Household energy demand in Urban China: Accounting for regional prices and rapid income change

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ABSTRACT

Understanding the rapidly rising demand for energy in China is essential to efforts to reduce the country's energy use and environmental damage. In response to rising incomes and changing prices and demographics, household use of various fuels, electricity and gasoline has changed dramatically in China. We estimate income and price elasticities for different energy types using two-stage budgeting and applying an AIDS model to Chinese urban household microdata. We find that total energy is price and income inelastic for all income groups after accounting for demographic and regional effects. For specific energy types, price elasticities range from -0.55 to -0.96. Demand for coal is most price and income elastic among the poor, whereas gasoline demand is elastic for the rich. Gas and electricity demand are inelastic.

Key Words: household energy demand, China, two-stage budgeting, LES-AIDS model

JEL Classifications: D12, Q41

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1. INTRODUCTION

Due to its rapid urbanization and economic growth, China's energy consumption is rising at one of the fastest rates in the world – at nearly 8% per year over the 2000–2011 period – and residential energy consumption has grown even more rapidly. Specifically, household electricity and natural gas use rose at annual rates of 12.5% and 19.4%, respectively, over the last decade[1]. Although household energy consumption per capita remains low compared with developed countries, it is rapidly closing that gap. For instance, total energy use for cooking and heating has more than doubled during this period, from 123 kilograms standard coal equivalent (SCE) in 2000 to 278 kilograms in 2011[2]. Household gasoline consumption increased at an annual rate of 17% during the 2000–2010 period due to rapidly increasing motor vehicle use[3]. The International Energy Agency (IEA 2011) projects that China will dramatically increase its share of global oil consumption, and Chinese household energy consumption patterns are converging on those of the western world. These changes will have a significant impact on China's total energy consumption, which, in turn, will have important implications for urban air quality.

Air pollution from past energy use has already led to serious damage. Utilizing conservative assumptions, the World Bank and SEPA (2007) has estimated that the health damage caused by air pollution alone amounted to 1.16% of GDP in 2003, in addition to another 0.26% worth of damage to agriculture and buildings. Higher numbers of household-owned vehicles are clearly a source of higher NOx emissions, even as reduced coal use by households has contributed to reduced levels of certain pollutants, such as particulate matter (PM). Nevertheless, most northern cities continue to rely heavily on coal for heating, which has maintained high PM levels. Current and projected levels of PM and ozone pose a severe public health challenge. Successful strategies to reduce pollution from household energy use require a solid understanding of the factors that drive residential energy demand, i.e., how households respond to changes in income, prices, technology and urban structure, given that demographic profiles are also changing.

[1] Table 8.13 in NBS 2013.

[2] Op. cit.

[3] Table 4.8 in China Energy Statistical Yearbook 2013.

Nonetheless, given the importance of this topic, research on urban household energy consumption using Chinese microdata are surprisingly scarce. Most recent studies of Chinese household energy consumption have concentrated on modeling aggregate demand because individual household data are generally unavailable (Shonali Pachauri and Leiwen Jiang, 2008; Li et al., 2011; Zhen et al., 2011). Because preferences for energy differ based on household characteristics, including age, employment status, household size, and stock of durables, energy consumption behavior is not estimated particularly well with aggregate data (Baker and Blundell, 1991).

Another group of papers on Chinese household energy demand has studied the demand for particular types of energy use based on household data using single equation models (Xu, 2012; Zheng et al., 2011; Murata et al., 2008). Such models impose strong separability restrictions and are thus unable to estimate the cross-price effects between different energy commodities (Labandeira et al., 2006). Current empirical research on Chinese household energy demand thus does not allow for accurate and comprehensive prediction of consumer responses to government policies.

One of the more sophisticated methods of modeling household energy demand consists of multiple equation systems that include all energy types and also allow for individual households to have different energy consumption patterns based on birth and education cohort, employment status, household size, stock of durables, etc. The availability of a long time-series of household data enables us to recover more precise price and income responses that take into account differences in demographic characteristics, housing, and the stock of durables. Jorgenson, Slesnick and Stoker (1988) estimated residential energy demand for electricity, natural gas, fuel oil, and gasoline at the household level, while Baker, Blundell, and Micklewright (1989) and Baker and Blundell (1991) estimated household energy demand for electricity, gas, and other energy sources that accounted for cross-price effects. More recent papers, such as Labandeira and Labeaga (1999), Tiezzi (2005), Labandeira et al. (2006), and Gundimeda and Köhlin (2008), have also estimated household demand for different types of energy using multiple equation modeling.

The main objective of this paper is to fill a gap in the literature and provide a better estimate of the income and price elasticities of household demand for various types of energy in urban China, while accounting for the vast differences in regional prices and incomes using microdata. It is well established that household demand for energy services conditional on appliance and housing stocks (McFadden et al., 1977; Hausman et al., 1979). Dennerlein and Flaig (1987), Baker and Blundell (1991), Zweifel et al. (1997), Alberini et al. (2011), and Fell et al. (2012) introduce appliance dummies to control for the effects of durables on energy consumption, whereas Garbacz (1984) and Tiwari (2000) define an appliance index as the durable stock for such conditional energy demands. Dwelling characteristics also lead to heterogeneity in consumption responses with respect to price and income (Baker and Blundell, 1991; Reiss and White, 2005; Labandeira et al., 2006). Our household data allow us to consider conditional demand in greater detail than previous research on Chinese household energy demand. In particular, the detailed information on the stock of each type of household appliance and housing characteristics enables us to estimate conditional responses to price and income.

It is essential to have accurate measurements of household incomes and prices to estimate elasticities. The quality and coverage of the consumption data in China have been widely discussed and debated, including the lack of estimates for owner-occupied housing (e.g., Benjamin, Brandt, Giles and Wang 2008). A secondary objective of this paper is to develop a more complete measure of housing expenditures (and related imputed incomes) and prices.

We use a two-stage budgeting approach in which total expenditures are allocated to energy and nonenergy consumption in the first stage. We must thus construct prices for the energy and nonenergy bundles. Because prices vary substantially across provinces in China, we must take local prices into account. Thus, following Brandt and Holz (2006), we construct energy and nonenergy price indices for each province in our sample, in addition to the values of the provincial energy and nonenergy baskets in the base year. We are able to estimate price and income elasticities more precisely with such wide spatial price differences.

Past research has indicated that energy preferences shift with household income (West and Williams, 2004; Gundimeda and Köhlin, 2008) and with the gender of the head of the household (Somani, 2013), the education and birth cohort of the head of the household, the employment status and age of the head of the household (Baker and Blundell, 1991; Labandeira et al., 2006), and the age of children (Labandeira et al., 2006). To control for this observable heterogeneity, we divide households into three groups based on expenditure levels (low, middle and high income), and we include dummies for the gender, education level, birth cohort and employment status of the head of the household, in addition to age-group dummies for children.

We thus collect detailed data on expenditures, household demographics, dwelling characteristics, and household appliances. Our household data set – the China Urban Household Survey (CUHS) – was collected by the National Bureau of Statistics (NBS) over the 2002–2009 period and included nearly 15,000 households each year. The CUHS data use a stratified multistage method to select samples and are used by the NBS to compute both the CPI and the consumption component in the National Accounts. The CUHS records information regarding energy consumption at the household level in great detail.

The remainder of this paper is structured as follows. Section 2 begins with the two-stage budgeting model of household energy demand, specifying all the household characteristics discussed above. In section 3, we describe the data, the construction of the spatial price indices, the appliance stocks, and imputation of owner-occupied housing, and we also describe the household demographic characteristics we utilize. In section 4, we present the empirical results, and we conclude the paper in section 5 by summarizing our main findings and the corresponding policy implications.

2. MODEL OF CONSUMER BEHAVIOR

2.1 Two-stage budgeting

The two-stage budgeting approach dates to Gorman (1959, 1971), and Jorgenson and Slesnick (1988) and Baker, Blundell and Mickelwright (1989) are some of the earlier papers to apply the method to household energy demand. In recent applications, households are assumed to behave as individual consuming units and to allocate their expenditures in two stages to maximize a utility function, which is conditional on the stock of durables and on leisure choices. In the first stage, total expenditures are allocated to a basket of energy commodities and other goods. In the second stage, total energy expenditures are allocated to different types of energy. Gundimeda and Köhlin (2008) represents a more recent application of two-stage budgeting using Indian microdata[4]. We follow this literature by allowing households to allocate total nondurable expenditures between a basket of energy commodities and a basket of nonenergy commodities in the first stage, and total energy expenditures are allocated in the second stage to four types of commercial energy, i.e., coal, gas, electricity and gasoline.

2.1.1 First-stage allocation

In the first stage, we allocate total expenditures to an energy bundle and a nonenergy bundle using a linear expenditure system (Fan, Wailes and Cramer, 1995 and Labandeira et al., 2006) in which the value of the demand of household *k* in province *pro* in period *t* for bundle *I* is the following:

$$p_{I,pro,t}q_{Ikt} = \gamma_I p_{I,pro,t} + \beta_I (y_{kt} - \sum_J \gamma_J p_{J,pro,t}) \quad I, J = \{energy, non-energy\} \qquad (1)$$

$p_{J,pro,t}q_{Jkt}$ represents the expenditures allocated to bundle *J*, $p_{I,pro,t}$ is the price index of *I*, y_{kt} represents total household expenditures and γ_J is the minimum required quantity of *J*, which may be interpreted as the subsistence consumption. Households then allocate the remaining non-subsistence expenditures $y_{kt} - \sum_J \gamma_J p_{J,pro,t}$ (the supernumerary expenditures) between energy and nonenergy commodities in fixed proportions β_I, where $\sum \beta_I = 1$. Hence, apart from the subsistence expenditures, total consumption is divided into fixed shares between energy and nonenergy commodities in the first stage.

2.1.2 Second-stage allocation

In the second stage, households' energy expenditures (y_{ekt}) were allocated to four types of energy, i.e., electricity, gas, coal, and gasoline[5]. "Gas" is the aggregate of coal gas, natural gas, piped petroleum gas and LPG in tanks. "Gasoline" includes both gasoline and diesel. Let y_{ekt} denote the total energy expenditures of household *k*, and the share of the i^{th} type of energy in y_{ekt} is:

[4] In Gundimeda and Köhlin (2008), the first stage contains the share of energy in total expenditures as a function of demographic characteristics and total expenditures. In the second stage, they estimate an AIDS model for wood, kerosene, LPG and electricity. Fan, Wailes and Cramer (1995) use a linear expenditure system for first-stage and an AIDS model for second-stage demand for individual food items.

[5] Most apartments in north China have central heating, and a fixed fee is charged based on the size of the house. We do not estimate the demand for heating, and we aggregate these fees with the nonenergy expenditures (following Labandeira et al. 2006). We include central heating as a dummy variable.

$$w_{ikt} = p_{ikt} x_{ikt} / y_{ekt} \qquad k = 1, \cdots, K \; ;$$

i = electricity, gas, coal, gasoline

where p_{ikt} is the price of the i^{th} type of energy that household k faces in period t, and x_{ikt} represents expenditures on the i^{th} type of energy used by household k in period t.

We assume that the k^{th} household allocates this energy expenditure according to an AIDS expenditure (i.e., cost) function:

$$\log C_{kt}(P_{kt}, u_{kt}) = (1 - u_{kt}) \log[a(P_{kt})] + u_{kt} \log[b(P_{kt})] \qquad (2)$$

where u_{kt} is the utility of household k in period t, P_{kt} is a vector of the individual energy prices that household k faces in period t, and $a(P_{kt})$ and $b(P_{kt})$ are defined as follows:

$$\log a(P_{kt}) = \alpha_0 + \sum_i \alpha_i \log p_{ikt} + \frac{1}{2} \sum_i \sum_j \gamma_{ij} \log p_{ikt} \log p_{jkt} \qquad (3)$$

$$\log b(P_{kt}) = \log a(P_{kt}) + \beta_0 \prod_i p_{ikt}{}^{\beta_i} \qquad (4)$$

$$i, j = \text{electricity,coal, gas,gasoline}; \quad k = 1, \cdots, K$$

Thus, the expenditure function is written out in full as the following:

$$\log C_{kt}(P_{kt}, u_{kt}) = \alpha_0 + \sum_i \alpha_i \log p_{ikt} + \frac{1}{2} \sum_i \sum_j \gamma_{ij} \log p_{ikt} \log p_{jkt} + u_{kt} \beta_0 \prod_i p_{ikt}{}^{\beta_i} \qquad (5)$$

where the coefficients α_i are allowed to differ by demographic characteristics. We assume $\alpha_i = \omega_{i0} + \sum_l \omega_{il} d_{lkt}$, where the dummy variable d_{lkt} represents the l^{th} characteristic, and ω_{i0} and ω_{il} are parameters to be estimated.

The expenditure shares of the k^{th} household are derived using Shephard's Lemma:

$$w_{ikt} = \omega_{i0} + \sum_l \omega_{il} d_{lkt} + \sum_j \gamma_{ij} \log p_{jkt} + \beta_i \log \frac{y_{ekt}}{P_{kt}} \qquad (6)$$

where $\omega_{il}, \gamma_{ij}, \beta_i$ are parameters, and y_{ekt} represents total energy expenditures[6]. The household price index P_{kt} is defined as:

[6] As discussed in Baker et al. (1989), symmetry and homogeneity restrictions must be imposed on the parameters. These are the following: $\sum_i \alpha_i = 1, \sum_i \beta_i = 0, \; \gamma_{ij} = \gamma_{ji}, \sum_j \gamma_{ij} = 0, \sum_i \omega_{i0} = 1, \sum_i \omega_{ik} = 0$

$$\log P_{kt} = \alpha_0 + \sum_i \alpha_i \log p_{ikt} + \frac{1}{2}\sum_i \sum_j \gamma_{ij} \log p_{ikt} \log p_{jkt} \qquad (7)$$

To begin the estimating procedure for (6), an initial value is required for the household price, P_{kt}, because (7) depends on the unknown parameters, and we follow Deaton and Muellbauer (1980) in using the linear price index developed by Stone (1954), defined by:

$$\log P_{kt} = \sum_i \bar{w}_{it} \log p_{ikt} \qquad (8)$$

where $\bar{w}_{it}$ represents the expenditure shares averaged over the entire sample.

Thus, in the first step, we use (8) to estimate the parameters in (6) using the seemingly unrelated regression (SUR) technique with homogeneity and symmetry restrictions imposed. Next, we compute a new price index for P_{kt} using the estimated parameters and (7). Then, the demand system (6) is re-estimated using the new price index. The procedure is repeated until the parameters converge.

2.2 Estimation method

In the first stage allocation, the linear expenditure system is estimated using nonlinear least squares. We have just described the iterative SUR procedure for the second stage. There is a complication, however, because few middle- and high-income households consume coal, and very few low-income households use gasoline. To avoid problems related to minimal shares, we assume that low-income households consume only electricity, coal and gas. Similarly, we assume that middle- and high-income households consume only electricity, gas and gasoline.

Even using these smaller sets of energy preferences, some households have zero expenditures on certain energy types. In other words, there are two decisions for each household: whether to consume a particular energy type and how much of it to consume. To correct for selection bias, we first estimate a probit function for choosing energy *i*:

$$P(x_{ikt} > 0 \mid p_{1kt}, \cdots, p_{4kt}, y_{kt}, d^*_{1kt}, \cdots, d^*_{mkt}) = \Phi(x_{kt} \cdot \upsilon) \qquad (9)$$

where Φ is the cumulative distribution function (CDF) of the standard normal distribution, and the selection function depends on prices, total energy expenditures and demographic characteristics.

From the probit regression, we obtain the inverse Mills ratio for type i energy, $\hat{\lambda}_{ikt} \equiv \lambda(x_{ikt} \cdot \hat{\upsilon})$, where ϕ is the normal density function and

$$\lambda_{ikt}(\cdot) \equiv \frac{\phi_{ikt}(\cdot)}{\Phi_{ikt}(\cdot)}.$$

When household k decides to consume energy type i, it will also determine how much to spend on it. To correct for sample selectivity, following Heien and Wessells (1990), many studies add $\hat{\lambda}_{ikt}$ to the second step and estimate the following:

$$w_{ikt} = \omega_{i0} + \sum_{l} \omega_{il} d_{lkt} + \sum_{j} \gamma_{ij} \log p_{jkt} + \beta_i \log \frac{y_{ekt}}{P_{kt}} + \xi_i \hat{\lambda}_{ikt} + \varepsilon_{ikt} \qquad (10)$$

Estimating (10) using the entire sample, however, is biased when there is a large number of censored observations, as noted by Shonkwiler and Yen (1999) (and also discussed in the Appendix of West and Williams, 2004). OLS regressions that use only the positive shares are also inconsistent. To avoid this inconsistency, we use the equation introduced by Shonkwiler and Yen (1999) for censored seemingly unrelated regressions (see also Yen et al. (2002) and Akbay et al. (2007)):

$$w_{ikt} = \hat{\Phi}_{ikt} \cdot (\omega_{i0} + \sum_{l} \omega_{il} d_{lkt} + \sum_{j} \gamma_{ij} \log p_{jkt} + \beta_i \log \frac{y_{ekt}}{P_{kt}}) + \xi_i \hat{\varphi}_{ikt} + u_{ikt} \qquad (11)$$

where Φ_{ikt} is the normal CDF of household k for individual energy i, and φ_{ikt} is the normal density function. Because the maximum likelihood (ML) probit estimators are consistent, using SUR estimation for equation (11) produces consistent estimates in the second stage.

The formulas for the elasticities are given by Blanciforti, Green, and King (1986), Yen et al. (2002), Yen et al. (2004) and Akbay et al. (2007)[7].

3. DATA

3.1 Data sources and issues

[7] The conditional (on the 1st stage) price elasticities are as follows:

$$\eta_{ij,I} = \hat{\Phi}_{ikt} \cdot (\frac{\gamma_{ij,I}}{E(w_{i,I})} - \beta_{i,I} \frac{\alpha_{i,I}}{E(w_{i,I})} - \frac{\beta_{i,I}}{E(w_{i,I})} \sum_{j,I} \gamma_{ij,I} \log p_{j.I}) \quad \eta_{ii} = -1 + \hat{\Phi}_{ikt} \cdot (\frac{\gamma_{ii,I}}{E(w_{i,I})} - \beta_{i,I} \frac{\alpha_{i,I}}{E(w_{i,I})} - \frac{\beta_{i,I}}{E(w_{i,I})} \sum_{i,I} \gamma_{ii,I} \log p_{i.I})$$

while the conditional income elasticity is expressed as follows: $e_{ie} = 1 + \hat{\Phi}_{ikt} \cdot \frac{\beta_{i,I}}{w_{i,I}}$,

The unconditional income and price elasticities are: $e_{iY} = e_{eY} \cdot e_{ie}$ and $\eta_{ij} = \eta_{ij,I} + e_{ie} w_{j,I} (1 + \eta_{II})$

We use annual micro-level CUHS data for the 2002–2009 period, and the CUHS data use a stratified multistage method to select its samples. Our data set covers nine provinces in eastern, central and western China: Beijing, Liaoning, Zhejiang, Anhui, Hubei, Guangdong, Sichuan, Shaanxi and Gansu[8]. The sampled households are required to keep a detailed record of their incomes and expenditures every day. The data also provide detailed information regarding demographic characteristics, housing and household expenditures, and – more importantly – detailed value and quantity data on individual types of energy.

There are some extreme values for expenditures, individual energy consumption and implied prices. We censor total consumption for each commodity type that is more than two times the 99th percentile. For those households whose head is unidentifiable, we choose the middle-aged male with the highest income as the head of the household. After data cleaning and treatment of outliers, we are left with 119,780 households for the 2002-2009 period.

The survey gives quantities and values for the purchases of coal, gas, electricity and gasoline. One can impute individual energy unit values from these data. However, because some households do not use all types of energy, we estimate shadow prices using the average price in the city in which the households are located. If no one in the entire city uses a particular type of energy, we assume that households in that city are offered the provincial average price.

3.2 Income groups and imputations

Given the large differences observed in consumption patterns, many studies estimate the demand functions separately for the rich and the poor. We also classified the households into three groups: low, middle and high income. We use household annual expenditures as a proxy for lifetime income and define the low-income group as households in the lowest 20% of the expenditure distribution. The next 60% of households are defined as the middle-income group and the highest 20% are in the high-income group.

China's consumption data – particularly regarding data quality and coverage – have been widely discussed and debated during the past decade (e.g., Benjamin, Brandt, Giles and Wang 2008). The biggest issue is housing consumption, which has changed dramatically. For example, in the early 1990s, urban

[8] The CUHS data for these nine provinces were provided by China Data Center, Tsinghua University.

residents rented from the public sector[9] at low rents, but the public sector has been selling housing to public employees since 1994, and the State Council required all public housing and that of state-owned enterprises to be sold to public employees. By 2009, more than 80% of urban Chinese households owned their residences, and housing prices had thus changed significantly. According to Xu et al. (2012), the share of housing costs out of total household consumption by 2010 was between 23.6% and 40.9% in four large cities (Beijing, Shanghai, Guangzhou, Shenzhen)[10]. However, this major consumption item is not explicitly noted in the National Accounts, as reported in the China Statistical Yearbook. Such owner-occupier expenditures are not included in the CUHS and its housing expenses are thus severely understated. The value of the residence – and thus the imputed rent – is strongly correlated with the household's durable goods and assets. Underestimating owner-occupied housing would overestimate high-income households' elasticities.

Imputing owner-occupied housing rents is difficult in China because of the lack of survey data. Liu (2001) and Zhao et al. (1999) estimated a 9% housing rent-price ratio in 2001 for residences in Shanghai. This ratio was too high to be used in other cities in China, even in the early years. Chen (2012) estimated the housing rent-price ratio in Beijing, Shanghai, Guangzhou and Shenzhen for the 1991–2010 period and found declining rent-price ratios as a trend. Most recently, the ratio was approximately 3% in the sample of those four cities. However, even with estimates of national housing prices, we still could not use these ratios directly. First, fewer than 20% of the households in those cities rented during that period. Second, similar studies do not compute the rent-price ratios for other types of cities. Housing prices are much higher in the largest cities; in other words, these cities have lower rent-price ratios than other cities.

To gain a more complete measure of household expenditures, we impute the owner-occupied housing rental equivalent using current housing values reported in the CUHS. Given the above results, and

[9] In the urban survey, the public sector includes both state-owned enterprises and institutions, and collective-owned enterprises and institutions.

[10] In the SNA, household consumption consists of two parts: market rent and the rental equivalent of owner-occupied housing (Xu et al., 2012). Market rent is the rental price that households actually pay in a market transaction. Owner-occupied housing rent is an imputed value that should ideally be based on equivalent rental units. In the Chinese National Accounts, the imputation is made based only on the depreciation of the structure's construction cost, with an assumed depreciation rate of 2% in the most recent Accounts.

assuming that Chen's (2012) 3% ratio for the largest cities underestimates the national rent-price ratio, we take a simple approach and assume a 4% national average rent-price ratio. That is, our imputation of the annual rentals of owner-occupied housing is the reported housing value multiplied by 4%.

3.3 Spatial prices

3.3.1 Spatial prices for the first-stage estimation

Following Brandt and Holz (2006), we first calculate the values of the energy and nonenergy baskets for each province in 2002, the base year. Using the provincial urban CPI, we then calculate the provincial energy and nonenergy price indices for the 2003–2009 period. In this paper, energy consumption includes coal, electricity, gas and fuel for motor vehicles. Nonenergy consumption includes food and other consumable goods, housing rents, and services.

Provincial energy price indices are constructed using the composite price indices of coal, gas and electricity published in the China Urban Life and Price Yearbook (CULPY) and provincial gasoline prices from International Petroleum Economics Monthly (IPE). The CULPY also publishes energy consumption shares by detailed energy types. Individual energy shares are used as weights to construct the energy basket price indices, and the nonenergy price indices can thus be calculated, as a consequence[11]. The Beijing price in 2002 is used to normalize the panel of provincial prices.

3.3.2 Spatial prices of the second-stage estimation

To estimate individual price and income elasticities, we divide energy consumption into three categories for each income group. The low-income group consumes electricity, gas and coal, and its minimal consumption of gasoline is ignored. The middle- and high-income groups are assumed to consume electricity, a gas-coal aggregate, and gasoline.

[11] The provincial price of energy (relative to Beijing) is calculated as the Tornqvist index of the four energy types: $\ln P^{E}_{pro,bj} = \frac{1}{2}\sum_{l=1}^{4}(w_{l,pro} + w_{l,bj})\ln(\frac{P^{l}_{pro}}{P^{l}_{bj}})$, . The price of the nonenergy basket is calculated as a residual from the provincial CPI aggregate:

$$\ln P^{CPI}_{pro,bj} = \frac{1}{2}\sum_{l \in energy, nonenergy}(w_{l,pro} + w_{l,bj})\ln(\frac{P^{l}_{pro}}{P^{l}_{bj}}) .$$

For the detailed energy types, we do not have to rely on provincial averages; following Gundimeda and Köhlin (2008), we impute unit prices using the quantity and value data for electricity and coal use in the household surveys for 2002–2009.

The CUHS only began reporting quantities and values for gases and transportation fuels in 2008. For transportation energy, there are expenditures for gasoline, diesel and electrical charging. More than 99% of household transportation fuel expenditures are for gasoline, and we simply assume that the transportation energy price is the gasoline price. Before 2008, only expenditures for transportation fuel are available, and for prices, we must use the annual provincial gasoline prices from IPE for all households in a given province. Using these provincial gasoline prices, we construct provincial transportation fuel inflation rates. These provincial inflation rates are then combined with county-level gasoline prices that we compute from the CUHS in 2008, giving us a series of county-level gasoline prices for 2002–2007.

There are four types of cooking gas in our data: coal gas, piped petroleum gas, natural gas, and bottled LPG. The survey reports expenditures on and quantities of these gases since 2008, and we can calculate unit prices[12]. For 2002–2007, the survey only reports bottled LPG and "gas", and there are no details for different types of gases. We turn to prices collected by the National Development and Reform Commission[13] to impute gas prices. We first identify the counties, or county-level cities, that did not change their type of piped gas. We can thus infer the types of gas that the households in those cities or counties used before 2008. We are then able to use the unit value of a given type of gas and convert the units to coal gas-equivalents. For the middle- and high-income groups, we only identify a single gas-coal

[12] We use heat values to convert the gas prices to a coal-gas equivalent price for household *k* for 2008–2009 as follows:

$$p_{kt}^{gas} = p_{kt}^{coal\ gas} w_{kt}^{coal\ gasy} + \frac{67}{217} p_{kt}^{LPG} w_{kt}^{LPG} + \frac{67}{160} p_{kt}^{natural\ gas} w_{kt}^{natural\ gas} + \frac{67}{486} p_{kt}^{petrolgas} w_{kt}^{petrolgas}$$

$p_{kt}^{coal\ gas}, p_{kt}^{LPG}, p_{k,t}^{natural\ gas}\, and\ p_{k,t}^{petrolgas}$ are the household unit prices of coal gas, LPG, natural gas and piped petroleum gas, respectively, and the w's are the corresponding shares within the gas basket. The conversion factors are from the Chinese Energy Statistical Yearbook 2011, Appendix IV.

[13] These data are surveyed by the National Development and Reform Commission every ten days. Information along the lines of county/city names, the name of the commodity, prices and survey data is offered at the following website:

http://www.cpic.gov.cn/fgw/ProxyServlet?server=e450&urls_count=1&url=info/S_0_0_0_0.htm

group. The price index of the gas and coal bundle for household *k* is then calculated as that of energy prices is calculated.

The Chinese government has different policies for different types of energy. For coal and gas, the pricing authority varies greatly across counties and districts, and local governments can determine their own energy supply investments and subsidies. In the CUHS data, we indeed observe rather large variations across regions and years. For electricity and gasoline, the central government has overwhelming pricing authority – and local governments have limited authority – although there are some variations across provinces. As a result, electricity and gasoline prices vary less compared with coal prices across regions and over time. To eliminate the time-series and cross-sectional fixed effects, we use year dummies, provincial dummies and the interaction of the year and provincial dummies in our regression.

Table 1 gives some summary statistics for the three income groups[14] and shows how energy consumption patterns differ greatly across groups; for example, the richer the household, the smaller the expenditure shares of coal and gas. Gasoline consumption is 20.6% of total energy consumption for rich urban households, but these households consume little coal. Electricity plays the most important role in urban household energy, and electricity prices are nearly the same across income groups and vary little over the sample period. However, the poorer households face somewhat lower coal prices in our sample, most likely because they are located in or near coal-producing regions. Gasoline prices are slightly cheaper for the higher income groups on average because of lower transportation costs to the urban centers in which they are disproportionately located.

Insert Table 1 Here

The household characteristics that we have chosen to include in our model are household size, presence and age of children, and the age, gender and employment status of the head of the household. Employment status distinguishes among those who work in the public sector and those who do not. Different income groups have different demographic compositions; for example, the low-income group has larger average household sizes and is more likely to have children, particularly younger children. For

[14] We use expenditure as proxy for life-time income.

poorer households, the household heads are younger, less often female and less likely to work in the public sector. In Table 2, we give the sample distribution by these demographic categories and income groups. To avoid collinearity in the 2^{nd} step of the Heckman two-step procedure, we exclude two demographic categories from (11) that are included in (9): gender of household head and age of children.

Insert Table 2 and Table 3 Here

Given the structure of compensation, we distinguish households by the employment status of the head. Most workers in state-owned enterprises (SOEs) or collective-owned enterprises (COEs) live in downtown areas, in which there is more convenient access to high-quality energy at lower prices. The public sectors also subsidize or provide food for their workers, which allows them to spend less on food at home and more on dining out. In Table 3, we give the average prices faced by the two employment groups as well as shares of total expenditures devoted to eating out of the home. We find that households in which the head works in the public sector have access to cheaper energy and have a higher share of dining out expenditures.

We include provincial dummies to capture the differences across provinces with respect to local culture, resource endowment and climatic conditions. Beijing, Zhejiang and Guangdong are the richer provinces, whereas Liaoning, Shaanxi and Gansu are poorer.

4. EMPIRICAL RESULTS

4.1 Price and expenditure elasticities of total energy consumption

The results of estimating the first-stage equation (1) are given in Table 4. All the parameters of the first-stage regression are significant at the 1% level. Recall that we only have provincial prices – and not household-specific prices – for the energy and nonenergy baskets.

Insert Table 4 Here

Table 5 gives the expenditure and price elasticities of the energy bundle by income group, which are all significant at the 1% level. Energy is a necessity for all groups; the expenditure elasticities range from 0.712 for the poor to 0.852 for the rich.

The price elasticities are significant at the 1% level and range from -0.367 to -0.180. The high-income group is less price elastic than the other two groups.

Insert Table 5 Here

4.2 Probit estimation of adopting individual energy

In Tables 6 and 7, we present the probit estimates for equation (9). We do not have to consider the electricity choice because nearly all households in urban China have access to and use electricity. These tables provide evidence of negative price effects for choosing a particular type of energy.

As noted above, the high- and middle-expenditure groups use very little coal; thus, we estimate the coal probit only for the low-income group. Households with higher expenditures on energy, or larger household sizes, are more likely to consume all types of energy. Old people with low incomes have a higher probability of choosing coal. Low-income households whose head works in a nonpublic company are more likely to use coal. Households with a female head are less likely to choose coal.

Regarding gasoline use among the middle- and high-income groups, higher gasoline prices significantly (at the 1% level) reduce the probability of its use. The higher total energy expenditures for a household are, the higher the probability of consuming gasoline. For the middle- and high-income groups, larger households and those with children have a higher probability of consuming gasoline.

Insert Tables 6 and 7 Here

Household size and children in the household have larger effects for the high-income compared with the middle-income group. Having young children (0–12 years old) has a greater effect on the choice of gasoline than having older children. Younger heads of households are more likely to consume gasoline in the middle- and high-income groups, and households with male or publically employed heads are also more likely to use gasoline.

Although commercial gas is available in most parts of urban China, not every household uses it; we find significant demographic effects, as Table 7 shows. Larger low- and middle-income households are more likely to use gas, whereas larger high-income households are not. Low-income female-headed households are more likely to use gas than coal. Households with a publically employed head are more likely to use gas because it is cheaper, particularly in the low-income group, as shown in Table 3.

4.3 Price and expenditure elasticities by expenditure group

We begin by noting an interesting correlation for coal prices in this CUHS data set; in Figure 1, we plot average provincial coal prices versus the mean per capita coal consumption. The prices over time are deflated using the CPI. There is a strong negative correlation between price and consumption that runs both across provinces at a point in time, and within provinces over time. This negative correlation results from provincial coal endowments and local government pricing policies.

The results of estimating the AIDS system for each of the three income groups are given in Tables 8, 9 and 10. Demographic characteristics affect household energy consumption significantly in various ways; households with more family members spend relatively more on electricity and less on coal and/or gasoline. Employment status is significant; poor households with publically employed heads spend relatively more on electricity and less on coal, whereas those in the middle- and high-income groups use more electricity because its prices are lower, and these groups use less gas. Recall their higher share of expenditures devoted to dining out, which lowers gas usage for cooking. Public employees in the middle-income group consume less gasoline but those in the high-income group Consume more. Younger people use less gas and more electricity in the middle- and high-income groups, which may be attributable to their lifestyle of dining out and using more electronic and electrical appliances. Older people in the middle-income group use less gasoline, whereas older people in high-income households use more.

Insert Figure 1 Here

Insert Table 8, 9, 10 Here

The coefficients from Tables 8–10 are used to compute the conditional elasticities of demand, which are presented in Table 11. For each income group, the conditional own-price elasticities are of the expected sign and significant at the 1% level; however, most cross-price elasticities are small or insignificant. Poor households are price sensitive with respect to the coal price, given the strong patterns shown in Figure 1.

Unconditional demand elasticities for individual energy are shown in Table 12. For all income groups, demand is price inelastic. Own-price elasticities for electricity do not vary greatly across income groups; however, those for gas vary considerably. Higher-income households are less price elastic for gas consumption, whereas poorer households are somewhat price elastic. For the low-income group, coal's price elasticity is high (-0.961), and cross-price elasticities have positive signs, implying that electricity and gas are substitutes for coal. Rich households are price inelastic with respect to gasoline.

The estimates of expenditure elasticities in the energy group indicate that coal is the most income-elastic energy commodity for poor people, whereas gasoline is more income elastic than other types of energy for the high-income group.

Insert Table 11 and 12 Here

5. CONCLUSION

We estimated the residential energy demand system in urban China using detailed micro-level household survey data, which was implemented in a two-stage budgeting framework that allowed for a simple but complete accounting of all nondurable consumption items. Prior to this study, such a set of national microdata has not been used to estimate Chinese household demand. We made a special effort to include the housing consumption value, which is not adjusted appropriately in either the official expenditure survey or in other national surveys.

We find that consumption patterns differ significantly by household size, age of the head of the household, the presence and age of children and the employment status of the head of the household. We also find that energy consumption has low income elasticity; in other words, it is a necessity for households.

Electricity and gas are cleaner and available to most urban households today, and they are widely used. In addition, middle- and high-income groups consume little coal today, but coal continues to constitute nearly 20% of the total energy expenditures of low-income households. Given overall income levels in China, the middle- and low-income groups consumed very little gasoline in 2008, whereas gasoline comprised more than 20% of the total energy consumption in high-income households. This number might be understated considering that a large part of gasoline consumption is paid by employers (through income-type transactions that is recorded as an intermediate business input).

Our estimated elasticities show that poor households are very sensitive to the price of coal and that rich households are sensitive to the price of gasoline. Each of the three groups is price inelastic for gas and electricity.

The results of this type of research are important for analyzing government policies regarding energy use and the environment, such as carbon control policies and gasoline taxes. A better understanding of household behavior is necessary to estimate the impacts of policies that affect energy prices. As incomes rise and more automobiles are put into use, rising vehicle emissions in China will continue to add to the already serious air pollution problem. Given our estimated elastic demand for gasoline, higher gasoline taxes may be an effective way to reduce pollution.

In addition, the Chinese government has invested heavily in electricity and pipe infrastructure. Given our estimated elasticities for electricity, gas and coal, it would appear to be good policy to make piped gas even more widely available to help make the transition toward cleaner fuels.

Although we had to make a number of simplifications in constructing the data series and had to make adjustments for owner-occupied housing – particularly for the time series to identify the first-stage function – we believe that we have obtained plausible estimates of household demand behavior in urban China and that we have laid the groundwork for future improvement in data analysis and econometric work. Our estimates also offer a better basis for projecting energy demand and thus for designing energy policies.

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Table 1: Summary statistics by expenditure group

Expenditure group	Low		Middle		High	
Variables	Mean	SD.	Mean	SD.	Mean	SD.
Expenditure (Beijing 2002 Yuan)	4154	1108	9034	2963	21546	9018
Shear of energy in total expenditure (%)	0.07	0.04	0.06	0.03	0.05	0.04
Price electricity (Yuan/kw· h)	0.55	0.10	0.55	0.09	0.56	0.09
Price coal (Yuan/kg)	0.66	0.39	0.67	0.33	0.69	0.30
Price gas (Yuan/cubic meter)	2.24	2.14	2.25	1.69	2.35	1.76
Price gasoline (Yuan/litre)	5.51	2.35	5.34	2.28	5.09	2.30
Electricity share of energy (%)	55.0	20.9	58.3	20.5	53.5	25.3
Coal share of energy (%)	9.4	18.7	3.2	10.6	0.8	5.3
Gas share of energy (%)	32.5	20.6	31.7	18.4	25.1	18.6
Gasoline share of energy (%)	3.0	10.1	6.8	17.1	20.6	30.3
Number of obs.	23,800		71,265		23,631	

Note: the prices of individual energy have been deflated using provincial CPI

Table 2: Sample distribution by demographic characteristics and expenditure group

		Expenditure group		
		Low	Medium	High
Household size (number of members)		3.33	2.87	2.60
Child (%)	No child	42.00	56.26	67.17
	Child: 0-12	36.69	26.14	19.62
	Child: 13-18	23.52	18.39	13.64
Age of household head (%)	Age of head 0-34	9.33	9.31	11.28
	Age of head 35-55	63.24	61.64	57.49
	Age of head 56+	27.43	29.05	31.23
Gender of household head (%)	male	74.54	70.27	64.64
	female	25.46	29.73	35.36
Occupation of household head (%)	public	38.73	49.14	48.15
	non-public	61.27	50.86	51.85

Table 3: Individual energy prices and dining out by employment status

Employment status of household head	Prices household faces (Yuan) electricity	gas	coal	Share of dining out (%)
Public	0.546	2.227	0.627	22.0
Non-public	0.555	2.312	0.701	16.6

Table 4: Estimates of LES model of total energy expenditures (first stage)

VARIABLES	Expenditure of total energy		
Expenditure group	Low	Middle	High
γ_e	144.9***	274.8***	505.5***
	(5.129)	(4.633)	(15.07)
γ_{ne}	1755***	3925***	7118***
	(342.5)	(290.0)	(895.9)
β_I	0.0543***	0.0412***	0.0424***
	(0.0010)	(0.0004)	(0.0006)
Observations	23,958	71,871	23,951
R-squared	0.778	0.718	0.643

Standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Note: provincial dummies, year dummies and the interactions are not reported

Table 5: Estimated Elasticities for energy in the first stage LES Model

	Low	Middle	High
price elasticity	-0.367***	-0.358***	-0.180***
std. dev.	(0.001)	(0.000)	(0.000)
expenditure elasticity	0.712***	0.713***	0.852***
std. dev.	(0.013)	(0.007)	(0.011)
Obs.	23, 958	71,871	23,951

Table 6: Probit estimate for coal and gasoline selection

	Choice of Coal	Choice of Gasoline	
VARIABLES	**Low**	**Middle**	**High**
Price electricity	0.700***	0.273***	0.495***
	(0.0900)	(0.0586)	(0.129)
Price gas (low income) or	0.335***	0.288***	0.298***
price coal & gas (middle, high)	(0.0204)	(0.0143)	(0.0210)
Price coal (low income) or	-1.613***	-4.352***	-0.532***
price gasoline (middle, high)	(0.0387)	(0.116)	(0.109)
Log of energy expenditure	0.0723***	0.452***	0.784***
	(0.0161)	(0.0117)	(0.0163)
Public sector: household head	-0.0806***	0.188***	0.0614***
	(0.0213)	(0.0101)	(0.0219)
Household size	0.0948***	0.110***	0.256***
	(0.0126)	(0.0142)	(0.0183)
Has child: age < 12	0.0253	0.103***	0.196***
	(0.0240)	(0.0212)	(0.0364)
Has child: 12<= age < 18	0.00111	0.000253	0.0647*
	(0.0247)	(0.0201)	(0.0347)
Gender of household head: Female	-0.0702***	-0.0222	-0.0383*
	(0.0222)	(0.0149)	(0.0229)
Household head’s age 35-54	-0.0154	-0.121***	-0.128**
	(0.0355)	(0.0337)	(0.0594)
Household head’s age 55+	0.218***	-0.0364	-0.152*
	(0.0422)	(0.0499)	(0.0804)
Durable dummies	Y	Y	Y
Constant	-0.111	-4.192***	-6.125***
	(0.289)	(0.125)	(0.164)
Observations	23,782	69,024	22,914

Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Note: provincial dummies, year dummies, the interactions, and age and education cohort[15] dummies are not reported.

[15] We define 11 age cohorts and 3 education groups for the household head. The age cohorts are: born before 1930, 1930-1934, 1934-1939, 1940-1944, 1945-1949, 1950-1954, 1955-1959, 1960-1964, 1965-1969, 1970-1974, and born after 1975. The education groups are: primary school, middle school, and college. There are similar dummies for the spouse.

Table 7: Probit estimate for gas selection

VARIABLES	**Gas**	**Gas & coal**	
Income group	**Low**	**Medium**	**High**
Price electricity	0.904***	0.771***	0.589***
	(0.0951)	(0.0652)	(0.164)
Price gas (low income) or	0.115***	-0.234***	-0.305***
price coal & gas (medium, high)	(0.0277)	(0.0237)	(0.0412)
Price coal (low income) or	0.849***	0.363***	0.222
price gasoline (medium, high)	(0.0423)	(0.135)	(0.255)
Log of energy expenditure	0.633***	0.395***	0.222***
	(0.0192)	(0.0130)	(0.0178)
Household size	0.0320	0.163***	-0.156***
	(0.0254)	(0.0180)	(0.0354)
Public sector: household head	0.134***	-0.119***	0.104***
	(0.0153)	(0.0224)	(0.0316)
Has child: age < 12	0.0149	0.00677	-0.0975*
	(0.0291)	(0.0341)	(0.0582)
Has child: 12<= age < 18	0.0216	0.0122	0.0108
	(0.0297)	(0.0318)	(0.0567)
Gender of household head: Female	0.0899***	0.0283	0.0520
	(0.0270)	(0.0225)	(0.0348)
Household head's age 35-54	0.0152	0.0370	0.00175
	(0.0414)	(0.0508)	(0.0891)
Household head's age 55+	-0.0904*	0.105	-0.0683
	(0.0497)	(0.0760)	(0.126)
Durable dummies	Y	Y	Y
Constant	-2.394***	-0.795***	-0.175
	(0.463)	(0.177)	(0.206)
Observations	23,503	69,024	22,814

Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Note: provincial dummies, year dummies, their interaction, and age and education cohort dummies are not reported.

Table 8: Estimates of LES-AIDS model for low expenditure group

	Low Income Group		
Share of	**electricity**	**Coal**	**Gas**
Price electricity	0.0478***	-0.0237***	-0.0241***
	(0.0103)	(0.0089)	(0.0041)
Price gas	-0.0241***	0.0626***	-0.0385***
	(0.0041)	(0.0038)	(0.0027)
Price coal	-0.0237***	-0.0389***	0.0626***
	(0.0089)	(0.0084)	(0.0038)
Log of energy expenditure	-0.0560***	0.0568***	-0.0008
	(0.0030)	(0.0021)	(0.0027)
Household size	0.0031	-0.0075***	0.0044**
	(0.0025)	(0.0025)	(0.0018)
Public sector: household head	0.009***	-0.00747***	-0.00160
	(0.0030)	(0.00272)	(0.00305)
Has child	0.0100***	0.0010	-0.0110***
	(0.0031)	(0.0027)	(0.0031)
Household head’s age 35-54	-0.0025	-0.0028	0.0053
	(0.0048)	(0.0043)	(0.0049)
Household head’s age 55+	-0.0028	0.0117**	-0.0089
	(0.0059)	(0.0053)	(0.0059)
Has heating system	0.0261***	-0.0208***	-0.0053
	(0.0061)	(0.0054)	(0.0061)
Number of refrigerators: 1	0.0396***	-0.0530***	0.0134***
	(0.0040)	(0.0034)	(0.0037)
Number of refrigerators: 2+	0.0337**	-0.0535***	0.0198
	(0.0147)	(0.0131)	(0.0147)
Has moped	0.0212***	-0.0063	-0.0149**
	(0.0063)	(0.0056)	(0.0063)
Number of Color TVs: 2+	0.0036	-0.0019	-0.0017
	(0.0040)	(0.0035)	(0.0040)
No. of air-conditioners: 1	0.0142***	-0.0209***	0.0067*
	(0.0041)	(0.0036)	(0.0038)
No. of air-conditioners: 2+	0.0309***	-0.0190***	-0.0119
	(0.0079)	(0.0071)	(0.0077)
Housing size (m^2)	0.0004***	-0.000008	-0.0004***
	(0.00004)	(0.00004)	(0.00004)
Inverse Mill’s ratio	N	Y	Y
Observations	23,503	23,503	23,503

Standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Note: provincial dummies, year dummies, and the interactions are not reported.

Table 9: Estimates of LES-AIDS model for medium expenditure group

	Medium income group		
Share of	**Electricity**	**Gas & coal**	**Gasoline**
Price electricity	0.0568***	0.0264***	-0.0832***
	(0.0117)	(0.00579)	(0.0107)
Price gas & coal	0.0722***	-0.0163***	-0.0560***
	(0.0043)	(0.0019)	(0.0049)
Price gasoline	-0.1290***	-0.0102*	0.1390***
	(0.0115)	(0.0057)	(0.0105)
Log of energy expenditure	-0.0565***	-0.0345***	0.0910***
	(0.0023)	(0.0020)	(0.0014)
Household size	0.0397***	0.0003	-0.0399***
	(0.0023)	(0.0013)	(0.0020)
Public sector: household head	0.0304***	-0.0265***	-0.0039***
	(0.0018)	(0.0017)	(0.0011)
Has child	0.0158***	-0.0194***	0.0036***
	(0.0019)	(0.0017)	(0.0012)
Household head's age 35-54	-0.0361***	0.0371***	-0.0009
	(0.0029)	(0.0026)	(0.0018)
Household head's age 55+	-0.0820***	0.0828***	-0.0008
	(0.0036)	(0.0033)	(0.0022)
Has heating system	-0.0215***	0.0268***	-0.0052**
	(0.0038)	(0.0035)	(0.0024)
Number of refrigerators: 1	0.0550***	-0.0543***	-0.0007
	(0.0032)	(0.0030)	(0.0021)
Number of refrigerators: 2+	0.0725***	-0.0706***	-0.0019
	(0.0062)	(0.0057)	(0.0039)
Has moped	0.0426***	-0.0178***	-0.0248***
	(0.0028)	(0.0025)	(0.0018)
Number of Color TVs: 2+	0.0193***	-0.0164***	-0.0029**
	(0.0018)	(0.0017)	(0.0011)
No. of air-conditioners: 1	0.0464***	-0.0442***	-0.0022
	(0.0021)	(0.0019)	(0.0013)
No. of air-conditioners: 2+	0.0760***	-0.0786***	0.0026
	(0.0027)	(0.0025)	(0.0017)
Housing size (m^2)	0.0003***	-0.0002***	-0.0001***
	(0.0000)	(0.0000)	(0.0000)
Inverse Mill's ratio	N	Y	Y
Observations	69,042	69,042	69,042

Standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Note: provincial dummies, year dummies, and the interactions are not reported.

Table 10: Estimates of LES-AIDS model for high expenditure group

VARIABLES	**High income group**		
Share of	**Electricity**	**Gas & coal**	**Gasoline**
Price electricity	0.0144	0.0221**	-0.0365*
	(0.0227)	(0.0111)	(0.0211)
Price gas & coal	0.0135**	-0.0144***	0.0009
	(0.0060)	(0.0033)	(0.0056)
Price gasoline	-0.0279	-0.0077	0.0356*
	(0.0217)	(0.0108)	(0.0200)
Log of energy expenditure	-0.0351***	-0.1030**	0.1380***
	(0.0031)	(0.0025)	(0.0021)
Household size	0.0715***	-0.0179***	-0.0536***
	(0.0044)	(0.0023)	(0.0041)
Public sector: household head	0.0193***	-0.0252***	0.0060*
	(0.0038)	(0.00296)	(0.0031)
Has child	0.0040	-0.0010*	0.0060
	(0.0049)	(0.0038)	(0.0042)
Household head’s age 35-54	-0.0425***	0.0011	0.0414***
	(0.0099)	(0.0075)	(0.0086)
Household head’s age 55+	-0.0571***	0.0326***	0.0245**
	(0.0130)	(0.0099)	(0.0113)
Has heating system	-0.0106	0.0088	0.0018
	(0.0082)	(0.0062)	(0.0071)
Number of refrigerators: 1	0.0017	0.0045	-0.0062
	(0.0116)	(0.0089)	(0.0010)
Number of refrigerators: 2+	0.0088	0.0089	-0.0177
	(0.0135)	(0.0103)	(0.0117)
Has moped	0.0382***	-0.0015	-0.0367***
	(0.0051)	(0.0039)	(0.0044)
Number of Color TVs: 2+	0.0343***	-0.0171***	-0.0171***
	(0.0035)	(0.0027)	(0.0030)
No. of air-conditioners: 1	0.0350***	-0.0331***	-0.0019
	(0.0057)	(0.0044)	(0.0049)
No. of air-conditioners: 2+	0.0622***	-0.0533***	-0.0089*
	(0.0061)	(0.0047)	(0.0052)
Housing size (m^2)	0.0004***	-0.0001***	-0.0003***
	(0.0000)	(0.0000)	(0.0000)
Inverse Mill’s ratio	N	Y	Y
Observations	22,814	22,814	22,814

Standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Note: provincial dummies, year dummies and the interactions are not reported

Table 11: Conditional price and income elasticities by expenditure group

Conditional price elasticity (Poor Group)			
	Electricity	Gas	Coal
Electricity	-0.860***	-0.053***	-0.034***
	(0.020)	(0.009)	(0.029)
Gas	0.005	-1.083***	0.072***
	(0.017)	(0.007)	(0.005)
Coal	0.003	0.140***	-1.054***
	(0.024)	(0.009)	(0.010)

Conditional price elasticity (Middle Income Group)			
	Electricity	Gas & coal	Gasoline
Electricity	-0. 869***	0.116***	-0.059***
	(0.019)	(0.013)	(0.008)
Gas & coal	0.149***	-0.980***	-0.041***
	(0.008)	(0.008)	(0.003)
Gasoline	-0.199***	0.037***	-0.984***
	(0.020)	(0.015)	(0.001)

Conditional price elasticity (Rich group)			
	Electricity	Gas & coal	Gasoline
Electricity	-0.944***	0.388***	-0.047*
	(0.038)	(0.035)	(0.017)
Gas & coal	0.022**	-0.736***	-0.000
	(0.011)	(0.022)	(0.005)
Gasoline	-0.076**	0.276***	-0.958***
	(0.037)	(0.037)	(0.015)

Conditional expenditure elasticity			
	Electricity	Gas	Coal
Low income	0.898***	0.995***	1.069***
	(0.006)	(0.007)	(0.003)
	Electricity	Gas & coal	Gasoline
Medium income	0.906***	0.914***	1.063***
	(0.004)	(0.005)	(0.010)
High income	0.941***	0.683***	1.107***
	(0.005)	(0.009)	(0.002)

Table 12: Unconditional price and income elasticities by expenditure group

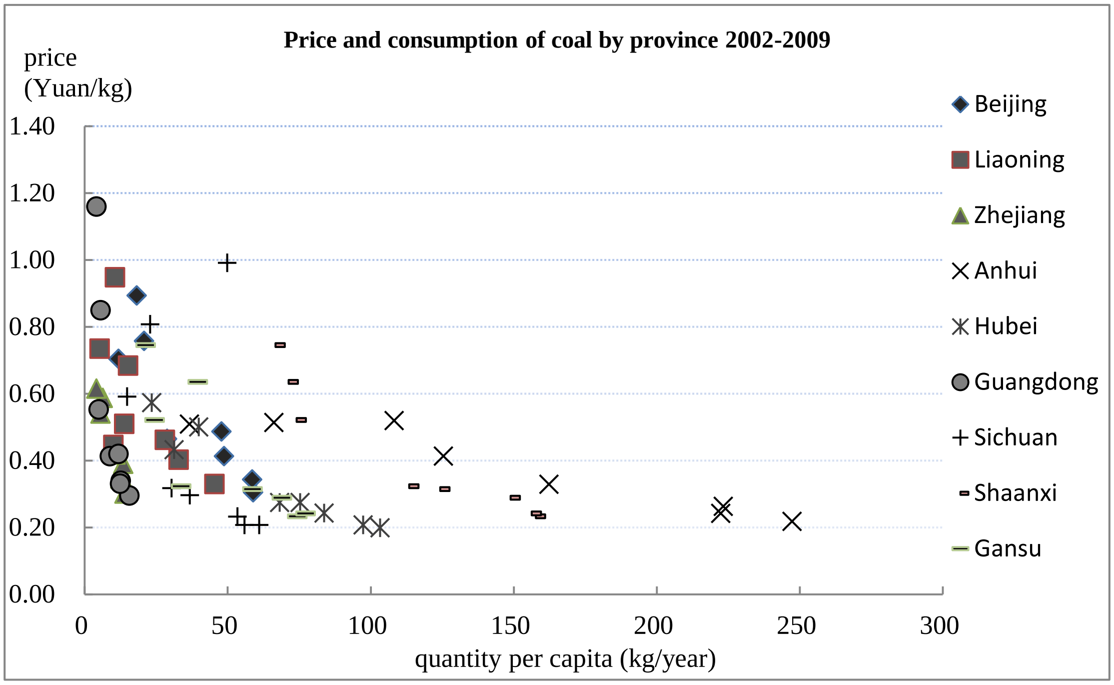
Unconditional price elasticity (Poor Group)			
	Electricity	Gas	Coal
Electricity	-0.569	0.266	0.301
Gas	0.177	-0.883	0.276
Coal	0.087	0.233	-0.961

Unconditional price elasticity (Middle Income Group)			
	electricity	Gas & coal	Gasoline
electricity	-0.559	0.437	0.302
Gas & coal	0.377	-0.743	0.233
Gasoline	-0.160	0.062	-0.944

Unconditional price elasticity (Rich group)			
	Electricity	Gas & coal	Gasoline
Electricity	-0.547	0.686	0.448
Gas & coal	0.229	-0.600	0.236
Gasoline	0.085	0.370	-0.794

Unconditional expenditure elasticity			
	Electricity	Gas	Coal
Low income	0.658	0.720	0.752
	Electricity	Gas & coal	Gasoline
Medium income	0.648	0.652	0.757
High income	0.801	0.587	0.942

Figure 1: Price and consumption of coal by province (2002-2009)



Note: coal prices are deflated using CPI