Electricity Demand and Basic Needs: Empirical Evidence from China's Households[1]

Xiaoping He #2 David Reiner 3

Abstract: An increasing block tariff (IBT) has been implemented nationwide in the residential sector in China since 2012. However, knowledge about IBT design is still limited, particularly how to determine the electricity volume for the first block of an IBT scheme. Assuming the first block should be set based on some measure of electricity poverty; we attempt to model household electricity demand such that the range of basic needs can be established. We show that in Chinese households there exists a threshold for electricity consumption with respect to income, which could be considered a measure of electricity poverty, and the threshold differs between rural and urban areas. For rural (urban) families, electricity consumption at the level of 7^{th} (5^{th}) income decile households can be considered the threshold for basic needs or a measure of electricity poverty since household electricity demand in rural (urban) areas does not respond to income changes until after 7^{th} (5^{th}) income decile. Accordingly, the first IBT block for some provinces (e.g., Beijing) appears to have been set at a level that is too high. Over time however, given continued rapid growth, the IBT will begin to better reflect actual basic needs.

Keywords: Electricity; Household; Basic Needs; Quantile Regression

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[2] XH, Collaborative Innovation Center for Energy Economics and Energy Policy, School of Economics, Xiamen University Xiamen City 361005, China, Email: xphe@xmu.edu.cn. Tel: +86 0592 2186076. Fax+86 0592 2186075.
[3] David Reiner: Energy Policy Research Group, Judge Business School, University of Cambridge, Trumpington Street, Cambridge, CB2 1AG, UK. Email: dmr40@cam.ac.uk.

1. Introduction

Over the past three decades, China's economic growth has driven rapid increases in electricity consumption. Between 1980 and 2012, electricity consumption in China increased at an annual growth rate of 9.2%. Over the same period, electricity demand in the residential sector, accounting for 13.3% of total electricity consumption, grew at an even faster rate of 12.0%.[4] Retail electricity prices are tightly controlled by the Chinese government and have long been kept at artificially low levels (Lin and Jiang, 2011, 2012). Moreover, electricity consumption in the residential sector is cross-subsidized by the industrial and commercial sectors, and retail prices for residential electricity are usually lower than its long-term marginal cost (Lin and Jiang, 2011). Reform towards cost-reflective tariffs has proven difficult because of concerns that increasing prices may impact the welfare of poor households and, as such, electricity prices are politically sensitive. Whereas electricity prices are subject to strict controls, the coal price has been liberalized since 1992. As a result, any cost increases borne by electricity producers could not be transferred to end users because of price controls (Wang, 2007). Moreover, the price dual-track for coal and electricity resulted in many disputes between the two industries and supply disruptions in many areas of the country.

Given the untenable situation, the Chinese government has begun to promote electricity price reforms. One reform measure is the increasing block tariff (IBT), which has been implemented nationwide in the residential sector since July 2012, so as to eventually reduce electricity cross subsidies and promote efficient use of electricity. IBT, a nonlinear pricing

[4] This is authors' calculation, based on original data provided by NBS (2014).

method [5] comprising a rising set of charges as consumption increases, has often been promoted as a solution, for multiple social (and/or financial) targets, such as equity, cost recovery, and environmental concerns. The nonlinearity of IBT implies that the expenditure on electricity is not linearly proportional to consumption. Under an IBT scheme, household electricity consumption can be divided into several blocks, and a prescribed price applied to each defined block. In theory, IBT has the capability of achieving economic efficiency and social equity simultaneously while enabling cost recovery by utilities. However, in practice, its effect depends largely on the details of the scheme. For example, a large volume of electricity in the initial block with a subsidized price might result in excessive subsidies. Although IBT has been the subject of considerable attention recently in China, knowledge about IBT design is still limited, particularly how to determine the rate and the electricity quantity for the first block of an IBT scheme.

In developing countries, the first block of IBT has usually been set at a subsidized price, with a nominal goal of ensuring the poor can pay for some minimum volume of energy services to perform such basic tasks as cooking, lighting and heating at an affordable price (usually described as a "lifeline" tariff). The philosophy behind lifeline rates is that electricity is a necessity in modern society and every family should be able to purchase enough electricity to meet its minimum needs without undue budgetary stress (Petersen, 1982). It is obvious that the ability of the IBT to deliver social equity on its promise of effectively targeting the poor depends on setting the volume of electricity in the initial block equal to the

[5] There are various pricing methods for public utilities, depending on the policy objective. The marginal cost pricing (MCP), largely targeting economic efficiency, is a typical linear method and has been widely used in utilities. With the MCP, the price per unit of service/product remains unchanged with increasing quantity of the consumption. However, linear pricing is usually not optimum when there are multiple policy objectives. Some nonlinear pricing methods such as two-part tariff (Coase, 1946) and block tariff have the advantage of meeting multiple targets. For instance, a two-part tariff is composed of fixed fee and service charge, and can be used to compensate the fixed cost (therefore meet the financial target), and as well, the marginal cost (hence to meet the efficiency target). If a nonlinear price scheme has more than two price blocks, it is known as the block tariff.

basic electricity needs. If a high volume be set, wealthier households would get more benefits from the low price. Therefore, if it is the case that "every family should be able to purchase enough electricity to meet its minimum needs", one empirical question concerning IBT is to model the household electricity demand such that the size of the minimum-need block can be established.

Based on a dataset drawn from a survey of three provinces in China, we attempt to define and quantify the basic electricity needs of rural and urban households, using the measurement for "energy poverty" developed by Khandker et al (2010). To our knowledge, no study has examined the basic electricity needs of households in China. To be specific, the first studies of IBT in China have mostly set the electricity volume of each block at a pre-determined level, rather than basing it on a quantitative analysis. Such an example is the study by Lin and Jiang (2012), who suggested setting the first block in the IBT scheme based on the "lifeline volume", and setting the second block to meet the "basic demand" of low-income households. In other studies, lifeline rates were usually based on either "essential needs" (Petersen, 1982; Hennessy, 1984) or "basic needs" (Wodon et al., 2003).

We attempt to establish a single measure of basic needs rather than distinguishing between "lifeline" needs and essential (or basic) needs. We provide an estimate of basic needs for electricity in Chinese households, but our primary purpose is to provide a conceptual discussion regarding how household electricity demand should be defined and measured. Our results have clear policy implications and provide empirical evidence to help improve the IBT scheme in China. The remainder of our study is organized as follows: in Section 2, we discuss household electricity consumption patterns in China. In Section 3, we present the analytical framework for defining and measuring households' basic needs for electricity, using a demand-based approach and drawing on a definition of "energy poverty".

In Section 4, we empirically investigate household electricity consumption in China, specifically how electricity consumption responds to the changes in income. Conclusions and policy implications are given in the final section.

2. Electricity Consumption of Chinese Households

Energy consumption patterns (and lifestyles) of Chinese households have changed drastically with rapidly rising income over the past three decades. In the 1980s, China's residential electricity consumption was almost entirely used for lighting. Since the 1990s, electricity has become one of the principal energy sources for recreation and social communication, being used for televisions, computers, DVD players, and audio systems, in addition to more 'basic' forms such as lighting, cooking, washing, cooling and heating. Lin and Jiang (2012) estimated that in the electricity consumption of urban low-income households, electricity used for recreation accounted for 18% (only televisions are considered). Though no further information on consumption patterns of other income groups is available, it is reasonable to assume that wealthier urban households would use more electricity for recreation. In rural areas, electricity is used not only for daily life but also for production, such as in home workshops. The energy used for productive activities accounted for more than 50% of rural residential energy consumption over the past twenty years (NBS, 2011a; 2013a), mainly in the form of coal, electricity and diesel. Although exact figures for electricity used as productive input is not available, its proportion in energy consumption of rural families must logically be quite significant.

Because we will have to use data from 2009 for our econometric analysis in Section 4, the data cited in this section are for 2009 to make it easier to compare, unless otherwise stated. The change between 2009 and 2012 well illustrate the dramatic increase in electricity consumption in just three years. During this period, total electricity consumption of China increased from 3703 to 4976 TWh, a growth rate of over 10% per annum. The proportion of residential consumption in total electricity consumption has held steady at about 13%, which is much lower than that of industry (about 73%). Meanwhile, in the residential sector, electricity consumption per capita has grown from 365 to 459 kWh (or 8% growth per annum). [6]

In 2009, per capita residential electricity consumption in rural and urban areas was 296 kWh and 439 kWh, [7] respectively. As a share of residential end-use energy consumption, electricity accounts for 25.9%, just behind coal at 29.5%. In rural areas, coal is still the most popular source of energy because of its availability and convenience, in addition to the low penetration of petroleum products and gas. The share of coal in energy consumption for rural households is as much as 57.7%, compared to 11.2% in urban areas.

In some rural areas, a variety of non-commercial energy sources, such as straw, firewood, biogas and solar, are still popular, mainly for cooking. Generally speaking, as income levels of rural households rise, the share of non-commercial energy consumption decreases. Luo and Zhang (2008) argued that energy consumption per capita of rural households was actually much higher if non-commercial energy were to be included, and hence energy consumption of urban households would be only 39% of that of their rural counterparts, according to their estimation.

3. Methodology

Access to basic energy services is often regarded as a universal human right (Bradbrook and Gardam, 2006). Basic needs of households are described as "basically linked to the needs of 'living' at the most general level (Bravo et al., 1983). Parikh (1978) argue that household

[6] These are calculated by the authors, according to original data provided by NBS (2011b, 2014).
[7] These figures are calculated by authors and based on data from NBS (2011a, 2011b).

energy requirements include following basic necessities: the energy required for producing food, for cooking and lighting, and the energy for transporting food and fuels to the people. Though it is generally recognized that energy services are central for the provision of basic human needs, there is no consensus on the amount of energy to meet basic household needs, exactly what should be included nor its extent.

To be clear, energy access and energy poverty are related but distinct concepts and normally, access is just one of several elements of energy poverty or a precondition for measuring energy poverty. Bhattacharyya and Ohiare (2012) describe how since 1998 access to electricity in rural China has increased via an ambitious program to upgrade rural electricity networks, which helped to halve transportation losses (from 25% to 12%), all of which helped in harmonising electricity tariffs of rural and urban consumers.

Energy needs vary significantly among countries and regions, depending on a number of factors, such as cultural practices, climatic conditions, social customs, subjective wants, and so on. Common energy services needed by households include cooking, space heating or cooling, lighting, entertainment or education (e.g., computer), and the services provided by means of household appliances, telecommunications, and mechanical power. Basic needs may be interpreted objectively in terms of minimum specified quantities of goods and services, or subjectively as the satisfaction of consumer wants as perceived by consumers themselves (Streeten, 1984). It is generally agreed that basic energy needs is the minimum needed for subsistence (Parikh, 1978; Krugmann and Goldemberg, 1983; Goldemberg et al., 1985; Ravallion and Bidani, 1994).

The definition of basic energy needs usually has a strong correlation to how the needs are measured. Absent a universally accepted measure of basic energy needs, researchers interpret the required minimum level of energy needs in different ways. Similar disagreements over definitions and metrics can be found in the literature on energy poverty. An energy poverty line specifies a minimum level below which household can be considered "poor" in terms of energy services, and the energy quantity corresponding to the level is regarded as the "basic needs" (Ravallion and Bidani, 1994; Pachauri and Spreng, 2004). Consequently, the notion of basic energy needs in concept is equivalent to the energy poverty and a definition of basic energy needs can be derived from the measure of energy poverty.

Energy poverty is often considered synonymous with fuel poverty. According to Osbaldeston (1984), Isherwood and Hancock were among the first to define fuel poverty in 1978. They defined "households with high fuel expenditure as those spending more than twice the median on fuel, light and power". Boardman (1991) defined a fuel poor household as one "unable to obtain an adequate level of energy services, particularly warmth, for 10 percent of its income." Her idea was basically adopted in the 2001 UK Fuel Poverty Strategy (DEFRA and DTI, 2001). The term fuel poverty is usually used in Europe (especially in the UK and Ireland), as it is experienced in industrializing countries and focuses on the issues of affordability. In developing countries, energy poverty is concerned with lack of access to utilities such as heating and electricity, as well as broader aspects of cost (Liddell et al., 2011). Pollitt (2009) derided the term as one that "makes little economic sense" and unnecessarily distortionary when there is an effective system for wealth transfers, but is more sympathetic to the need for price intervention for poor consumers in developing countries where for "unresponsive or poorly developed welfare systems this may be not be an option".

Measuring energy poverty requires a definition of an energy poverty line, and as well, techniques to measure this line. Since the study by Boardman (1991), there have been various attempts to calculate the amount of basic energy needs and to define energy poverty. Early studies mostly aimed at estimating basic energy needs on the basis of subjective assessment of what constitute the basic needs. More recent studies have tried to derive an energy poverty line from a conventional income or expenditure poverty measure.

Broadly speaking, there are two ways to define the energy basic needs, namely a physical quantity approach (or engineering type calculation) and an expenditure method approach.

3.1. The physical quantity approach

If basic needs is defined according to the minimum amount of energy demand required for a basket of goods and services, then that is viewed as adopting a physical approach. The calculation, in addition to defining a set of basic needs at the household level, relies largely on a number of assumptions regarding the number and type of energy consuming appliances, their size, efficiency and utilization.

In defining the basic needs required at household level, Bravo et al. (1983) suggested that the following energy services be included, in order of importance: a) preparation and preservation of food and supply of water; b) space conditioning; c) personal cleanliness; and d) recreation and social communication. Using the physical quantity approach, Parikh (1978) estimated the energy required for subsistence-level activities in developing countries ranging from 0.3 to 0.4 tce per capita. Krugmann and Goldemberg (1983) and Bravo et al. (1983), provided estimates for the energy poverty line ranging from 0.29 tce per capita in hot urban areas to 1.79 tce in cold rural areas. Some studies have taken a fairly wide scope – for example, Nussbaumer et al. (2012) defined energy poverty according to a multidimensional index, which includes use of modern fuels for cooking, access to electricity/lighting, having a fridge, having a radio or television and having a telephone whether landline or mobile. Others argue for greater consideration of specific goods and services, for example, Sovacool et al. (2012).

Obviously, the principal disadvantage of any such method is the difficulty in pinning down what are the exact contents of the basket of goods and services, owing to the absence of universally accepted definition of basic needs (Pachauri and Spreng, 2004). Reaching an agreed definition may be even more problematic for the case of electricity than for energy more generally since there is little previous work describing a "right to electricity" in particular. Since any quantification of basic needs is contingent on context (norms, climatic conditions, etc.), there will be variation from region to region and country to country and the definition may even change over time. Energy poverty based on physical quantity analysis is therefore not invariant, indeed, the cutoff point for the energy poverty line is inevitably arbitrary and inconsistent (Barnes et al., 2011).

3.2. The expenditure based approach

Adopting an expenditure approach defines basic energy needs by one's financial ability to meet basic needs and accordingly, energy poverty is essentially a form of income poverty. There are two typical ways that expenditure is used to define energy poverty and measure basic needs: the expenditure method and the expenditure *share* method.

In the expenditure method, energy poverty is defined by the level of energy demanded by households who fall below a prescribed expenditure or income poverty threshold; hence, families that are poor in terms of income are also considered energy-poor. This method is fairly attractive since there is no need to measure how much and what kinds of energy are actually used by individual households; furthermore, income poverty is usually well-defined in most countries and regions (Barnes et al., 2011). One can then simply measure average energy demand for households at the income poverty line and equate that demand with the level of basic energy needs. The idea behind the method is quite clear, the resulting definition of basic need is precise, the data needed is readily available and the measurement technique is relatively simple. The disadvantage, of course, is that it assumes that energy poverty follows exactly the same pattern as expenditure or income poverty, thus the income poor are defined as energy poor regardless of access to energy supply, climatic conditions or societal norms. As Hills (2012) pointed out, income poverty and fuel poverty are not the same, although disentangling the two is by no means straightforward.

The expenditure share method examines the proportion of household income spent on energy. A household is classified as energy-poor if the share of its energy expenditure in income is greater than a specific percentage. The idea here is that households forced to spend a large proportion of their income on energy are deprived of other basic goods and services, and their welfare is therefore reduced. A common value used for the expenditure share threshold is 10% of available income (Boardman, 1991; Fankhauser and Tepic, 2007). According to Hills (2012), this particular threshold appears to "derive from an original calculation that in 1988 the median household spent 5 per cent of its net income on fuel and that twice this ratio might be taken as being unreasonable".

The expenditure share method captures the ability of a household to maintain its current energy expenditure over time without having to increase the share of its budget spent on energy. However, it does not take account of various dynamic effects including changing energy efficiency, price effects, and shifts in real income (Hatfield-Dodds and Denniss, 2008). With this method, many assumptions have to be made to generate the required outputs, and the final result is sensitive to those assumptions and the threshold chosen (Liddell et al., 2011). Similar to other approaches discussed above, to a large extent, it is arbitrary why a number such as 10 percent or any other preset expenditure ratio is selected. Apart from the question of defining the energy poverty line (as a proportion of expenditure), there are a number of possible ways to measure income and energy costs.

3.3. Energy demand-based approach

The physical quantity approach and the expenditure-based approach all tend to ignore important criteria and suffer from the similar defect of setting an arbitrary threshold to define energy poverty; hence, the level of basic energy needs obtained is also arbitrary.

The idea of a demand-based approach is that the role of energy use in household welfare should be assessed based on the demand for energy services and not energy expenditures alone. This method seeks to set a threshold at the point energy consumption begins to rise with increasing income. At or below the threshold point, households are consuming what is effectively a minimum level and can be considered energy poor (Liddell et al., 2011).

The "minimum end-use" (MEE) method, proposed by Barnes and his co-authors (Khandker et al., 2010; Barnes et al., 2011), is a specific demand-based method. The threshold is defined as the income decile where household energy consumption starts to respond to changes in income. This definition of energy poverty is similar in concept to the expenditure approach. However, it overcomes some of the drawbacks of other methods in terms of arbitrariness and inflexibility, since it does not specify a predefined figure as the threshold. Rather, the assessment of basic energy needs is based on the energy demand function, taking into account a range of important exogenous factors.

We use the MEE approach to determine the basic electricity demand of households in China and how it varies with changes in income, after controlling for a few exogenous factors. The premise for identifying a basic level of electricity needs is that there exists a threshold level of electricity that a household must consume in order to maintain a minimum level of welfare, which is independent of its income. More specifically, electricity consumption may be influenced by a variety of influences. These factors are likely to be quite different between urban and rural areas and between various regions. However, the relationship between electricity demand and income should be weak for a household that is merely meeting its basic electricity needs.

4. Empirical Analysis

4.1. Model specification

The electricity needed for subsistence varies with region, climate, lifestyle, culture, etc. In an attempt to determine an approximate range of the minimum electricity requirement of households, we investigate how household electricity demand varies with the change in income by estimating an electricity demand function as follows:

$$ln\mathrm{E}_{ij} = \beta_0 + \sum_l \beta_l \mathrm{X}_{ijl} + \sum_{k=2}^{10} \alpha_k \mathrm{Y}_{\mathrm{decile}_{ijk}} + \varepsilon_{ij} \quad (1)$$

In Eq.1, $\mathrm{E_{ij}}$, measured in kWh per capita, is the monthly electricity consumption of household i in district j. Assuming household wealth is a key determinant in identifying its electricity needs, we use nine dummy variables that categorize per capita income of households by income decile. $ln\mathrm{E}_{ij}$, the logarithm of electricity consumption, is regressed on the income dummies, $\mathrm{Y}_{\mathrm{decile}_{ijk}}$ (k=2,3…,10) , and a vector of control variables (X_{ij}) that represent the household and district characteristics. ε_{ij} is the unobserved random error, and β_0, β_l and α_K are the coefficients to be estimated.

The focus is on the impact of different levels of income on electricity consumption, which is captured by the parameter vector β_l. The indicator $\mathrm{Y}_{\mathrm{decile}}$ splits the sample into ten categories. Specifically, all observations are categorized by the quantiles of per capita income, using observed values of the income as category cut points. The income indicator is constructed using households' disposable cash income and lagged for one period.

An alternative measure for wealth might be to use household expenditure, which is more reflective of long-term income, however, an expenditure measure cannot properly account for the distribution of wealth across households when saving rates are high and unequally distributed (Démurger and Fournier, 2011). Given that insurance and credit markets in China are often absent or imperfect, most Chinese households have limited access to formal insurance mechanisms and consequently have to turn to savings, as reflected by high saving rates. Therefore in comparison with expenditure, income is a better indicator of household wealth.

Monetary income does not represent the true level of household wealth, particularly for rural households where self-consumption is common and important. Therefore, in addition to the income dummy variables based on cash income, we introduce household assets to control for the wealth effect on electricity demand. As a stock indicator, the advantage of assets variables is that it captures the characteristics of wealth accumulation and its different manifestations between rural households and urban ones.

While urban household assets can usually be well accounted for by non-productive assets, such as real estate, financial assets (e.g. deposits, stocks, and securities) and durable goods, the assets of rural households include both non-productive and productive assets (e.g. pasture, farmland and woodland). Further, unlike urban households, rural households in China are rarely involved in financial markets, and their accumulated wealth is reflected in real estate and agricultural machinery.

In what follows, we use different indicators for rural and urban areas to capture the wealth effect of household assets on its electricity needs. In particular, for urban households, an indicator of financial assets is introduced to control wealth effect; for rural households, an indicator of agricultural land ownership is used to reflect the impact of productive assets on electricity demand.

To control the influence of demographic characteristics, four demographic factors are introduced into the model: family size, age of the head of household, their level of education and their gender. With regard to family size, we expect that households with fewer members would consume more electricity per capita than larger families, due to the possible existence of scale economies. How age, education and gender might affect electricity consumption is less obvious and is therefore an empirical question to be explored.

Other household-level controls used in the model reflect living conditions, including the size of the household living area, the distance of the household to the nearest local commercial center and the frequency of electricity outages. Studies have shown that housing size is a key determinant of energy demand. For example, Liu and Yang (2010) found that in China's rural areas, as housing size declines, efficiency in resource use decreases and demand for resources increases. Accordingly, we expect that housing size be positively related to electricity consumption. Households with unreliable electricity service would be more likely to make use of other fuels so that the frequency of outage is expected to be negatively correlated to electricity consumption. As far as distance of the household to the nearest local commercial center, how it affects electricity consumption is not obvious, although one might expect that homes in remote rural areas would be more likely to make use of other fuels such as firewood or diesel for generators, because of the unreliable electricity service.

Part of the regional variation in electricity use by households might be explained by climatic differences owing to the need for space conditioning. Heating or cooling degree days would usually be considered a suitable indicator, but no appropriate data is available at the district level in China. Since climatic conditions are largely determined by geographical location,[8] , latitude at the district level is used as the proxy for climate conditions.

[8] The duration of sunlight in a day varies throughout the year, and basically depends upon latitude. In the same hemisphere, the higher the latitude, the shorter the day during winter. Thus, more artificial lighting might be needed at higher latitudes, which implies more electricity demand.

Energy prices can directly (or indirectly) affect electricity demand. Both electricity and gas prices are included in the model to capture the responsiveness of electricity demand to a change in price of itself and its substitutes. During the period this survey was conducted, the older fixed price scheme for electricity was still in effect.[9] As a result, there was limited intra-provincial variation in electricity price, which might produce collinearity in the data if region dummies are included in the model. Prices of residential gas, the main alternative energy fuel for household cooking, were set by the government; hence the gas price variable may have similar collinearity problem. In order to avoid any collinearity arising from simultaneously using energy prices and region dummies in the model, region dummies are excluded from the control variables.

4.2. Sample and Data

The advantage of survey data is that it better reflects the household characteristics and adds more details to our knowledge of residential consumption behavior. To date, empirical studies of residential electricity consumption in China using micro-level data are extremely rare. The dataset used here is built on a population sample of households representing the provinces of Beijing, Shanghai, and Guangdong. The survey was conducted by Peking University and funding by the China Family Panel Studies (CFPS) project. The survey data contain socioeconomic characteristics on various aspects of the households. The first survey was carried out in 2008, covering 2375 households, of which 1,940 were followed up the next year.

The full sample of 1,940 households cannot be used because some households did not report electricity usage. Keeping the households that are observed in both years and with

[9] With government' control, prices for residential electricity in each province have been fixed, largely uniform and adjusted rarely until 2012 when IBT reforms started nationwide (Liu et al., 2013). The nominal electricity price in 2009 for Beijing, Shanghai, and Guangdong was 0.488, 0.536, and 0.599 Yuan/ kWh, respectively.

non-missing electricity usage for 2009, the sample size is reduced to 1,748 households. To avoid endogeneity of explanatory variables that may give rise to estimation bias, notably those variables representing household wealth, we use observations lagged for one period (i.e., using 2008 data) to define income dummies and household assets. The dependent variable, electricity consumption, and other control variables are based on observations from 2009.

One major limitation of this survey data is that it was not designed especially for studying energy use. Except for the quantity of electricity consumed, other detailed information on energy services are not available from this survey, such as amount of energy used for cooking and transportation, expenditures on specific fuels, and the quality of energy services. However, since this is one of very few comprehensive household surveys and covers both rural and urban areas of the three regions, together with other available information sources, it is still possible to estimate with some accuracy the levels of basic electricity needs in rural and urban households.

Table 1 here

Descriptive statistics are reported in Table 1. In our sample of 1,748 households, monthly electricity consumption is 42.4 kWh per capita, which is higher than the national average of 30.5kWh at the time. This is because the three regions where the data were collected are among the most developed regions of China.[10] For rural households in the

[10] According to statistics by NBS (2011b), the average monthly electricity consumption in the residential sector across the three regions was 50 kWh per capita, implying there is a slight downward bias in our sample. This is likely the product of oversampling of rural population (roughly 30% for this sample) relative to its share in the overall population of the three regions. The share of rural population in Beijing and Shanghai provinces is slightly over 10%, and roughly one-third in Guangdong province, according to data from NBS (2013b).

sample, monthly electricity consumption per capita was 19.1 kWh, less than half of the 52.1 kWh in urban areas.

4.3. Estimation results of the controls

Of the 1,748 households in the sample, several households did not report their income or other key control variables, such as living area and the distance to the commercial center. Though using only complete observations certainly simplifies analysis, it leads to information loss in the incomplete observations. For the variables with missing values, we adopt Rubin's (1987) multiple-imputation (MI) technique to fill in the missing values with the predictive mean matching imputation method. [11]

Table 2 here

A complete list of independent variables can be found in Table 2, along with the parameter estimates and their associated test statistics. The upper half part of the table presents effects of the control variables on electricity needs. Correlation analysis is used for collinearity diagnostics. The correlation coefficients among independent variables are largely insignificant, while those significant coefficients only show weak correlations (the coefficient is smaller than 0.3), implying a low probability of multicollinearity. The results provide supports for the assumption there is no collinearity among the independent variables.

4.3.1. Family size and housing size

Family size and household living area significantly influence household electricity

[11] Instead of filling in a single value for each missing value, the MI procedure replaces each missing value with a set of plausible values that represent the uncertainty about the right value to impute. Hereafter, we use the multiply imputed data to do analysis with standard estimation procedure for complete data and combining the results from these analyses. Actually, no matter which complete-data analysis is used, the process of combining results from different data sets is essentially the same (Rubin, 1987).

demand in both rural and urban areas. Family size has a significant and negative impact on per capita electricity consumption, which is consistent with other studies, such as Zhou and Teng (2013). Holding aggregate household electricity use constant, on one hand, households with more members can afford less electricity per capita; on the other hand, economy of scale in electricity use could result in larger families consuming less electricity per capita. As expected, larger living area increases household electricity consumption.

4.3.2. Demographic factors

As far as demographic characteristics are concerned, of the three variables representing age, education level and gender of the household head, a significant relationship was found between the age of the head of household and electricity demand in rural areas, at a 10% level of significance, which implies that older people weakly tend to be more energy-saving. Gender and education were found to have significant influence on electricity demand in urban areas.

In urban areas, an increase of the education level of the head of household by one year results in a 0.035% increase in electricity consumption. This is partly because the education level of the head of household may affect the fuel choice of a family, and the choice is usually biased towards electricity. Démurger and Fournier (2011) suggested that increasing education is a key factor in energy consumption behavior, especially when dealing with energy source switching behavior. Several studies on energy transitions have found that a higher level of education is associated with households choosing to use more modern and efficient sources of energy (Luo and Zhang, 2008; Pachauri and Jiang, 2008). In the sample of this study, the average education level for heads of household in rural and urban areas is 6.8 and 9.0 years, respectively. Only 0.8% of the rural household heads had an undergraduate education or higher. By contrast, the proportion of urban heads of household with an undergraduate education or higher was 15.1%. The low level of education overall helps to explain the insignificance of its impact on consumption behavior of rural households.

It is striking that urban households with a female head of household would consume more electricity, as it is a common view that women are more frugal. For example, a study by the United Nations (2005) found that women in all age and income groups consumed less energy, while Barnes et al. (2011) and Khandker et al. (2010) respectively found that a male-headed household would tend to consume more energy or electricity. By contrast, all else being equal, our findings show a female-headed household has a small but statistically significant 0.155% increase in its electricity consumption. In a female-headed household, women may have more say over the fuels they use (e.g. they may prefer electricity over traditional fuels such as firewood, dung and agricultural wastes) and have more say over appliance purchases and utilization.

4.3.3. Distance to commercial center

By examining the distance from a household to its nearest commercial center, the impact of transportation convenience can be revealed. It is unsurprising that distance affects the electricity needs of rural households rather than urban households. Where an urban family lives may influence its travel pattern and thereby affect the demand for gasoline, but it may not affect the demand for electricity. For a rural family, greater distance to the commercial center implies easy access to the mountains and forests where rural households can collect firewood for cooking, thereby reducing the demand for electricity.

4.3.4. Latitude of district

The estimates of latitude are all significant and negative, regardless of rural and urban families, implying households locating at higher latitude consume less electricity. At higher latitudes, due to shorter days during winter and average lower temperatures, energy needs increase for heating, hot water and lighting whereas needs for cooling decrease. The net impact of variations in latitude on electricity consumption depends on which of these two opposite effects dominates: increased demand for heating/lighting and decreased demand for cooling.

Of the three regions, Beijing is located at the highest latitude with the longest winter and lowest annual mean temperature, while Guangdong is the southernmost location with the highest annual mean temperature. Shanghai and Guangzhou, both located south of the Yangtze River, experience long, hot summers and hence require more electricity for cooling, refrigeration and freezing purposes. Especially in Shanghai where it is cold and wet in the winter, electricity is extensively used for heating because there is no district heating network. Beijing experiences longer periods with lower temperatures and people have to heat their houses for up to half a year, hence requiring more energy for heating. However, higher heating demand in Beijing does not necessarily translate into electricity demand, because its urban areas are extensively covered by heating networks while in its rural areas, using of stoves burning coal or wood still prevail. All of above factors lead to lower electricity demand for heating in Beijing, compared to the other two regions.

4.3.5. Energy prices

The coefficients of the price variables indicate that gas and electricity prices negatively and significantly impact electricity consumption of the households; and furthermore, rural residents are more sensitive to price changes than urban residents. Holding constant all other determinants of demand, a 1% increase in the price of electricity results in a 3.59% decrease in electricity demand by rural residents, and a 2.91% decrease by urban residents. This provides the evidence that raising prices of electricity may be more detrimental to rural families. A 1% increase in the price of gas results in a 1.36% decrease in the electricity demand by urban households, and a 2.03% decrease by rural households. Negative sign of the coefficients of gas price imply there is no substitution between the consumptions of gas and electricity.

4.4. Basic electricity needs

The key hypothesis is that if there is a minimum amount of electricity consumption that a household needs for basic welfare, then electricity consumption up to that level would be unresponsive to changes in household income. Thus, the basic electricity needs is determined by the cut-off point after which electricity consumption starts to be sensitive to income changes. The estimated coefficients of income dummies are reported in the lower half part of Table 2.

The main findings on the relationship between income and electricity demand are described as follows. Firstly, electricity consumption at higher income deciles responds positively and significantly to changes in income, while electricity consumption at lower income deciles does not. Secondly, at the same income decile, rural electricity demand is less sensitive to income than urban demand. For example, at the 8^{th} income decile, the elasticity of electricity demand with respect to income for urban households is 0.408 whereas for rural households it is only 0.272. Thirdly, high-income families are *generally* more sensitive than low-income families to income changes.

The energy "saturation" hypothesis (Galli, 1998; Medlock and Soligo, 2001) states that the elasticity of energy demand with respect to income would decline as a country moves beyond a certain phase of development as supported by several empirical studies. Accordingly, there might be a theoretical saturation point, after which household energy needs would not increase further proportionate with rising income. Our findings provide little evidence of the hypothesis. In other words, for the case of China's electricity consumption, the saturation point is still far from having been reached.

On average, the cut-off point for rural and urban households appears at the 7th and 5th income deciles, respectively. More precisely, the household electricity demand in rural areas does not respond to income changes until after the 7th income decile and urban household demand for electricity does not respond to income changes until after the 5th income decile. For rural (urban) families, electricity consumption at the 7^{th} (5^{th}) income decile can be considered the threshold for basic needs or a measure of electricity poverty.

Table 3 here

Table 3 presents the average electricity consumption of rural and urban households by income decile. On average, the threshold for the basic needs level for electricity consumption is 22.8 kWh per capita per month in rural areas, and 47.7 kWh in urban areas, although there is still notable variation beyond the threshold.

It may seem surprising that electricity demand for a rural family is still much lower even when its per capita income is roughly equal to that of an urban family, but consider the differences in the energy mix between rural and urban households. Household energy consumption pattern changes dramatically from village to city. In urban areas, electricity is the main energy source for households. Using electricity for heating in winter and cooling in summer is far more common than in rural areas. Urban households have more electrical appliances than rural households in terms of both quantity and variety, and electricity use for entertainment and household appliances is greater in urban areas. By contrast, in rural areas, many households still consume traditional biomass resources collected from forests and farmland for cooking, such as straw and fuel wood. Rural households mainly use electricity for lighting and some appliances like televisions, and the share of electricity used for lighting is larger in rural districts.

Energy transition theory suggests that there is a ladder of fuel preferences from low-quality biomass-based fuels to more efficient and versatile modern fuels (Leach, 1992; Masera et al., 2000). The theory predicts that energy forms used in rural households are less convenient and less efficient than those used in urban areas. Although detailed information about energy type consumed by the sampled households is not available from this survey, there is some evidence supporting the existence of fuel preferences, which can be observed by examining the fuels used for cooking in the sampled households. In our sample, 56.4% of rural households use firewood for cooking, 21% use gas, and 16.5% use electricity. By comparison, 83.3% of urban households use gas for cooking and 9.3% use electricity.

Although coal use by households has declined in absolute terms, it remains an important source of heating energy in many provinces, especially in rural northern China. Beijing is an extreme example – the average coal consumption of rural households is 567 kg, almost 16 times that of urban households in the province, which leads to its rural households having a higher primary energy consumption than urban households (BBS, 2010). Pachauri and Jiang (2008) also found that in China, primary energy consumption of rural households per capita exceeds that of urban households as a consequence of their continued dependence on inefficient solid fuels, even though urban households consume a larger share of electricity and fossil-based energy sources.

5. Conclusions

Any definition of basic energy needs is inevitably arbitrary in some sense, so no technique can unambiguously identify an "optimal" measure for basic electricity needs, which is an even more subjective concept. The method defining basic electricity needs used in our analysis at least does not specify any preset figure as the dividing line nor use an arbitrary share of income or expenditure to define it; rather, basic electricity needs is defined based on the concept of "energy poverty" and estimated from the electricity demand function. Our identification strategy is based on actual household demand for electricity, after controlling for various exogenous factors that may influence the electricity demand of a household and therefore provides a region-specific measure. We conclude from the empirical results as follows:

Firstly, household electricity consumption would become income-sensitive at higher income levels, controlling for characteristics of the household and district and other exogenous factors. Some household-related factors do significantly affect electricity consumption. For example, electricity consumption per capita tends to be higher if the household lives at lower latitudes, has a larger living area, has a smaller number of family members, or uses electricity as an input in the production of family workshop.

Secondly, there exists a minimum level of electricity consumption that a household requires to satisfy some measure of basic needs and where electricity consumption up to that level is unresponsive to changes in household income. Until a household crosses the threshold, even if there is a decrease in household income, its electricity demand would not necessarily decrease, although its expenditure on electricity may increase significantly relative to its income.

Finally, the basic electricity needs of rural households are less than that of urban households, and biomass and coal still play an important role in rural areas. In the case of China's electricity consumption, the theoretical saturation point that household electricity needs would not further rise proportionately to income increase remains far from having been reached.

Though our study quantifies basic electricity needs for rural and urban households, setting any IBT block level will still subject to further discussion given its political sensitivity. There may be interest, for example, in differentiating our results by province since ultimately setting of blocks and tariffs is a provincial matter and there is a notable effect that latitude (heating and cooling degree days) has on the outcome.

The existence of an income threshold implies that the burden imposed by electricity expenditures could be high for low-income families if the electricity price rises. The concern is particularly salient in rural areas, as rural families are found to be more sensitive to changes in electricity price. Given the increasing price structure of the IBTs in China, it is critical to select the volume and price of the first block in an IBT scheme so as to mitigate the burden of expenditure on electricity for low-income families and thereby ensure access to basic energy services by explicitly targeting low-income families.

A major challenge in setting the level and rate of the first IBT block is that it can become politicized. Boland and Whittington (1998) examine the history of IBT use in the water sector (over half of water utilities in Asia were using some forms of IBT by the 1990s). They argue that the main difficulty is not a theoretical issue, but one of implementation, namely that "water utilities find it difficult to limit the size of the initial block for residential users due to political and other pressures". As a result, the majority set the initial block at a level far higher than 'basic needs' (i.e., of 17 water utilities surveyed by the Asian Development Bank, only two set the first block at a level roughly that of the "basic needs" level of 4-5 cubic meters per month per household and the majority set the level at 15 cubic meters or higher).

Under the newly instituted IBT, Beijing households were able to keep the pre-existing rate for monthly usage of up to 240 kWh, pay roughly 10% more between 241 - 400 kWh, followed by a substantial increase in rates of 60% for usage above 400 kWh. The schemes for other provinces are broadly similar with some relatively minor variation. Assuming an average of roughly 3 residents per urban household and 4 per rural household, we estimate basic needs to be only 90 kWh per month for rural households and roughly 150 kWh for urban households. Thus, the first IBT block appears to have been set at a level that is too high, roughly equivalent to the average consumption of the *top* decile of urban residents. The danger of such an approach is that, when introduced, only a very small percentage of residents will have needed to pay the highest rate and almost all residents would have fallen within the lowest block, which includes both those just barely able to meet their basic needs and those consuming at a significantly higher level. Therefore, the initial policy targets that motivated the introduction of the IBT, such as stimulating energy-saving behavior and subsidizing basic energy services for targeted consumers, will be difficult to achieve. The more positive interpretation though is that, from a political economy perspective, such a tariff would have been relatively easy to introduce given the situation in 2012, but, given the likelihood of continued increases in household residential consumption, over time fewer households will fall into the first block and more will be subject to the highest rate. Therefore such an approach may produce a more sustainable tariff structure that will become increasingly more effective over time.

There is, of course, much more work that must be done in this area. Our results are based on the results of a survey that was not intended primarily for studying energy consumption and so there would be significant benefit of being able to design and implement a survey with energy in mind.

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Table 1. Summary statistics of variables used in the study

	obs.	Mean	Std. Dev.	Min	Max	Std. Err.	95% Conf. Interval	
Rural (514 households)								
Household monthly electricity use (kWh per capita)	514	19.08	16.87	1	125	0.74	17.62	20.54
Family size (members)	514	4.01	1.66	1	11	0.07	3.86	4.15
Household living area (m^2)	501	107.89	77.24	10	600	3.45	101.11	114.67
Age of head of household (HH) (year)	514	53.01	11.41	15	94	0.50	52.02	54.00
Gender of HH (1=female, 0=male) [a]	514	0.19	0.39	0	1	0.02	0.16	0.22
Education of HH (year)	514	6.77	2.56	3	15	0.11	6.55	7.00
Household distance to the nearest commercial center (minutes) [b]	513	24.57	21.33	0	300	0.94	22.72	26.42
Household has frequent electricity outages (1 = Yes, 0 = No) [a]	514	0.03	0.18	0	1	0.01	0.02	0.05
Latitude of district	514	30.76	7.83	22	40	0.35	30.08	31.44
Household uses electricity for production (1 = Yes, 0 = No) [a]	514	0.08	0.27	0	1	0.01	0.05	0.10
Rural household agricultural land (mu) [c]	514	8.25	36.25	0	800	1.60	5.10	11.39
Household disposable income (yuan per year)	503	7825	40708	20	900000	1815	4259	11391
Urban (1234 households)								
Household monthly electricity use (kWh per capita)	1234	52.12	50.04	1	700	1.42	49.33	54.92
Family size (members)	1234	3.23	1.44	1	15	0.04	3.15	3.31
Household living area (m^2)	1215	90.65	76.10	5	1103	2.18	86.36	94.93
Age of head of household (HH) (year)	1233	53.54	13.60	0	95	0.39	52.78	54.30
Gender of HH (1=female, 0=male) [a]	1234	0.47	0.50	0	1	0.01	0.44	0.50
Education of HH (year)	1234	9.04	3.37	1	18	0.10	8.85	9.23
Household distance to the nearest commercial center (minutes) [b]	1222	17.42	16.30	0	240	0.47	16.50	18.33
Household has frequent electricity outages (1 = Yes, 0 = No) [a]	1234	0.01	0.11	0	1	0.00	0.01	0.02
Latitude of district	1234	32.12	6.78	22	40	0.19	31.74	32.50
Household uses electricity for production (1 = Yes, 0 = No) [a]	1234	0.03	0.17	0	1	0.00	0.02	0.04
Urban household stocks, bonds and deposits (10^4 yuan)	1234	20.33	83.20	0	2000	2.37	15.68	24.98
Household disposable income per capita per year (yuan)	1133	16785	33868	20	538000	1006	14810	18759

Notes: All figures, unless otherwise stated, are from CFPS. Total sample size was 1,940 households. Two rounds of fieldwork were undertaken in 2008 and 2009, respectively. Keeping the households that are observed in both years and with non-missing electricity usage for 2009, the sample size of this analysis is reduced to 1,748 households.

[a] Dummy variables represent the household has a female head, has frequent electricity outages, and uses electricity for productive activities. These dummies are equal to 1 for the households who have the corresponding backgrounds and 0 otherwise.

[b] This indicator means the travel time by whatever mode is used most commonly by the individual household.

[c] The "mu" is a Chinese unit of area, and 1 hectare = 15 mu.

Table 2. Estimates of household's electricity demand [a]

Variable	Rural Coef.	Rural t-statistic	Urban Coef.	Urban t-statistic
Constant	5.1720***	2.88	5.1452 ***	6.63
Family size	-0.1427***	-6.87	-0.1778 ***	-11.95
Log of household living area	0.1464***	2.67	0.1788 ***	6.08
Age of head of household	-0.0053*	-1.85	-0.0001	-0.60
Gender of head of household (1=female, 0=male)	0.0630	0.83	0.1546 ***	3.77
Education of head of household	0.0133	1.00	0.0345 ***	5.35
Distance to local commercial center	-0.0042***	-2.68	0.0000	-0.01
Household has frequent electricity outages (1 = Yes,0 = No)	-0.1554	-0.92	-0.0648	-0.37
Latitude of district	-0.0825**	-2.40	-0.0848 ***	-5.41
Area of household agricultural land	0.0003	0.42		
Stocks, bonds and deposits of household			0.0000	-0.08
Household uses electricity for production (1 = Yes, 0 = No)	0.4845***	4.37	0.3240 ***	2.74
Log price of electricity	-3.5902***	-4.10	-2.9125 ***	-7.48
Log price of gas	-2.0307**	-2.19	-1.3587 ***	-3.20
Household income by decile [b]				
2	-0.0283	-0.20	0.0075	0.07
3	-0.0497	-0.37	0.0394	0.39
4	-0.0135	-0.10	0.1448	1.37
5	-0.0572	-0.45	0.3324 ***	3.41
6	0.1410	1.04	0.2529 **	2.55
7	0.3353 **	2.48	0.3812 ***	3.79
8	0.2716 **	2.02	0.4063 ***	4.20
9	0.2896 **	1.98	0.3930 ***	4.00
10	0.3890 **	2.88	0.4625 ***	4.47

*, ** and *** represent significance level of 0.10, 0.05 and 0.01, respectively. F = 20.29 (rural regression), F = 19.35 (urban regression). During the process of research, we proposed some other potential controls besides the variables shown in Table 1, and tried alternative specifications with those controls. We conducted collinearity diagnostics by using correlation analysis to select appropriate controls, and accordingly, excluded from the regressions the variables that may cause multicollinearity. Because a number of independent variables are dummies, we use Spearman Rank Correlation coefficients to test the correlations among variables. The independent variables presented in Table 1 and results in Table 2 have been verified by collinearity diagnostics. Test results show that in the remaining independent variables (that appear in Table 2) there is only weak correlation among education and income, at a 0.10 significance level.

[a] The model is estimated with maximum likelihood optimization, the results are multiple-imputation estimates, with the number of imputations equal to 30.

[b] These Dummy variables categorize per capita income of households by income decile. The reference is decile 1, representing the poorest 10% of households. The dummy is equal to 1 for the households categorized as group *i* (*i*=2, 3, …, 10), and 0 otherwise.

Table 3. Electricity consumption by income decile

Income decile	Rural			Urban		
	Electricity per capita (kWh)	Income per capita (yuan)	Family size (person)	Electricity per capita (kWh)	Income per capita (yuan)	Family size (person)
1	10.6	366	4.0	38.3	624	3.0
2	11.4	1068	3.6	40.2	2562	3.1
3	10.1	2108	4.6	37.7	4430	3.4
4	12.7	2849	3.9	44.8	6103	3.3
5	12.8	3669	4.2	47.7	8228	3.1
6	15.9	4764	4.6	47.8	10994	3.0
7	22.8	6038	4.4	54.0	13729	2.9
8	20.3	7884	4.6	64.9	17273	2.8
9	24.3	10831	4.0	61.3	23262	2.9
10	27.1	34967	4.1	87.6	72943	2.4

Note: The electricity per capita by income decile presented in the table is authors' calculation, based on data of the sample.