Electricity Price, Residential Electricity Demand, and Renewable Energy Development Policies in Vietnam *

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Abstract

This study presents a first household-level estimate of the demand for residential electricity in Vietnam using a 2015 World Bank household survey. Estimating a reduced-form demand function with instrumental variables for endogenous price, we have found that the demand for electricity is almost unitarily elastic to the average price and even more elastic to the marginal price. We conclude that the residential demand for electricity is more responsive to price in Vietnam than it is in several comparable developing countries, including India and China, and many developed countries. Meanwhile, the income and cross price elasticity is approximately 0.05 - 0.07, consistent with most of the literature. This result carries a significant implication for the energy development strategy in Vietnam. Proper demand side management by pricing instruments, coupled with a sufficient feed-in-tariff for renewables on the supply side, could help offset significant future generation capacity if the economy and real personal income keep growing at a high level, as observed over the last two decades.

Keywords: residential electricity demand, increasing block rate (IBR), average price, instrumental variables
JEL code: Q21, Q28, Q40

1 Introduction

As one of the most rapidly developing countries, Vietnam has witnessed an exponential increase in energy consumption over the past two decades. Since 1990, the demand for electricity has increased 16-fold, from 8.7Twh in 1990 to 141Twh by 2014 (FPT Securities Electricity Sector Report, 2015; Electricity of Vietnam, 2016). Since 2000, the

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cumulative annual growth rate of energy consumption has reached 13%, meaning that the electricity supply must double every six years to meet with the insatiable demand (Figure 1, Appendix). Economic restructuring and drastic shifts from primarily agrarian economy toward heavy reliance on industrial and construction sectors, coupled with a rising living standard of many Vietnamese, put significant stress on the electricity sector. Rapid urbanization and migration from rural sectors to the cities to find jobs and to settle in new lives is a major driving factor behind energy consumption, for both residential and commercial uses, in big cities. World Bank statistics indicate that the number of urban dwellers increased from 24% to 34% of the population during 2000-2015, because of a higher birth rate, better health care, expansion of urban areas, and the inflow of migrants.

Vietnam has achieved incredible success in the rate of electrification, providing almost universal access to electric grids by all communes and up to 98% of all households. This has helped raise the annual per capita electricity consumption from 41Kwh in 1971 to 1,439Kwh in 2014 (World Bank, 2014). Maintaining a low electricity tariff to promote rapid industrialization contributes to the steep rising demand from most heavy users. Higher personal income and a rising living standard are accompanied by a higher demand for energy inputs, for several reasons. As energy-intensive appliances such as air conditioners and electric cookers become more accessible to middle-income families, the use of traditional fuels, such as coal or firewood, has become a nuisance for urban dwellers. Currently, almost all households in Vietnam have televisions and a rice cooker (FPT Securities Electricity Sector Report, 2015). Refrigerators have also become popular, with up to 60% of households having one. Although only 8% of households own air conditioners, these rank as the most electricity consuming appliances in Vietnam, followed by refrigerators and electric lights (Electricity of Vietnam-Hanoi, 2016). As real income rises, more households plan to buy air conditioners, computers, refrigerators and washing machines. This will undoubtedly raise electricity consumption among the urban population in the near future.

The increasing energy dependency is indicative of a serious structural problem with economic growth in Vietnam. The electricity elasticity of GDP (growth rate of electricity consumption/growth rate of GDP) is one of the highest in the world, reaching 1.8-2 during the last decade (Figure 2, Appendix), which is higher than that of China [1.3 in 2010 as in Yao et al. (2012)] and is much higher than that of India [less than 0.8, Government of India (2017)]. Consequently, to maintain a high economic growth rate, generation capacity must expand at twice the rate of economic growth. In the face of essentially exhausted hydropower potential and limited renewables' deployment, the Vietnamese government seems eager to embrace coal-generated electricity as the only alternative, which is catastrophic for public health concerns and for the environment. Despite having significant potential in terms of renewable resources, Vietnam is dependent on hydropower and thermal power plants for up to 95% of total electricity production. As of 2014, hydropower and coal electricity each generated about 35% of the total supply, followed by gas turbine (20%), and diesel (5%); there were supplemented by a minuscule amount of off-grid solar photo-voltaic (PV) cells and wind farms (Electricity Regulatory Authority of Vietnam, 2015). This energy landscape puts significant stress on the power system during critical times such as the months of April-June when business activities shift into high gear after a long national holiday period. Seasonal effects of weather on energy demand could be substantial as hot and dry periods often come with extended droughts and a low water level for hydropower to supplement other sources.

To meet the resulting challenges, the Vietnamese government must manage both the demand for and the supply of electricity. The Vietnamese government recently passed the revised Vietnam Power Development Plan (PDP) VII, which places a strong focus on developing a competitive electricity generation market and attracting investment in renewable energy (GIZ, 2016). Developing clean power from solar radiation and wind are among the top priorities, considering vast untapped potential of these resources. Gradual deregulation of the electricity market from a quasi-monopolistic market dominated by Electricity of Vietnam (EVN) to include more players will help reduce red-tape and raise the overall efficiency. Notably, the government has removed nuclear power from the electricity pool, due to both prohibitive technical barriers and to incorrect projections of future consumption after the passage of the revised plan.

On the demand side, however, there is limited discussion on both energy efficiency and the role of economic restructuring to shift from energy-intensive industries to light manufacturing and services. In this context, understanding the characteristics of residential demand for electricity is important, as this segment accounts for almost a third of the electricity generation. In this study, we have found that the own price elasticity of electricity demand is unitary elastic; raising the price will reduce consumption proportionately. We evaluated the impact of a potential progressive price increase of 10% and 20% on residential consumption and welfare. The higher price will help reduce consumption by 4%-6% a year, while having minimal impact on household welfare. We propose a simple mechanism to incorporate the price change and associated revenue collection with renewable energy development. A sufficient price increase combined with raising the feed-in-tariff for solar photo-voltaic cells could help Vietnam meet its planned solar power expansion. The associated environmental benefit from such a proposal would be very substantial.

2 Method and Data

2.1 Modeling Electricity Demand

Econometric Models

We adopted a reduced-form demand function that models consumed quantity on the purchase price, the disposable income, prices of substitutes, and other explanatory variables that control for demographic and housing characteristics at the household level (Olmstead, 2009; Filippini and Pachauri, 2004; Wiesmann et al., 2011). We utilized a double-log function which is a dominant specification used in demand estimation:

$$lnE_i = \beta_0 + \beta_1 \times lnP_i + \beta_2 \times lnIncome_i + \beta_3 \times lnP_i{}^s + \sum_j X^j{}_i \times \beta_j + \varepsilon_i \quad (1)$$

with E being the average monthly quantity of electricity consumed, in KWh. The explanatory variables include the price of electricity, P_i; household income; price of substitute energy, $P_i{}^s$; and for other control variables, X_j. Additional variables that could be predictive in a demand function estimation may include lagged structure such as the previous consumption quantity or price, and locational effects to control for regional heterogeneity. The double-log demand function then allows for a straightforward explanation of β_1, β_2, and β_3 as the own price, income, and cross price elasticity of demand, respectively.

Hartman (1979) distinguished short-run and long-run estimates by dividing house-hold level energy decisions into three types. The first type is the decision whether to either buy or replace fuel-burning capital goods to provide a particular service. The second involves technical and economic characteristics of the equipment purchased. And the third concerns the frequency and intensity of use. If the capital stock and its characteristics are fixed, as would be expected in the short-run, the household's decision is limited to how much it uses such equipment. In the long run, both the capital stock and the type of fuel use and economic characteristics are allowed to change, according to the capital and operating costs of alternative choices. A typical cross-sectional model, estimated at static market equilibrium, would produce a long-run estimate of the demand function. In such a model, the capital stock would adjust instantaneously to a change, or the expectation of changes, in either price or income (Hartman, 1979). More complicated dynamic partial adjustment models, requiring panel data, can explicitly model capital stock adjustments as a result of short-run variations in prices and, thus, energy-dependent appliances.

In the context of block-rate pricing, which is popular in water and energy sectors, the literature suggests two major approaches to the demand estimation, depending on the assumption of consumer behaviors toward the expected price. Structural models such as the Discrete/Continuous Choice (DCC) approach used by Hewitt and Hanemann

(1995) deal with the increasing/decreasing block rate price and, thus, a nonlinear budget constraint. This approach estimates a joint decision of appliance choices and electricity use in each block. The authors found that consumers are very responsive to price in the water market, a result unanticipated by utility managers, who assumed that few people made consciously economic decisions and would, therefore, have zero elasticity. However, this approach is technically demanding, due to the two-level decision framework imposing restrictive conditions in constructing the likelihood function. A simpler reduced-form approach is to model electricity demand based on the average price, which could be extrapolated from electricity bills [for example, Shin (1985)]. Comparing the two approaches, Olmstead (2009) did not show a clear advantage of the DCC approach over the reduced-form with instrumental variables.

Estimating demand based on the average price has become particularly relevant, ever since a recent study using detailed California data showed that consumers responded to the average price, rather than the marginal price (Ito, 2014). The principle of a nonlinear pricing scheme is the premise that consumers will respond to the marginal price. However, consumers may neither understand complex pricing structure nor possess the information required to adjust their consumption corresponding to the marginal price. Thus, rational consumers may respond either to the expected marginal price or to the average price as an approximation of the marginal price. Ito (2014) showed that consumers responding to the average price resulted in suboptimal behavior, which prevents block pricing from achieving its conservation goals in certain cases.

In this study, we estimated the demand elasticity to both the average price and the marginal price.

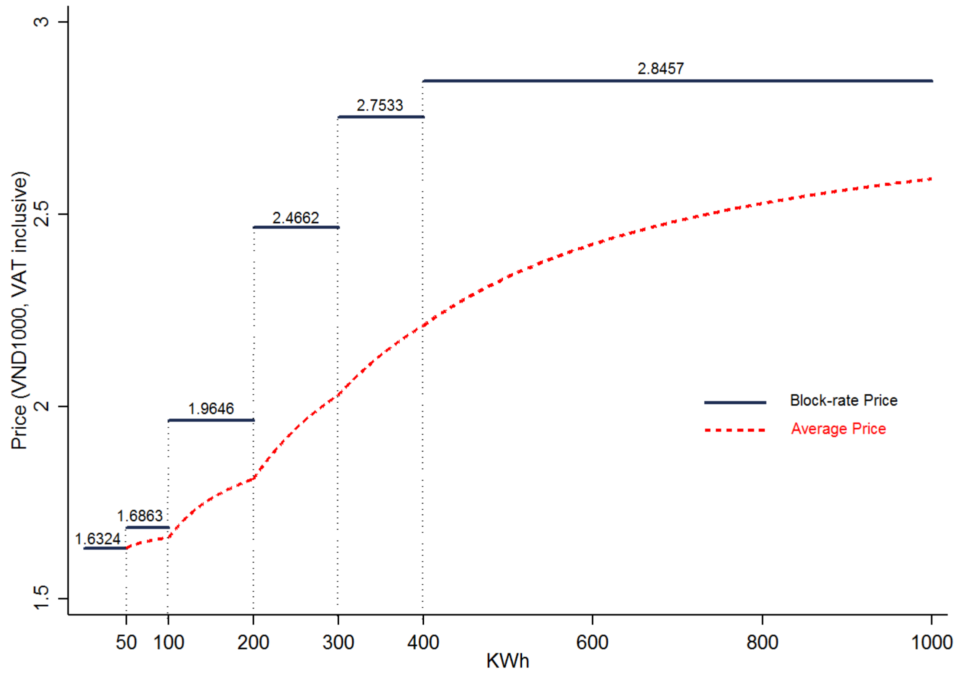
Econometric Identification

In many countries, electricity price is regulated, most often through increasing block-rate pricing that costs more per unit as consumption increases. Vietnam is not an exception. The current price structure in Vietnam is set for six different tiers (Table 1 and Figure 3). The government sets a low price for the first 50Kwh to increase the accessibility of electricity to the vast majority of the population. Designated poor households and households of special social considerations ("gia dinh thuoc dien chinh sach") receive a monthly electricity allowance of 30Kwh. The price increases at higher consumption levels, reaching the highest level of VND2,587 (US11.5c, subject to 10% VAT, as of now) per kilowatt-hour for consumption exceeding 400Kwh per month.

Table 1. Residential Electricity Price in Vietnam

Tier	Consumption Block (KWh)	Price (VND1000, subject to 10% VAT)
Tier 1	≤ 50	1.484
Tier 2	51 - 100	1.533
Tier 3	101 - 200	1.786
Tier 4	201 - 300	2.242
Tier 5	301 - 400	2.503
Tier 6	> 400	2.587

Figure 3: Increasing Block-Rate Price and the Average Price.



As both price and quantity demanded are simultaneously determined, ordinary least squares estimation of a reduced-form demand function, taking price as given, will produce a biased and inconsistent estimate of the price elasticity coefficient. As price is positively correlated with quantity consumed, as in the case of increasing block-rate pricing, a positive correlation between the error terms and the price variable is expected. Then, the least squares estimate of own price elasticity is upwardly biased. In many cases, OLS estimates of equation (1) will produce a positive own price elasticity to demand, which is not consistent with either electricity or water being a normal good (Olmstead, 2009).

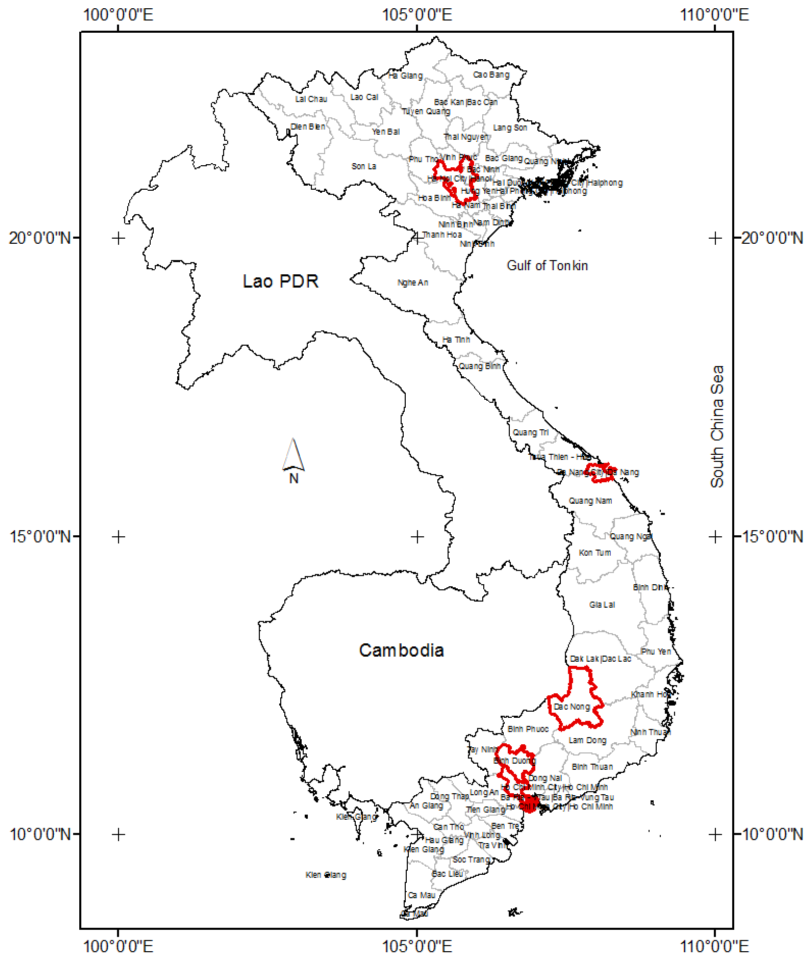
$$\beta_{\texttt{OLS}} = \beta_{\texttt{true}} + \frac{\texttt{cov}(\texttt{P}, \varepsilon)}{\texttt{var}(\texttt{P})}$$

The reduced-form approach models the statistic market equilibrium at which the supply and the demand intersects. To consistently estimate the demand function, a supply shock that induces multiple demand-supply equilibria along a single demand curve needs to be identified. Identifying such a shock, or an instrumental variable for the endogenous price, is crucial because most socio-economic factors are mutually correlated. (Olmstead, 2009) used a fixed fee charged at different volumes as an instrument for the marginal price, because it is correlated with price, but not demand. Fell et al (2010) used the lagged price of gas and coal as supply cost shifters. In this study, due to the availability of detailed household level data, we have been able to identify the registration status, the connection types, and the payment method as instruments for price. We justify the instruments in the following section.

2.2 Data

Data Source

Figure 4: Locations of the surveyed provinces in the World Bank's Vietnam Household Registration Study 2015.



We used a recent household survey, the Household Registration Survey, conducted by the World Bank (2015). The Household Registration Survey was designed to investigate the registration status ("Ho Khau") and its impact on accessibility to public services and welfare. The survey collected data on income and employment, expenditure, household welfare, public service access, migration history and registration status. The sampling frame came from the most recent Vietnam Population and Housing Census 2009, which had largely overlapping questions for many sections containing demographics and dwelling characteristics.

The survey was conducted in five provinces Ha Noi, Ho Chi Minh, Da Nang, Binh Duong and Dak Nong - with the highest migrant populations in the country (Figure 4). Overall, 5,000 households were interviewed, 1,000 in each province, based on a stratified random sample. Up to half of the households in the sample were migrant households, based on Ho Khau status.

Explanation of the Instrumental Variables

The most important task is the derivation of the quantity of electricity consumed and the corresponding price. Here, we have explained an innovative use of household registration status and related variables as instruments for electricity price. The household registration system (Ho Khau in Vietnam, or hukou in China) is an official monitoring policy in communist countries. It is an essential administrative tool of "public security, economic planning, and control of migration, at a time when the state played a stronger role in direct management of the economy and the life of its citizens" (World Bank and Vietnam Academy of Social Sciences, 2016). The government issues a household registration book for each household to keep track of the biographical and residential information of each household member. A registration status is determined by having a permanent residential address and by passing from parents to children. Some people have official registration status, and some have temporary migrant status. In between these two, a third category, long-term migrant status, is applied to those who migrated from another province and obtained KT3 status by having a work contract of at least one year in the host province.

The existence of Ho Khau has been subject to much controversy, because it creates a dual system that discriminates against those without an official registration status. The Vietnamese constitution recognizes free movement of its citizens. In reality, movements have been limited, for both economic and political reasons. Economically, having an official registration status affords the household with many economic benefits, including government-stipulated utility prices (electricity, water), schools for children, vehicle registration, and, to some extent, jobs as public servants. However, workers in the private sector, in foreign invested companies, and even in state-run enterprises are not affected by household registration. Those without official registration status are affected the most by public services. For example, temporary migrants may have to pay a commercially higher price for electricity or water. The middle category KT3 households can obtain government-run electricity or water services but are not on an entirely equal footing to those with a permanent registration status.

The registration status and related variables are crucial to identifying the demand function by inducing household-level variations in electricity price. In the surveyed data, we observed that a household either pays a flat rate price or an IBR price. For the flat price, the average price is the same as the marginal price, independent of consumed quantity. The IBR price has an increasing average price and an increasing marginal price with higher consumption. The type of price that a household pays is affected by whether the household has either permanent or temporary registration status, the type of connection to the electricity grid, and the method of payment.

In Table 2, most temporary households pay a flat rate price (1,586 out of 1,734 households), while most permanent households pay an IBR price (2,534 out of 3,086 households). Regarding the connection types in Table 3, up to half of those paying a flat rate (833 out of 1,734 households) connect to the electricity grid indirectly through other households. This is because temporary households live in rented houses and share a single connection with the landlord, using their own separate meters. In contrast, most households paying an IBR price connect directly to the grid (2,931 out of 3,086 households). Regarding the payment method in Table 4, most households paying a flat price pay to the landlord, who then pays back to the electricity provider at the end of each billing cycle. Often, landlords charge renters a higher flat price than they would pay the utility provider; thus, the landlords make some profit off the renters by selling access to electricity (World Bank and Vietnam Academy of Social Sciences, 2016). Meanwhile, all households paying an IBR price pay directly to the electricity company.

The flat rate price is known from the survey. This enables the exact quantity consumed to be calculated by dividing the average monthly electricity expenditure by the flat price. For those paying the IBR price, there is no unique price paid by each household. Therefore, we derived the average price based on the six consumption blocks, as indicated in Table 1. This average price varies, depending on the amount of consumption (Figure 3). We also identified the applicable marginal price, which is the highest block rate corresponding to the consumption level. Knowing the expenditure also allows extrapolation of the consumed quantity.

Table 2. Pricing Schemes by Household Registration Status.

	Flat rate price		IBR price	
Registration Status	Frequency	*Percent*	Frequency	*Percent*
Permanent	148	8.54	2,534	82.11
Temporary	1,586	91.46	552	17.89
Observations	1,734	100	3,086	100

Table 3. Pricing Schemes by Electric Connection Types.

	Flat rate price		IBR price	
Connection Types	Frequency	*Percent*	Frequency	*Percent*
Directly, with separate meter	710	40.95	2,931	94.98
Directly, with shared meter with other	191	11.01	124	4.02
Indirectly, through other households	833	48.04	16	0.52
National electricity system not available	0	0	15	0.49
Observations	1,734	100	3,086	100

Table 4. Pricing Schemes by Whom Electricity Bill Was Paid to.

	Flat rate price		IBR price	
Whom to Pay to	Frequency	*Percent*	Frequency	*Percent*
Owner of rented house	1,632	94.12	0	0
Other household living together	59	3.4	0	0
Other	43	2.48	0	0
Directly to electricity company	0	0	3,071	100
Observations	1,734	100	3,071	100

The registration status, the connection type, and the payment method are strongly correlated with price schemes, either a flat rate or an increasing block rate, and, eventually, with either the average price or the marginal price per kilowatt-hour paid by households. At the same time, we argue that these variables do not affect the demand for electricity in any way. The World Bank and Vietnam Academy of Social Sciences (2016) study found that there is no difference in wages for similar workers by registration status (Figure 5, Appendix). The study also indicated that the number of people affected by limited social protection access for temporary registrants is limited. In addition, it is not easy to manipulate the treatment status (i.e., where households attempted to obtain a permanent registration status to defray electricity or water costs), because this process is prohibitively expensive and time consuming. It is possible that having a permanent house might affect the propensity to invest in more energy efficient appliances and housing improvements that save energy, thereby violating the exclusion restriction condition. Therefore, we have controlled for an extensive list of variables to account for the impact of housing characteristics and asset ownerships. We have also presented a series of endogeneity tests, overidentification tests, and weak instruments tests to confirm the obtained result.

Derivation of Variables

<u>Dependent Variables</u>

To estimate the electricity demand at the household level, we derived the dependent variable as the average quantity of electricity in Kwh used in the last 12 months, the average electricity price, and the applicable marginal price. Note that the average price and the marginal price are the same for households paying a flat-rate price. The average price is lower than the marginal price for those paying according to the increasing block rate price (Figure 3).

<u>Income</u>

We derived the average monthly income as the sum of the income of all family members from wage and non-wage sources, including asset leasing, providing agricultural services, cultivation, forestry, fisheries, husbandry, aid, and remittances. Excluding households who reported a zero income and zero electricity price (not necessarily a coding error, because some may live with host households and have free limited use) and outlying observations (where income or electricity expenditure are greater than the mean by more than 5 standard deviations), the usable sample contained 4,820 observations out of the original 5,000 surveyed households.

<u>Price of Substitutes</u>

Ideally, to account for the impact of substitution for electricity, we should have the price of other energy types used by each household. The most popular fuels are liquefied natural gas used for cooking (4,075 out of 4,820 households), followed by oil, kerosene, and coal, which was used by only a small fraction of the sample. However, these prices are not available. We replaced the price of substitutes with the monthly total expenditure on other fuels, assuming that expenditure relates positively to price.

<u>Demographics</u>

We controlled for an extensive list of demographic variables, including those of the household heads and of all household members. We included the urban/rural status, the gender, the age, and the highest academic degree of the household head. Moreover, we included the household size, the number of female in the family, the number of persons in seven age categories, and the number of persons with an academic degree, from primary school to those with master's and doctoral degrees.

<u>Building characteristics</u>

As the survey shared many similar questions with a decennial population and housing census, we were able to control for many aspects of the electricity demand that are directly related to building characteristics. We included the floor size, dwelling types, roof materials, wall materials, floor materials, and toilet types.

Assets ownerships

Assuming that the stock of electricity-used appliances is fixed at the time of survey, we could examine the impact of having different types of appliance on the energy demand. Here we focused on the most energy intensive appliances, including air conditioners, water heaters, rice cookers, washing machines, induction cookers, microwaves, refrigerators, and personal computers.

Summary statistics are provided in Table 9 in the Appendix.

2.3 Electricity Demand Model with Instrumental Variables

We estimated the following demand function in a single-step, two-staged regression with instrumental variables. In the first stage, endogenous prices were estimated with a combination of one to three instrumental variables – the registration status (permanent or temporary), the grid connection types (direct with a separate meter, direct with shared meter, indirect through other households, and no grid available), and the payment method (to the owner of rented house, to other households living together, directly to electricity company, and other) – along with other explanatory variables.

$$lnP_i = \alpha_0 + \alpha_1 \times HHregis_i + \alpha_2 \times Grid_i + \alpha_3 \times PayMethod_i + ... + \sum_j X^j{}_i \times \alpha_j + \eta_i \quad (2)$$

In the second stage, the demand for electricity is estimated with the instrumented prices:

$$lnE_i = \beta_0 + \beta_1 \times \widehat{lnP}_i + \beta_2 \times lnIncome_i + \beta_3 \times lnP_i{}^s + \sum_j X^j{}_i \times \beta_j + \varepsilon_i \quad (3)$$

The quantity, price, income, expenditure on other fuels, and floor size entered the equations in logarithm, while the remaining variables in either level or binary represent either building characteristics or asset ownerships. We also included a set of district dummies to control for district-level location effects, such as differences in neighborhoods, localized urban heat islands, and micro-climate, which may affect heating or cooling equipment. The models were estimated with standard errors clustered at the provincial level, and with the sampling weights. We present two separate models for the average price and the marginal price.

3 Estimation Results and Discussion

3.1 Estimated Electricity Demand Function

For the main finding, we present three different results for each model of the average price and the marginal price, corresponding to IV models, both with and without district-level effects, using all three instruments and an OLS estimate. The full results are included in Table 10-11 in the Appendix.

First-stage regressions show that the payment methods are highly related to the endogenous price, while the coefficients of household registration status and connection types are not (Table 5). When examining these models with single instruments (Table 12), the instruments are all statistically significant and carry the expected signs. This is due to the correlation between these instruments, such as households with a permanent registration status likely having a direct connection to the grid, and paying directly to the electricity company. The first stage indicates that households with a permanent registration status often pay a lower price per kilowatt-hour than do those with a temporary registration status. Connecting directly to the grid with separate meter costs less than do other options. Moreover, households paying to owners of rented houses often pay a higher price than do those paying directly to the electricity company.

Second-stage estimates of own price elasticity are highly statistically significant in all models. The own price elasticity is almost unitarily elastic in the average price model, meaning that, for a one-percent increase in the average price, there is a one-percent reduction in quantity consumed, *ceteris paribus* (Table 6). The elasticity is even more responsive in the marginal price model. These estimates are higher than -0.77 to -0.15 in China (Lin et al., 2014) and -0.51 to -0.29 in India (Filippini and Pachauri, 2004).

The income elasticity is approximately 6-7%, confirming the potential impact of rising income on electricity consumption. This estimate is in the reasonable range obtained from developed countries by studies such as Fell et al (2010) or Wiesmann et al. (2011), but is less elastic than in China or India. Furthermore, the cross-price elasticity with other fuels shows a limited substitutability between electricity with other types of energy, such as LNG or firewood. Increasing the fuel price by 10% only leads to an increase of 0.5-0.6% in electricity use.

Regarding other important coefficients, owning air conditioners, washing machines, microwaves, refrigerators, and personal computers have the strongest influence on electricity demand. Cooking with electricity also raises electricity use dramatically. The types of dwellings, the roof, floor and wall materials, and the floor size also have an impact on energy use. These factors are likely to change in the long run, causing the demand for electricity to shift as income growth drives increased consumption indirectly via building

Table 5. First-Stage Regression (selected coefficients).

	Coeff.	*t-stat*	Coeff.	*t-stat*
Average Price Model				
Household Registration (permanent = 1, temporary = 0)	-0.0096	-1.15	-0.0060	-0.74
Connection Types (reference is "directly, with separate meter")				
Directly, with shared meter with other households	-0.0200	-1.27	-0.0245	-1.16
Indirectly, through other households	-0.0385	-1.64	-0.0518	-1.33
Payment Method (reference is "direct to electricity company")				
Owner of rented house	0.4660	11.43	0.4731	10.59
Other household living together	0.3236	6.33	0.3366	6.62
Other	0.2992	23.03	0.2888	14.58
Marginal Price Model				
Household Registration (permanent = 1, temporary = 0)	-0.0014	-0.15	-0.0002	-0.02
Connection Types (reference is "directly, with separate meter")				
Directly, with shared meter with other households	-0.0208	-1.31	-0.0257	-1.17
Indirectly, through other households	-0.0403	-1.72	-0.0529	-1.33
Payment Method (reference is "direct to electricity company")				
Owner of rented house	0.3264	7.6	0.3365	7.28
Other household living together	0.2155	3.17	0.2276	3.33
Other	0.2107	11.39	0.1943	6.75
District effects	Yes		No	
Observation	4,805		4,805	
R2 (AP)	0.6517		0.6179	
R2 (MP)	0.4937		0.4457	

The dependent variable is the logarithm of price.
Robust provincial clustered standard errors are used.

Table 6: Estimated Demand Functions (selected coefficients).

	IV with DE		**IV without DE**		**OLS**	
Explanatory Variables	Coefficient	*z-stat*	Coefficient	*z-stat*	Coefficient	*t-stat*
Average Price Model						
lnPrice	-0.9717	-10.63	-0.8497	-13.24	0.1767	1.97
lnIncome	0.0674	6.01	0.0602	3.49	0.0450	3.59
lnFuel	0.0508	9.52	0.0565	10.95	0.0442	11.17
Marginal Price Model						
lnMP	-1.4075	-7.95	-1.2063	-9.39	0.4772	4.34
lnIncome	0.0754	7.87	0.0654	3.59	0.0395	2.65
lnFuel	0.0579	8.93	0.0631	10.35	0.0410	10.01
District effects (DE)	Yes		No		Yes	
Observations	4,805		4,805		4,820	
R2 (AP)	0.7153		0.7032		0.7557	
R2 (MP)	0.6530		0.6486		0.7617	

The dependent variable is the logarithm of electricity consumption, in Kwh.
Robust provincial clustered standard errors are used.

improvements and more energy-intensive appliances.

Lastly, the OLS estimates are contradictory, indicating a positively sloping demand curve. However, this is not unexpected, due to the simultaneity of price and quantity, which biased up the price coefficients, as in Olmstead (2009).

Sensitivity Analysis

We checked the obtained results against an extensive range of possibilities. We obtained stable estimates of elasticity in models with a single instrument (Table 12), models of urban and rural areas (Table 13), and models of provincial demand (Table 14). The World Bank and Vietnam Academy of Social Sciences (2016) suggests that people without permanent registration may face discrimination in hiring for public jobs, but not for private sector jobs, thereby possibly violating the exclusion restriction. We eliminated households from the sample that had a member working in the public sector. The result remained almost unchanged (Table 15). We also estimated separate models for the lower income group and the upper income group (Table 16). The own price elasticity remained in the same region as established earlier. We observed that the price elasticity of the lower income group to be slightly less responsive than is that of the higher income group (-0.93 vs -1.03). This is not surprising, because the average consumption of the two groups is vastly different (141 Kwh for the lower income group vs. 235 Kwh for the higher income group). The former group likely uses electricity for basic household activities, such as lighting, powering a refrigerator, and rice cooking. Members of this group also face a lower average price than do the higher income households.

Earlier literature, such as Dubin (1985) and Henson (1984), which realized that, in cases of decreasing block rate, there is an income effect due to the extra consumption at a lower marginal price, made an adjustment to income, the rate premium structure (RPS), to account for this effect. We derived the RSP as being the difference between the actual electricity bill based on the increasing block rate structure and the marginal price of the highest consumed block. The RSP is zero for households paying a flat rate price and negative for those paying the IBR price. The results from the model with income adjusted for the RSP are practically identical to those from the models without adjustments (Table 17), which is as expected, because the RSP represented a negligible 0.67% of the total income on average. Table 18 and Figure 6 show the results and the distributions of estimated coefficients from a bootstrapped quantile regression with 500 replications with essentially identical results.

Last, but not least, one could argue that ownerships of electric appliances are determined endogenously by electricity price, income, and other socio-economic determinants, especially in the long term, with complete adjustments to all three decision levels, as described in Hartman (1979). A higher electricity price would likely discourage potential buyers of energy intensive appliances, such as air conditioners or electric cooking stoves, as well as prompting switches to more energy efficient appliances. Table 19 corresponds to a standard static equilibrium model, without the asset ownerships variables. We report more responsive elasticity coefficients to own price, income, and substitutes, which strengthens the overall finding of an elastic electricity demand to price.

Weak Instruments and Over-identification Tests

Table 7: Endogeneity, Weak Instruments and Over-identification Tests

	IV with DE		IV without DE	
Average Price Model				
Endogeneity test, adjusted for 5 clusters		*p-value*		*p-value*
F(1,4)†	16.9190	0.0147	16.0738	0.0160
First stage weak instrument test		*p-value*		*p-value*
F-stat†	266.522	0.0000	48.9335	0.0012
Cragg and Donald minimum eigenvalue statistics‡				
	393.316		416.917	
Over-identification test‡		*p-value*		*p-value*
Sargan (score) $\chi^2(5)$	2.5484	0.7692	1.4886	0.9144
Basmann $\chi^2(5)$	2.4845	0.7788	1.4658	0.9170
Marginal Price Model				
Endogeneity test, adjusted for 5 clusters		*p-value*		*p-value*
F(1,4)†	23.0946	0.0086	21.7343	0.0096
First stage weak instrument test		*p-value*		*p-value*
F-stat†	53.1031	0.0010	95.8621	0.0003
Cragg and Donald minimum eigenvalue statistics‡				
	154.603		172.757	
Over-identification test‡		*p-value*		*p-value*
Sargan (score) $\chi^2(5)$	2.3145	0.8041	2.3892	0.7931
Basmann $\chi^2(5)$	2.2564	0.8127	2.3531	0.7984

† Regressions with weights and clustered standard errors, statistics were calculated with forceweights option in STATA.
‡ Regressions without weights or clusters. Stock and Yogo (2002) critical values of the maximal IV size corresponding to 10, 15, 20, and 25% size for models of one endogenous variable and six instrument are 29.18, 16.23, 11.72, 9.38, respectively.

We first tested for the endogeneity of price variables used in the demand models. Wu-Hausman tests of both the average price and the marginal price indicated very strong evidence of endogenous prices, necessitating the need for the instrumental variables approach (Table 7). For weak instruments, we conducted an F-test on the instruments described in Stock and Yogo (2002), which is based on the minimum eigenvalue of the Cragg-Donald G_T statistics. We presented two F-statistics, corresponding to a model both with and without the district-level effects. The critical values are taken from Stock and Yogo (2002) for the maximal IV size of 10, 15, 20, and 25%. The null hypothesis of weak instruments was rejected at the 10% level in all models. We also tested whether the models suffered from over-identifying restrictions based on the Sargan's and Basman's χ^2 tests. As the three categorical instruments show up in six binary indicators (1 for the registration status, 2 for the connection types, and 3 for the payment methods), the χ^2 statistic assumes a degree of freedom of 5. We did not reject the null hypothesis, confirming the validity of all three instruments.

3.2 Discussion and Implications for Renewable Energy Development Policy

Table 8: Impacts of Price Increase on Consumption and Welfare.

Block	**Share**	**Baseline**	**Scenario 1†**			**Scenario 2‡**		
			ΔP	Q	ΔW	ΔP	Q	ΔW
(Kwh)	(%)	(Kwh)	(%)	(Kwh)	(VND1000)	(%)	(Kwh)	(VND1000)
≤ 50	21.79	29	0	29	0	0	29	0
$50-100$	25.02	75	0	75	0	0	75	0
$100-200$	33.63	143	3	139	7	3	139	7
$200-300$	10.84	241	6	227	26	6	227	26
$300-400$	4.05	344	7	320	48	8	315	57
≥ 400	4.67	770	9	703	161	15	656	266
Average Price Change (%)			**2.34**			**2.68**		
Average Consumption (Kwh)		**149**		**142**		**140**		
Consumption Reduction (%)				**-4.75**		**-6.34**		
Average Welfare Loss (VND1000)					**14.836**			**20.047**
Average Welfare Loss (% of household income)					**-0.14**			**-.19**

† Scenario 1 considers a uniform price increase of 10% from the current rate.
‡ Scenario 2 considers a 10% price increase for households using between 100-300Kwh, and a 20% price increase for consumption greater than 300Kwh a month.
The baseline is 2014 average consumption pattern. All scenarios assume a lifeline of 100Kwh unchanged.

We examined the possibility for a price adjustment and potential implications for renewable development in two hypothetical scenarios, which raise the marginal price uniformly by 10%, and by 10% and 20%, respectively, for consumption blocks between 100-300Kwh and greater than 300Kwh. The scenarios assume that the government offers the same lifeline for households using no more than 100Kwh. Table 8 shows the pattern of household consumption in 2014 (Electricity of Vietnam, 2015) and the impact of these price changes on household consumption, using a price elasticity of -1.

The equivalent average price increase is approximately 2.34% and 2.68% for scenarios

1 and 2, respectively. That corresponds to reductions of approximately 4.75% and 6.34% in total residential energy demand, or about 1.8-2.4Twh a year, assuming that 22 million households are connected to the grid. As only a small number of households currently consume in the highest price block, a progressively increasing price has only a limited impact on the total demand. The average welfare loss for households is approximately VND14.836 and VND20.047 (less than one US dollar) a month for scenarios 1 and 2, respectively. However, the variation is very large. Households currently consuming no more than 100Kwh, which includes up to 46% of all households, incur no loss, while those using more than 300Kwh a month bear most of the burden. As a percent of the average household income, these losses represent between 0.14% − 0.19% reduction in household welfare, measured as either the loss of consumer surplus, the compensating variation, or the equivalent variation (Figure 7), whose effects are expected to be minimal.

The revenue generated from the higher tariff would be approximately VND3,900-5,200bn (US$173-231m) a year. We explored a clean energy fund model, as in Milford et al. (2012). The fund would utilize the additional revenue to subsidize relatively more expensive solar power which is currently purchased at a feed-in-tariff of US$9.35c per kilowatt-hour, below a break-even price of about US$12-13c per kilowatt-hour. A back-of-the-envelope calculation indicates that Vietnam could easily meet the planned solar PV coverage of 4,000Mw installed capacity, representing 1.6% total electricity production (GIZ, 2016), by 2025, according to scenario 1.[1] The share of solar power could be even bigger in scenario 2. Such a clean energy fund would be jointly administered by multiple government agencies, utility providers, and third parties, including independent private or non-profit entities. The fund would draw revenue from the electricity price differential to finance renewable energy developers, through either subsidizing initial capital investment or a payment per kilowatt-hour generation basis.

Although not explicit in the analysis, a price hike would likely spur investments in electric appliances that consume less energy and promote environmentally friendly behaviors. The environmental benefit would be substantial, if the price hike is universally applicable to all households.

4 Conclusion and Policy Implications

We investigated the factors affecting demand for residential electricity, focusing on the elasticity of electricity demand to price, income, and price of alternative fuels. A reduced-form approach with instrumental variables was implemented to address the simultaneity issue involving electricity price and quantity. We used the household registration status,

[1] Assuming that each 1kw installed solar PV capacity generates 5 Kwh of electricity per day, 365 days a year. The subsidy payout is US2.65c per kwh electricity produced.

electricity connection types, and payment methods as instruments for price in newly surveyed household registration data. We found that the demand is almost unitarily elastic to the average price and is more elastic to the marginal price. The results are robust after controlling for an extensive list of demographic and housing characteristics, in addition to the stock of electric appliances. This is the first known estimate of electricity demand in Vietnam using household-level data.

The estimated price elasticity in Vietnam is higher than in many countries, such as China or India, indicating the potential of using pricing instruments for demand side management. Currently, pricing instruments have not been effectively used to encourage electricity savings, as the retail price is kept below the long-run marginal cost of production. A price increase may not affect the total revenue, while reducing consumption proportionately. Our calculation shows that a selective 10% increase in the block price for those consuming more than 100Kwh could reduce consumption by as much as 4.75% from the 2014 consumption baseline, while imposing minimal welfare loss on the consumers.

The Vietnamese government has recently adopted a plan to lessen the focus on coal and has removed nuclear power from the energy development program. A buyback program allowing the largest utility provider EVN to purchase excess power from rooftop solar PVs is a positive development, although it is not enough. A proposed clean energy fund could facilitate a quicker transition to cleaner and more sustainable resources, such as solar and wind power. If the right steps are taken, Vietnam could accelerate solar power supply, from almost nonexistence to providing a significant share of the total electricity production by 2025. Such a development will have immense implications for combating air pollution, mitigating greenhouse gas emissions and climate change, and improving environmental health benefits for the people.

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Additional Tables and Figures

Figure 1: Energy consumption trend in Vietnam in 2000-2014.

(FPT Securities Electricity Sector Report, 2015)

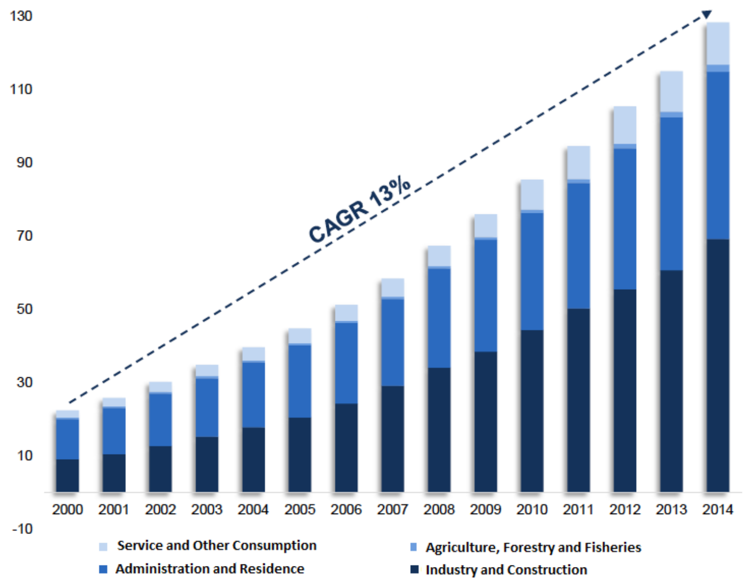


Figure 2: Trend of GDP Growth and Electricity Demand.

(FPT Securities Electricity Sector Report, 2015)

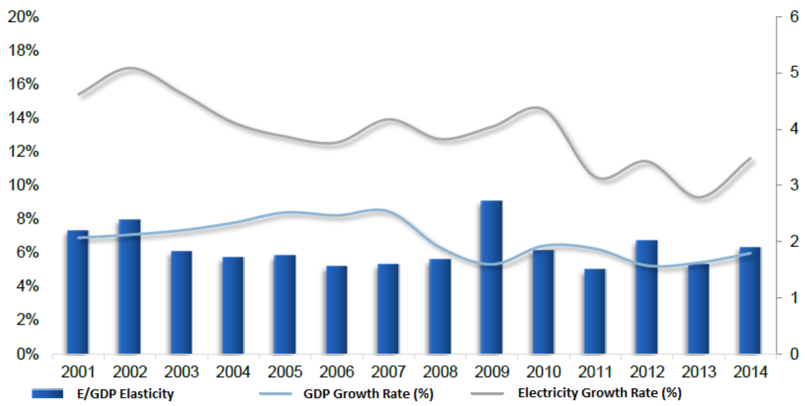


Figure 5: Distribution of hourly wages on log-scale by registration status.

(World Bank and Vietnam Academy of Social Sciences, 2016)

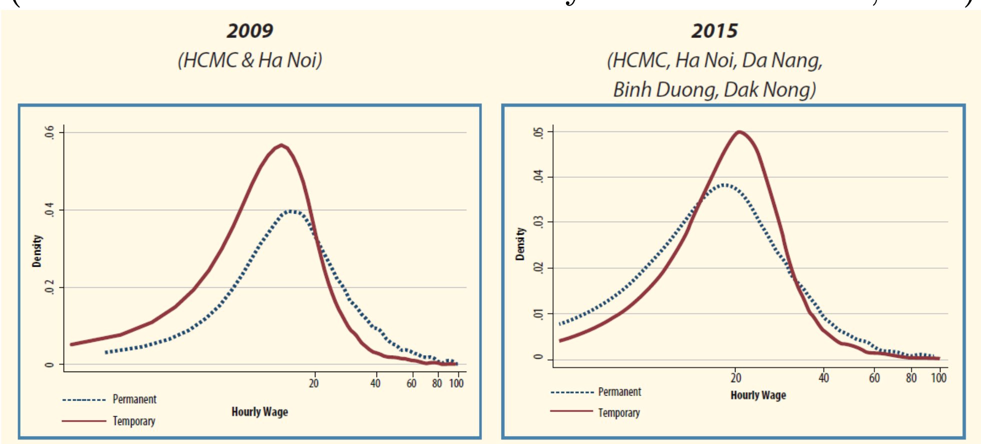
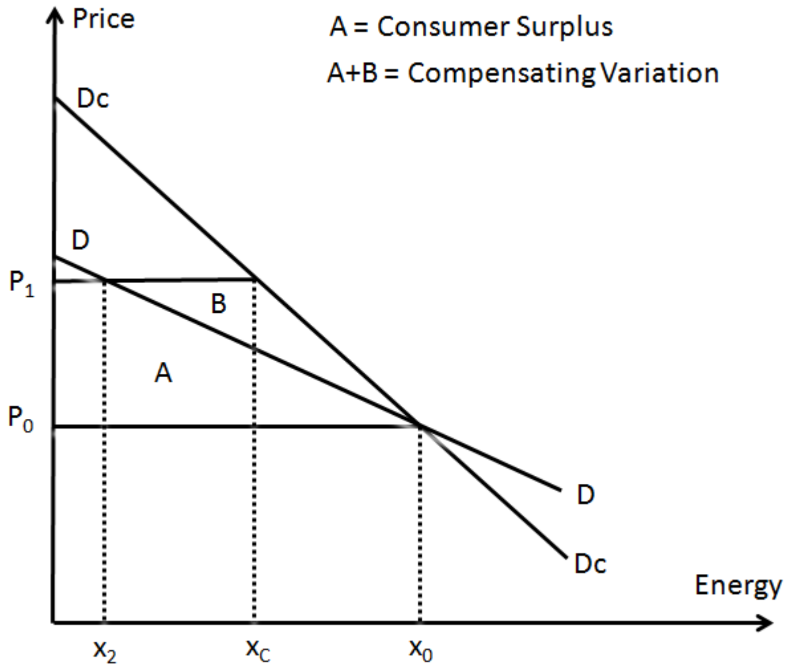


Figure 7: Price Change and Welfare Implication.



Following Hope and Singh (1995), suppose that the demand for good x as a function of own price p_x, price of substitutes p_s, and income y is:

$$x = f(p_x, p_s, ..., y)$$

From the Slutsky's equation:

$$\eta_{xp} = \eta^s_{xp} - s_x \times \eta_{xy}$$

with s_x is the budget share of good x, η_{xp}, η^s_{xp}, and η_{xy} the own price, cross price, and income elasticity. Due to a low budget share and a low income elasticity of electricity consumption, the impact of a price change will be mostly affected by the substitution effect. In the accompanying graph, for simplicity, assuming all demand curves are linear. A welfare change associated with a price increase from P_0 to P_1 could be measured by a change to the consumer surplus ($CS = A$ under the same demand curve DD), or the compensating variation ($CV = A + B$ under the compensated demand curve D_cD_c), or the equivalent variation (not shown). If the substitution effect dominates the income effect as in the case of electricity demand, all three measures above could be close. Then, a change in the consumer surplus could be approximated as:

$$\Delta CS = \int_{P_0}^{P_1} D(p)dP \approx x_0(P_1 - P_0)(1 + 0.5 \times \eta_{xp} \times \frac{P_1 - P_0}{P_0})$$

Table 9: Summary Statistics

Variable	Description	Obs	Mean	Std.	Min	Max
Monetary values						
Electricity	Monthly electricity consumption, VND1000	4,820	411.52	408.97	7	3000
Income	Monthly income, VND1000	4,820	10386.39	7892.43	100	60000
Fuel	Total expenditure on other fuel (gas, oil, coal, wood)	4,820	136.37	111.73	0	1000
Demographics						
urban	Urban/Rural status	4,820	0.58	0.49	0	1
hhsize	family size, persons	4,820	3.46	1.60	1	14
Age	Age of household head	4,820	39.59	12.11	17	80
Sex	Gender of head (male=1)	4,820	0.63	0.48	0	1
Female	Number of female in household	4,820	1.11	1.25	0	8
Number of persons in each age group						
age0	$\leq$ 5 years old	4,820	0.36	0.61	0	4
age1	5-10 years old	4,820	0.29	0.54	0	4
age2	10-20 years old	4,820	0.50	0.75	0	5
age3	20-30 years old	4,820	0.81	0.92	0	5
age4	30-40 years old	4,820	0.60	0.80	0	5
age5	40-50 years old	4,820	0.45	0.71	0	4
age6	50-60 years old	4,820	0.34	0.66	0	3
Education						
Degree	Highest education level of household head		Percent			
	No education	4,820	28.32		0	1
	Primary	4,820	23.61		0	1
	Secondary	4,820	21.62		0	1
	Vocational	4,820	11.8		0	1
	College	4,820	14.17		0	1
	MA and PhD	4,820	0.48		0	1
Number of household members at each education level						
Primary		4,820	0.61	0.86	0	6
Secondary		4,820	1.22	1.13	0	9
Vocational		4,820	0.20	0.50	0	6
College		4,820	0.47	0.82	0	6
Ma and Phd		4,820	0.03	0.20	0	3
Housing characteristics						
Floor	Floor area, m2	4,820	81.85	89.45	5	900
Aircon	Having air conditioner	4,820	0.28		0	1
Heater	Having water heater	4,820	0.29		0	1
Cooker	Having rice cooker	4,820	0.95		0	1
Stove	Having induction stove	4,820	0.93		0	1
Fridge	Having fridge	4,820	0.68		0	1
Washing	Having washing machine	4,820	0.48		0	1
Dwelling Type			Percent			
	Detached unit occupied by one household	4,820	65.31		0	1
	Detached unit occupied by several house	4,820	4.52		0	1
	Separate apartment	4,820	4.4		0	1
	Apartment shared with several household	4,820	0.77		0	1
	Room in a larger unit	4,820	22.68		0	1
	Shared room or dormitory	4,820	1.87		0	1
	Improvised/leu lan	4,820	0.29		0	1
	Others	4,820	0.17		0	1

Table 9: Summary Statistics - Continued

Variable	Description	Obs	Mean	Std.	Min	Max
Housing characteristics						
Roof material			Percent			
	Reinforced concrete	4,820	25.81		0	1
	Tile (baked clay)	4,820	5.98		0	1
	Sheets (asbestos/metal)	4,820	67.57		0	1
	Leaves/thatch/oil-paper	4,820	0.15		0	1
	Others	4,820	0.5		0	1
Wall material			Percent			
	Reinforced concrete	4,820	10.95		0	1
	Bricks/rocks	4,820	79.05		0	1
	Wood, metal	4,820	9.02		0	1
	Bamboo wattle/bambbo screen/plywood	4,820	0.56		0	1
	Others	4,820	0.41		0	1
Floor material			Percent			
	Concrete	4,820	9.59		0	1
	Wood	4,820	1.2		0	1
	Tile	4,820	74.56		0	1
	Lino	4,820	12.63		0	1
	Clay/earthen	4,820	1.95		0	1
	Others	4,820	0.06		0	1
Water source			Percent			
	Individual tap	4,820	51.31		0	1
	Public tap	4,820	6.22		0	1
	Bought water (in tank, bottle)	4,820	7.32		0	1
	Deep drill well with pump	4,820	22.32		0	1
	Deep well, constructed well	4,820	10.39		0	1
	Filtered spring water	4,820	0.46		0	1
	Hand dug well	4,820	0.73		0	1
	Rain water	4,820	0.98		0	1
	River, lake, pond	4,820	0.25		0	1
	Other	4,820	0.02		0	1
Toilet type			Percent			
	Septic tank/semi-septic tank	4,820	83.32		0	1
	Suilabh	4,820	8.51		0	1
	Double vault compost latrine	4,820	2.37		0	1
	Toilet directly over the water	4,820	0.29		0	1
	Other	4,820	1.6		0	1
	No toilet	4,820	3.92		0	1
Cooking fuel			Percent			
	Gas	4,820	84.54		0	1
	Electricity	4,820	6.18		0	1
	Oil, kerosene	4,820	0.1		0	1
	Wood	4,820	6.8		0	1
	Coal	4,820	0.89		0	1
	Other	4,820	1.47		0	1

Table 9: Summary Statistics - Continued

Variable	Description	Obs	Mean	Std.	Min	Max
Household registration and connection types						
Registration Status			Percent			
	Permanent	4,820	55.64		0	1
	Temporary	4,820	44.36		0	1
Type of connection to electricity system			Percent			
	Directly, with separate meter	4,820	75.54		0	1
	Directly, with shared meter with other	4,820	6.54		0	1
	Indirectly, through other households	4,820	17.61		0	1
	National electricity system not available	4,820	0.31		0	1
Who to pay electricity bill to			Percent			
	Directly to electricity company	4,805	63.91		0	1
	Owner of rented house	4,805	33.96		0	1
	Other household living together	4,805	1.23		0	1
	Other	4,805	0.89		0	1
Average Price, VND1000						
	Full sample	4,820	2.2524	0.6478	1	8
	Flat-rate price sample	1,734	2.8581	0.6878	1	8
	Block-rate price sample	3,086	1.9120	0.2601	1.5060	2.6236
Marginal Price, VND1000						
	Full sample	4,820	2.4847	0.6005	1	8
	Flat-rate price sample	1,734	2.8581	0.6878	1	8
	Block-rate price sample	3,086	2.2748	0.4185	1.6324	2.8457
Calculated consumption, Kwh/month						
	Full sample	4,820	188	169	2.33	1200
	Flat-rate price sample	1,734	77	84	2.33	1200
	Block-rate price sample	3,086	250	173	7	1143

Table 10: Average Price Model, Full Results.

	IV with DE		IV without DE		OLS	
Variables	Coefficient	*z-stat*	Coefficient	*z-stat*	Coefficient	*t-stat*
lnPrice	-0.9717	-10.63	-0.8497	-13.24	0.1767	1.97
lnIncome	0.0674	6.01	0.0602	3.49	0.0450	3.59
lnFuel	0.0508	9.52	0.0565	10.95	0.0442	11.17
Demographics						
urban	-0.0337	-1.59	-0.0304	-1.12	-0.0456	-2.7
hhsize	0.1462	3.7	0.1710	5.07	0.1091	3.69
Age	0.0019	1.24	0.0024	1.95	0.0056	5.29
Sex	0.0356	2.75	0.0271	1.8	0.0382	2.7
Female	-0.0059	-0.37	-0.0112	-0.68	0.0116	0.76
age0	-0.0564	-1.87	-0.0859	-3.43	-0.0265	-1.16
age1	-0.0709	-2.12	-0.1070	-3.82	-0.0236	-0.91
age2	-0.0911	-1.67	-0.1178	-2.35	-0.0556	-1.29
age3	-0.0653	-1.29	-0.0868	-1.61	-0.0378	-0.95
age4	-0.0234	-0.46	-0.0474	-0.81	0.0058	0.14
age5	0.0162	0.44	-0.0090	-0.22	0.0364	1.35
age6	-0.0032	-0.1	-0.0193	-0.53	-0.0025	-0.09
Household head's highest degree (base is no education)						
primary	0.0495	1.59	0.0486	1.9	0.0810	2.44
secondary	-0.0146	-0.32	-0.0059	-0.14	-0.0002	0
vocational	-0.0689	-1.22	-0.0649	-1.23	-0.0404	-0.8
college	0.0470	0.65	0.0606	0.93	0.0528	0.76
maphd	-0.0446	-0.39	-0.0330	-0.28	-0.0999	-0.95
Number of members with the highest degree (base is no education)						
primary	0.0497	1.94	0.0527	2.18	0.0421	2.24
secondary	0.0207	0.79	0.0281	1.08	0.0007	0.04
vocational	0.0489	1.55	0.0428	1.48	0.0293	1.13
college	-0.0187	-0.62	-0.0251	-0.8	-0.0289	-1.28
maphd	0.0008	0.01	-0.0244	-0.36	-0.0310	-0.69
Housing characteristics						
lnSize	0.1377	10.75	0.0851	5.06	0.1828	36.2
aircon	0.2878	7.24	0.3989	11.55	0.2607	10.44
heater	0.0216	1.06	0.0093	0.29	0.0264	0.85
cooker	0.0971	1.91	0.0712	1.38	0.1532	4.54
washing	0.1686	5.37	0.1641	8.93	0.1651	4.26
stove	0.0273	0.52	0.0107	0.15	0.0241	0.27
fridge	0.6225	12.53	0.6320	13.81	0.6860	9.93
PC	0.0821	3.5	0.1019	3.62	0.0617	1.79
microwave	0.0655	4.36	0.0859	3.55	0.0603	4.49
fuelcook	0.2706	16.98	0.3097	10.68	0.2276	10.59
Dwelling type						
Detached unit	0.0842	2.12	0.1082	2.4	0.0096	0.2
Separate apartment	0.1053	3.08	0.1186	4.53	-0.0773	-1.22
Apartment shared	0.4408	3.65	0.4203	3.64	0.1849	1.76
Room in a larger unit	-0.0448	-1.68	-0.0538	-1.14	-0.2253	-5.54
Shared room	0.0214	0.5	-0.0531	-1.63	-0.1830	-11.68
Improvised/leu lan	-0.1964	-1.1	-0.2111	-1.26	-0.1275	-0.49
Others	-0.1905	-4.93	-0.2530	-8.73	-0.3877	-4.66

Table 10: Average Price Model, Full Results (continued).

	IV with DE		IV without DE		OLS	
Variables	Coefficient	*z-stat*	Coefficient	*z-stat*	Coefficient	*t-stat*
Roof material						
Tile	0.0348	1.13	0.0420	0.92	0.0231	0.83
Sheets	-0.0065	-0.23	-0.0577	-1.07	0.0094	0.3
Leaves	0.0490	0.21	0.0844	0.37	0.0503	0.2
Others	0.1993	2.87	0.1438	2.14	0.1464	2.07
Wall material						
Bricks/rocks	-0.0133	-0.44	-0.0242	-0.5	0.0071	0.26
Wood, metal	-0.0640	-2.1	-0.1381	-1.71	-0.0350	-0.88
Bamboo	0.0059	0.15	-0.1244	-1.91	-0.1286	-1.98
Others	-0.2865	-1.6	-0.3004	-1.73	-0.2804	-2.56
Floor material						
Wood	-0.2090	-2.49	-0.1259	-2.29	-0.0516	-0.99
Tile	-0.1029	-4.87	-0.0619	-1.8	-0.1021	-4.61
Lino	-0.0893	-2.93	0.0301	1.84	-0.0946	-3.45
Clay/earthen	0.0334	0.52	0.0748	1.08	0.0623	1.11
Others	-0.4505	-3.49	-0.3782	-2.27	-0.8101	-7.11
Water						
Public tap	-0.0590	-1.73	-0.1029	-2.39	-0.0470	-1.04
Bought water	0.0467	1.88	0.0322	1.36	-0.0110	-0.26
Deep drill well	0.0330	2.47	0.0216	0.6	0.0102	0.46
Constructed well	-0.0946	-5.3	-0.2521	-4.45	-0.0671	-4.95
Filtered spring water	-0.0250	-0.33	-0.1663	-1.81	-0.1193	-2.71
Hand dug well	-0.1566	-2.49	-0.3262	-3.43	-0.0926	-2.02
Rain water	-0.0474	-0.84	-0.0362	-0.53	-0.0361	-1.27
River, lake, pond	-0.5466	-8.47	-0.6635	-7.66	-0.5952	-11.61
Other	-0.4233	-3.05	-0.5846	-3.4	-0.3731	-3.22
Toilet						
Suilabh	-0.0038	-0.22	-0.0441	-2.05	-0.0140	-0.74
Latrine	-0.0113	-0.18	-0.0209	-0.34	-0.0279	-0.45
Toilet directly	-0.1059	-4.71	-0.1471	-5.05	-0.0708	-2.14
Other	-0.1096	-1.17	-0.1084	-0.93	-0.0398	-0.44
No toilet	-0.1116	-7.69	-0.1645	-12.38	-0.0474	-1.94
Constant	3.3671	19.12	3.1902	14.76	2.3007	34.1
District effects	Yes		No		Yes	
Observation	4,805		4,805		4,820	

Table 11: Marginal Price Model, Full Results.

	IV with DE		IV without DE		OLS	
Variables	Coefficient	*z-stat*	Coefficient	*z-stat*	Coefficient	*t-stat*
lnMP	-1.4075	-7.95	-1.2063	-9.39	0.4772	4.34
lnInc	0.0754	7.87	0.0654	3.59	0.0395	2.65
lnFuel	0.0579	8.93	0.0631	10.35	0.0410	10.01
Demographics						
urban	-0.0424	-1.71	-0.0338	-1.07	-0.0445	-1.98
hhsize	0.1541	3.26	0.1810	4.6	0.1016	3.89
Age	0.0012	0.66	0.0019	1.26	0.0064	6.5
Sex	0.0394	2.36	0.0282	1.53	0.0372	2.96
Female	0.0007	0.04	-0.0055	-0.31	0.0115	0.79
age0	-0.0680	-1.74	-0.1004	-3.2	-0.0180	-0.95
age1	-0.0738	-1.83	-0.1147	-3.54	-0.0159	-0.68
age2	-0.1004	-1.62	-0.1290	-2.31	-0.0476	-1.25
age3	-0.0769	-1.36	-0.1001	-1.68	-0.0299	-0.84
age4	-0.0340	-0.6	-0.0601	-0.93	0.0132	0.36
age5	0.0149	0.36	-0.0135	-0.29	0.0395	1.59
age6	0.0005	0.01	-0.0175	-0.43	-0.0031	-0.13
Household head's highest degree (base is no education)						
primary	0.0450	1.83	0.0440	2.26	0.0867	2.45
secondary	-0.0181	-0.4	-0.0076	-0.19	0.0029	0.07
vocational	-0.0773	-1.4	-0.0709	-1.39	-0.0339	-0.7
college	0.0523	0.71	0.0665	1.03	0.0519	0.77
maphd	-0.0372	-0.26	-0.0303	-0.22	-0.1099	-1.17
Number of members with the highest degree (base is no education)						
primary	0.0588	2	0.0600	2.24	0.0379	2.2
secondary	0.0319	1.08	0.0397	1.4	-0.0061	-0.4
vocational	0.0634	1.7	0.0548	1.62	0.0214	0.96
college	-0.0118	-0.35	-0.0197	-0.56	-0.0330	-1.73
maphd	0.0102	0.17	-0.0198	-0.27	-0.0386	-0.95
Housing characteristics						
lnSize	0.1535	9.94	0.0894	4.56	0.1831	39.16
aircon	0.3222	6.16	0.4464	12.02	0.2456	10.83
heater	0.0267	1.08	0.0126	0.35	0.0252	0.75
cooker	0.0754	1.3	0.0528	0.91	0.1637	5.02
washing	0.1965	6.3	0.1879	12.69	0.1552	3.87
stove	0.0363	0.66	0.0166	0.21	0.0218	0.23
fridge	0.6416	16.45	0.6501	18.29	0.6877	9.13
PC	0.0978	3.23	0.1182	3.42	0.0539	1.47
microwave	0.0761	3.71	0.0974	3.23	0.0561	5.15
fuelcook	0.2848	14.49	0.3268	11.62	0.2173	8.97
Dwelling type						
Detached unit	0.1051	2.4	0.1287	2.56	-0.0079	-0.16
Separate apartment	0.1305	2.86	0.1385	4.51	-0.1102	-1.63
Apartment	0.5180	3.91	0.4850	3.81	0.1244	1.05
Room in a larger unit	-0.0334	-1.07	-0.0476	-0.87	-0.2535	-5.1
Shared room	0.0680	1.45	-0.0244	-0.6	-0.2265	-7.9
Improvised/leu lan	-0.2448	-1.33	-0.2540	-1.44	-0.1002	-0.36
Others	-0.1779	-3.89	-0.2561	-6.49	-0.4186	-4.59

Table 11: Marginal Price Model, Full Results (continued).

	IV with DE		**IV without DE**		**OLS**	
Variables	Coefficient	*z-stat*	Coefficient	*z-stat*	Coefficient	*t-stat*
Roof material						
Tile	0.0275	0.83	0.0398	0.78	0.0244	0.93
Sheets	-0.0146	-0.5	-0.0736	-1.26	0.0141	0.43
Leaves	0.0834	0.38	0.1234	0.55	0.0392	0.16
Others	0.2461	2.93	0.1797	2.4	0.1239	1.86
Wall material						
Bricks/rocks	-0.0162	-0.58	-0.0279	-0.56	0.0105	0.38
Wood, metal	-0.0694	-2.08	-0.1561	-1.65	-0.0322	-0.81
Bamboo	0.0762	2.19	-0.0982	-1.42	-0.1741	-2.43
Others	-0.2745	-1.21	-0.2966	-1.39	-0.2882	-3.32
Floor material						
Wood	-0.2621	-2.92	-0.1553	-2.84	-0.0168	-0.33
Tile	-0.1040	-4.59	-0.0557	-1.39	-0.1037	-4.55
Lino	-0.0863	-2.54	0.0539	3.06	-0.0984	-3.9
Clay/earthen	0.0393	0.55	0.0855	1.12	0.0635	1.2
Others	-0.4695	-3.52	-0.3834	-2.18	-0.8521	-8.63
Water						
Public tap	-0.0636	-1.69	-0.1161	-2.38	-0.0438	-0.97
Bought water	0.0538	1.99	0.0352	1.68	-0.0212	-0.45
Deep drill	0.0360	2.43	0.0206	0.56	0.0061	0.23
Deep well	-0.1197	-4.76	-0.3005	-4.12	-0.0547	-3.7
Filtered spring water	-0.0185	-0.2	-0.1914	-1.73	-0.1126	-3.28
Hand dug well	-0.1926	-2.28	-0.3883	-3.15	-0.0729	-1.81
Rain water	-0.0368	-0.5	-0.0169	-0.21	-0.0379	-1.37
River, lake, pond	-0.6150	-7.25	-0.7536	-6.59	-0.5695	-12.72
Other	-0.4475	-2.67	-0.6266	-3	-0.3554	-3.07
Toilet						
Suilabh	-0.0069	-0.36	-0.0557	-2.46	-0.0134	-0.62
Latrine	-0.0222	-0.3	-0.0309	-0.46	-0.0258	-0.45
Toilet directly	-0.1578	-9.54	-0.1975	-11.83	-0.0501	-1.36
Other	-0.1653	-1.57	-0.1604	-1.25	-0.0138	-0.16
No toilet	-0.1592	-7.69	-0.2142	-7.35	-0.0235	-0.92
Constant	3.6990	15.15	3.4700	12.53	2.0516	32.4
District effects	Yes		No		Yes	
Observation	4,805		4,805		4,820	

Table 12. Sensitivity Analysis with a Single Instrument.

Instrument	Connection Type		Payment Method		Registration Status	
	Coefficient	*z-stat*	Coefficient	*z-stat*	Coefficient	*z-stat*
Average Price Model						
LnPrice	-0.9086	-2.33	-0.9784	-10.8	-1.0471	-9.69
lnIncome	0.0658	3.66	0.0675	5.97	0.0685	5.62
lnFuel	0.0498	9.01	0.0508	9.53	0.0505	9.06
First Stage						
Connection Types						
Base (directly with separate meter)						
Directly	0.0619	2.09				
Indirectly	0.0778	1.84				
No grid	-0.1464	-4.02				
Payment Method						
Base (direct to electricity company)						
Owner of rented house			0.4559	11.72		
Other household living together			0.2988	5.64		
Other			0.2779	127.08		
Household Registration (permanent = 1, temporary = 0)					-0.1389	-6.98
Marginal Price Model						
LnMP	-0.9963	-1.18	-1.4352	-7.85	-1.5942	-5.63
LnIncome	0.0670	2.72	0.0759	7.75	0.0781	6.56
LnFuel	0.0536	5.69	0.0581	9.01	0.0588	7.79
First Stage						
Connection Types						
Base (directly with separate meter)						
Directly	0.0354	1.48				
Indirectly	0.0401	1.06				
No grid	-0.1699	-4.38				
Payment Method						
Base (direct to electricity company)						
Owner of rented house			0.3126	7.27		
Other household living together			0.1891	2.72		
Other			0.1883	14.72		
Household Registration (permanent = 1, temporary = 0)					-0.0912	-5.5
District effects	Yes		Yes		Yes	
Observation	4,820		4,805		4,820	

All models were estimated with district effects and provincial clustered standard errors.
The table shows selected coefficients only. The full results are available from the author up on request.

Table 13. Sensitivity Analysis
Separating Electricity Demand for Urban and Rural Areas.

	Urban		Rural	
	Coefficient	*z-stat*	Coefficient	*z-stat*
Average Price Model				
lnPrice	-1.0233	-14.78	-0.9410	-4.15
lnIncome	0.1015	12.09	0.0257	3.45
lnFuel	0.0451	3.95	0.0560	7.93
Marginal Price Model				
LnMP	-1.4662	-9.07	-1.3215	-4.31
lnIncome	0.1096	13.75	0.0332	5.23
lnFuel	0.0533	4.76	0.0613	10.23
District effects	Yes		Yes	
Observation	2,818		1,987	

All models were estimated with district effects and provincial clustered standard errors.
The table shows selected coefficients only. The full results are available from the author up on request.

Table 14. Sensitivity Analysis with Provincial Demands.

	Ha Noi		Da Nang		Dak Nong		Binh Duong		Ho Chi Minh	
	Coeff	*z-stat*	Coeff	*z-stat*	Coeff	*z-stat*	Coeff	*z-stat*	Coeff	*z-stat*
Average Price Model										
lnPrice	-0.9590	-6.56	-0.9497	-5.96	-0.9753	-4.28	-0.7729	-3.02	-1.0639	-5.72
lnIncome	0.0856	3.53	0.1122	4.02	0.0164	0.72	0.0545	1.33	0.0649	2.10
lnFuel	0.0320	2.11	0.0707	3.94	0.0443	3.09	0.0576	2.45	0.0494	2.65
Marginal Price Model										
lnMP	-1.3277	-6.14	-1.1503	-5.39	-1.2685	-3.68	-1.4238	-2.96	-1.5676	-4.89
lnIncome	0.0871	3.38	0.1104	3.62	0.0214	0.84	0.0515	1.15	0.0901	2.53
lnFuel	0.0347	2.15	0.0771	3.89	0.0513	3.11	0.0674	2.59	0.0592	2.83
District effects	Yes		Yes		Yes		Yes		Yes	
Observation	970		980		894		989		972	

All models were estimated with district effects and provincial clustered standard errors.
The table shows selected coefficients only. The full results are available from the author up on request.

Table 15. Sensitivity Analysis. Excluding Households with Government Employment.

	Coefficient	*z-stat*
Average Price Model		
lnPrice	-1.0138	-9.67
lnIncome	0.0609	6.25
lnFuel	0.0518	10.64
Marginal Price Model		
LnMP	-1.4653	-7.13
lnIncome	0.0686	8.57
lnFuel	0.0591	9.91
District effects	Yes	
Observation	4,259	

Table 16. Sensitivity Analysis. Separating Income Group by the 50th Percentile (pct50th=VND8,833,000).

	income <50th percentile		**income > 50th percentile**	
	Coefficient	*z-stat*	Coefficient	*z-stat*
Average Price Model				
lnPrice	-0.9305	-11.52	-1.0269	-7.96
lnIncome	-0.0085	-0.55	0.1844	3.81
lnFuel	0.0565	10.68	0.0423	3.23
Marginal Price Model				
lnMP	-1.2398	-9.58	-1.6756	-6.14
lnIncome	-0.0053	-0.36	0.2053	4.09
lnFuel	0.0639	12.29	0.0480	3.01
District effects	Yes		Yes	
Observation	2,395		2,410	

Table 17. Sensitivity Analysis.
Income Adjusted for the Rate Structure Premium (RSP) in the Marginal Price Model.

Variables	Coefficient	Std	z	*p-value*	95% CI Lower	95% CI Upper
lnMP	-1.4078	0.1769	-7.96	0	-1.7546	-1.0610
lnAdjustedIncome	0.0871	0.0110	7.94	0	0.0656	0.1086
lnFuel	0.0578	0.0065	8.86	0	0.0450	0.0706
District effects	Yes					
Observation	4,805					

$\texttt{RSP} = \texttt{Quantity} \times (\texttt{Marginal Price} - \texttt{Average Price})$

$\texttt{AdjustedIncome} = \texttt{Income} - \texttt{RSP}$

The RSP is zero for flat-rate households and those consumed no more than 50Kwh a month. RSP rises with a higher consumption.

Table 18. Sensitivity Analysis. Bootstrapped Quantile Regression with Instrumental Variables with 500 Replications (selected coefficients).

Variables	Coefficient	Bootstrap Std	z	*p-value*	95% CI Lower	95% CI Upper
Average Price Model						
LnPrice	-0.8433	0.0894	-9.43	0.0	-1.0185	-0.6680
lnIncome	0.0647	0.0141	4.59	0.0	0.0371	0.0923
lnFuel	0.0410	0.0096	4.27	0.0	0.0222	0.0599
Marginal Price Model						
LnMP	-1.2024	0.1183	-10.16	0.0	-1.4343	-0.9704
LnIncome	0.0708	0.0140	5.06	0.0	0.0434	0.0982
lnFuel	0.0466	0.0093	5.02	0.0	0.0284	0.0648
District effects	Yes					
Observation	4,805					

Figure 6: Quantile Regression Plots.

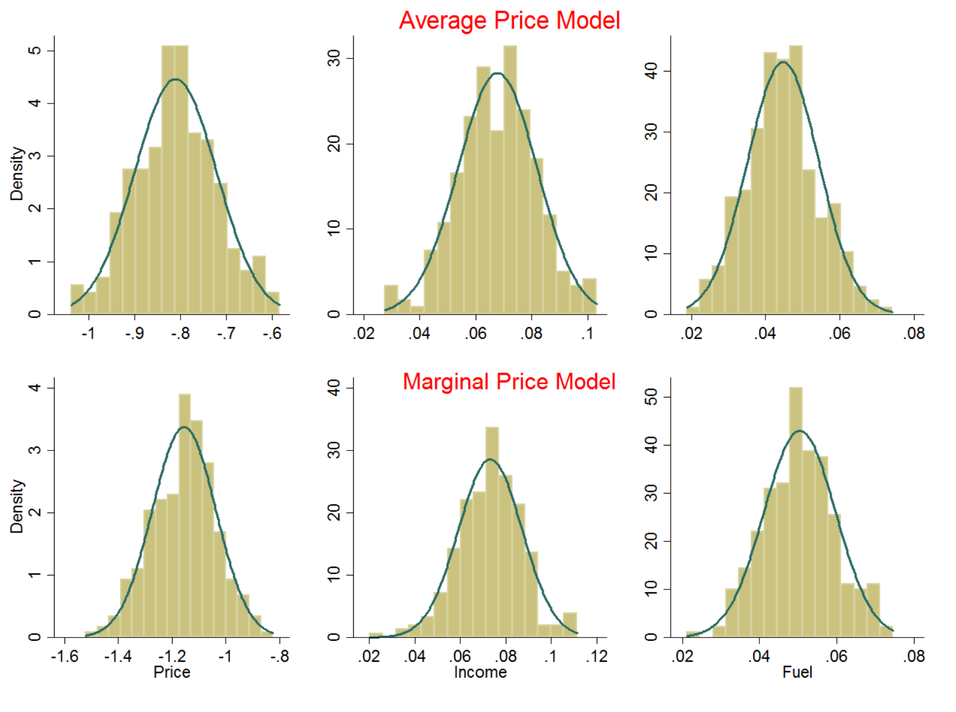


Table 19. Sensitivity Analysis.
Excluding Asset Ownerships Variables.

	Coefficient	*z-stat*
Average Price Model		
lnPrice	-1.6307	-10.19
lnIncome	0.1486	7.50
lnFuel	0.0848	7.61
Marginal Price Model		
LnMP	-2.4704	-6.61
lnIncome	0.1751	8.15
lnFuel	0.0999	7.1
District effects	Yes	
Observation	4,805	