the coastal provinces. Therefore, we conclude that overall pipeline natural gas is indeed a substitute for electricity in China, except in inland rural areas.

Conclusion and policy implications

A principal motivation for this paper is to evaluate the implications of the new residential electricity pricing system in China and to understand how households respond to changes in electricity prices across Chinese provinces differentiating between urban and rural households as well as across income groups. The issue of Chinese electricity demand at household levels has received little attention in the academic literature despite its considerable policy relevance. We apply panel data models to investigate demand responsiveness of households to change in electricity own-price and household income when controlling for other relevant factors, such as substitute energy prices, electricity supply reliability and weather condition using annual data from 29 provinces over the period 1998-2011.

The main argument in the paper is that the perceived “low price” of domestic electricity in China may be true when referring to the economic development for the whole country. However, the “low price” is not true when different levels of average household income are considered. Our findings suggest that income is the prime driving force of residential electricity demand which mediates a variation in own price elasticity across three categories of provinces. The residential electricity price elasticity is fairly high for the urban households in inland provinces compared to the coastal urban households. The second argument is that study on residential electricity consumption should not ignore the effect of electricity supply reliability due to electricity shortages and less advanced technology in developing countries, including China; otherwise, estimates may be biased.

The results suggest that the new residential electricity pricing system in China should take into account the variation in price responsiveness, in particular, for urban households in inland provinces and for rural households. These households are more than five times as sensitive to changes in electricity prices as the households living in coastal urban areas which have average to high incomes. Furthermore, the electricity pricing system should take into account the variation in elasticity across the different tiers of the price schedule. In other words, important differences in the price elasticity in different blocks of the rate structure should be considered in the new electricity pricing system. For instance, for high-income households there is considerable room for price increase which can be used to finance the development of the supply system.

While our findings are robust, a limitation of the paper is that the conclusions are drawn from a relatively small dataset and fixed effects models. Future work should include prices of other conventional energy sources to investigate in more detail the effects in rural areas. Also, residential bill data could help to further examine baseline quantities as well as to distinguish between short-run and long-run effects.

Notes

1. Inner Mongolia Electric Power Company, 1998, The History of Chinese Electricity Industry: Inner Mongolia Electricity Industry from 1903 to 1996, Inner Mongolia People' Publishing press.
2. "The review of Chinese Electricity Pricing System reform", 2009, Center for Industrial Energy Efficiency.
3. See footnote 2.
4. The Local Chronicles of Guangxi Province: Electricity Industry Volume, 1992, China Water Power Press.
5. The Local Chronicles of Wuhan City from 1980 to 2000: Electricity Industry Volume, Wuhan University Press.
6. On the 4th of April in 1998, the NDPC issued "Strengthen the administration of electricity prices in rural area, and forbidden collecting fees, apportion and fine illegally to end-users" (document No. 39); on the 30th of April in 1998, the SGCC issued "Strengthen the administration of electricity prices in rural area and reducing the burden on farmer" (document 02).
7. The National Development and Reform Commission: Most provinces achieved one price, http://www.ndrc.gov.cn/xwfb/t20000630_27822.htm, accessed on 01/2011.
8. It is generally accepted that there is high level of income inequality in China. For example, a study from Song, Zhu, and Mukhopadhyay (2009).
9. See Athukrala and Wilson (2010), Filippini and Pachauri (2004), Halicioglu (2007), Holtedahl (2004), Nakajima and Hamori (2010), Sa'ad (2009), Narayan,

Smyth and Prasad (2007), Narayan and Smyth (2005), Nakajima (2010).

10. See the relevant summary of previous studies by Narayan and Smyth (2005).
11. This view is also supported by Hartman and Werth (1981), Reiss and White (2002) and Acton, Mithell and Mowill (1976).
12. The China Price Information Network http://www.chinaprice.com.cn/fgw/chinaprice/free/index.htm accessed on10/2012.
13. The Weather Underground provides the most localized weather condition available, and it is committed to delivering the most reliable, accurate weather information possible. It includes almost 19,000 weather stations in the US and over 13,000 weather stations across the rest of the worlds.
14. See Equation 1 and 2 for the definition of each variable.
15. See Yao, Chen and Li (2012).

References

Alberini, Anna, and Massimo Filippini. 2011. "Response of residential electricity demand to price: The effect of measurement error." *Energy Economics* 33, pp. 889-895.

Athukrala, P.P.A Wasantha, and Clevo Wilson. 2010. "Estimating short and long-term residential demand for electricity: new evidence from Sri Lanka." *Energy Economics* 32, pp. S34-S40.

Beenstock, Michael, Ephraim Goldin, and Dan Nabot. 1999. "The demand for electricity in Israel." *Energy Economics* 21, pp. 168-183.

Blazquez, Leticia, Nina Boogen, and Massimo Filippini. 2012. "Residential electricity demand in Spain: New empirical evidence using aggregate data." *Energy Economics*, doi:10.1016/j.eneco.2012.11.010.

Cerrato, Mario, and Sarantis Nicholas. 2002. *The cross sectional dependence puzzle*. London Guildhall University.

Dang, Guoying. 2000. "The report of Chinese rural electricity pricing issues." *Review of Economic Research* (China) 14, pp. 24-32.

Dergiades, Theologos, and Lefteris Tsoulfidis. "Estimating residential demand for electricity in the United States, 1965-2006." *Energy Economics* 30, pp. 2722-2730.

Filippini, Massimo, and Shonali Pachauri. 2004. "Elasticities of electricity demand in urban Indian households." *Energy Policy* 32, pp. 429-436.

Fisher, Franklin M. and C. Kaysen. 1962. *A study in econometrics: The demand for electricity in the United States*. Amsterdam: North Holland Publishing Co..

Halicioglu, Ferda. 2007. "Residential electricity demand dynamics in Turkey." *Energy Economics* 29, pp. 199-210.

Hausman, J.A.. 1978. "Specification tests in econometrics." *Econometrica* 46, pp.1251–1271.

He, Y.X, L.F Yang, H.Y. He, T. Luo and Y.J. Wang. 2011. "Electricity demand price elasticity in China based on computable general equilibrium model analysis." *Energy* 36, pp.1115-1123.

Holtedahl, Pernille, and Frederick L. Joutz. 2004. "Residential electricity in Taiwan." *Energy Economics* 26, pp. 201-224.

Houthakker, H.S.. 1951. "Some Calculations on Electricity Consumption in Great Britain." *Journal of the Royal Statistical Society* Vol.114: No.3.

Hill, R.Carter, William E. Griffiths, and Guay C Lim. 2008. *Principles of Econometrics*, 3rd ed., John Wiley&Son Inc.

Jan, Action, Mitchell Bridger, and Mowill Ragnhild. 1976. "Residential demand for electricity in Los Angeles: an econometric study of disaggregated data." *The Rand Corporation* R-1899-NSF.

Kirschen, Daniel S. 2003. "Demand-Side View of Electricity Markets." *IEEE Transactions On Power Systems* 18, No.2.

Pesaran, H.. 2004. "General Diagnostic Tests for Cross Section Dependence in Panels." *CESIfo* Working Paper 1229.

Lam, Pun-Lee. 2004. "Pricing of electricity in China." *Energy* 29, pp. 287-300.

Larsen, B. M., and R. Nesbakken. 2004. "Household electricity end-use consumption: result from econometric and engineering models." *Energy Economics* 26, pp. 179-200.

Lin, Bo Q.. 2003. "Electricity demand in the people's republic of China: Investment requirement and environmental impact." *Asian Development Bank*, Economics and research department working paper series: NO.37.

Matsukawa, Isamu. 2004. "The effects of information on residential demand for electricity." *The Energy Journal* Vol 25, No.1.

Nakajima, Tadahiro, and S. Hamori. 2010. "Change in consumer sensitivity to electricity prices in response to retail deregulation: a panel empirical analysis of the residential demand for electricity in the United States." *Energy Policy* 23, pp. 2470-2476.

Nakajima, Tadahiro. 2010. "The residential demand for electricity in Japan: an examination using empirical panel analysis techniques." *Journal of Asian Economics* 21, pp. 412-420.

Narayan, P. K, R. Smyth and A. Prasad. 2007. "Electricity consumption in G7 countries: a panel cointegration analysis of residential demand elasticities." *Energy Policy* 35, pp. 4485-4494.

Narayan, P.K., and R. Smyth. 2005. "The residential demand for electricity in Australia: an application of the bounds testing approach to cointegration." *Energy Policy* 33, pp. 467-474.

Saad, Suleiman. 2009. "Electricity demand for South Korean residential sector." *Energy Policy* 37, pp. 5469-5474.

Sarafidis, Vasilis, and Tom Wansbeek. 2012. "Cross sectional dependence in panel data analysis." *Econometric Reviews* 31, pp.483-531.

Song, Shunfeng, Erqian Zhu, and Sankar Mukhopadhyay. 2009. "Urban Poor in China: A Descriptive Analysis." *The Chinese Economy* 42, pp.44-62.

Wills, John. 1977. "Residential demand for electricity in Massachusetts." Working paper NO.MIT-EL: 77-016 WP. The work was supported by National Science Foundation Fellowship.

Wooldridge, J.M.. 2002. *Econometric Analysis of Cross-Section and Panel Data*, MIT Press, Sec. 10.5.4, p. 274.

Xu, Shaofeng, and Wenying Chen. 2006. "The reform of electricity power sector in the PR of China." *Energy Policy* 34, pp. 2455-2465.

Yao, Chunsheng, Chongying Chen, and Ming Li. 2012. "Analysis of rural residential energy consumption and corresponding carbon emissions in China." *Energy Policy* 41, pp. 445–450.

Zhang, C., and T. C. Heller. 2007. "Reform of the Chinese electric power market: economics and institutions." Edited by Victor D. and Heller T.C., The Political Economy of Power Sector Reform, Cambridge University Press.

Zhao, Xiaoli, Thomas P. Lyon, and Cui Song. 2012. "Lurching towards markets for power: China's electricity policy 1985-2007." *Applied Energy* 94, pp. 148-155.