Family size, Increasing block tariff and Economies of scale of household electricity consumption in Vietnam from 2010 to 2014

Nguyen Hoai-Son[1,2], Ha-Duong Minh[1,3]

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[1] Clean Energy and Sustainable Development Lab (CleanED), 18 Hoang Quoc Viet, Cau Giay, Ha Noi, Vietnam
[2] National Economics University (NEU), Vietnam
[3] International research center on environment and development (CIRED), National Center for Scientific Research (CNRS), France
Email: hoaisonkt@gmail.com; minh.haduong@gmail.com

Abstract
Household electricity consumption potentially offers economies of scale, since lighting, cooling or cooking can be shared among household members. This idea needs to be tested empirically. Under an increasing block tariff schedule the marginal and average price of electricity increases with total consumption. Does this effect offset economies of scale in the larger families?. This paper uses data from Vietnam Household Living Standard Survey (VHLSS) in 2010, 2012 and 2014 to investigate whether there is economies of scale for Vietnam household electricity consumption in that period. The data will be tested formally by an OLS model and check robustness by visualization of local linear regressions. Estimates results and robust check confirm that in general, economies of scale do exist for household electricity consumption in Vietnam from 2010-2014.

Keywords: household economies of scale, electricity use, increasing block tariffs.

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1. Introduction

Vietnam has changed to market-oriented economy in 1986, however, electricity is still one some special goods whose prices are set by government. Since 1994, the government has set electricity price in increasing block form to support for low income household and give a disincentive to high consumption due to the mismatch between demand and supply. In the newest proposal for electricity price reform, EVN proposed three alternative schedules including two progressive tariff schedules and one single price schedule (EVN, 2015). However, many experts disagree with the single price schedule and are in favor of progressive tariff schedule. The remain debatable topic is the number of blocks; the price gaps between blocks and the impacts of the progressive schedules on low income households (Châu Anh, 2015; Đình Dũng, 2015).

Yet, there is no research or official discussion on the impact of the progressive tariff schedules on large size households. This is a serious gap since large size households will suffer the high price due to high demand while the household usually has low income[1]. In that case, progressive tariff may turn out to be a penalty for some low-income households instead of protecting them.

This paper will use data from Vietnam Household Living Standard Survey (VHLSS) 2010-2014 to investigate whether the current progressive tariff has negative impact on large size households' electricity consumption. In other word, we will examine how the progressive tariff schedules impact on economy of scale of household electricity consumption in Vietnam from 2010 to 2014. The result will provide empirical evidences for policy makers to design electricity price in future. The paper contains five parts. The next part is literature review following by data and methodology. The next one is results and discussion. The last part is conclusion.

2. Literature review

Economies of scale

Economies of scale in household consumption is the phenomenon in which the cost per capita that maintains a given level of living standard may reduce as household size increases (Nelson, 1988, p. 1301). Economies of scale of household consumption may come from three sources (see Nelson, 1988 for review).

- First, economies of scale comes from increasing return in household production such as cooking meals.
- Second, it may come from "bulk buy". When household size increases, demand for goods and services increases. The household may have discount for purchasing large amount of goods and services.
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- Third, it may come from the consumption of public goods in which the consumption of one household member does not rule out or rule out completely the consumption of other members. Since the public goods such as lighting or air conditioners can be shared, as the size of household increases, the cost of the goods per capita declines. In addition, the increase in household sizes can also reduce the cost per capita for that public goods because of the increases in the utilization rate of the public goods which are indivisible such as water heating, pilot light or refrigerator room.

So far, economy of scale in household consumption is found in many goods and services. Nelson (1988) found substantially and statistic significantly economy of scale for 5 classes of goods and services including food, shelter, household furnishing/operation, clothing and transportation in US data during 1960/61 and 1972/73. Deaton and Paxson (1998) found that at any given household expenditure per capita, expenditure per head on food falls as the household size increases in seven countries including USA, Great Britain, France, Taiwan, Thailand, Pakistan and South Africa.

A major empirical problem in detecting economies of scale is to separate the impact of household size from the impact of household composition. Nelson (1988, p. 1302) indicated that "Observed household demands

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1 Correlation between household size and income per capita in VHLSS 2014 is negative and significant at the 0.05 significance level

may be expected to vary with household size not only because of economies of scale, but also because of the varying preferences or needs of household members, from infants to grandparents."

Two approaches are employed to handle this problem so far. The first approach is to require strictly assumption that preferences are identical among all household members (Nelson, 1988). In empirical section, Nelson (1988) studies only all-adult households with "heads" aged 35-55. Thus, he can get rid of the impacts of composition factor in observed demand.

The second approach is to use two separate variables for household size and composition (Ironmonger, Aitken and Erbas, 1995; Deaton and Paxson, 1998). The household size variable is the total number of households' members. The household composition can be represented by category variables (Ironmonger, Aitken and Erbas, 1995) or continuous variables (Deaton and Paxson, 1998). Ironmonger, Aitken and Erbas (1995) uses this approach for 3 types of adult-only household including young household with adults from 15 to 45, older household with adults over 45 and mixed household with adults over 15. Deaton and Paxson (1998) use (k-1) variables for household composition. Each household is separated to k groups defined by age and sex. Each of the (k-1) variable above is the ratio to household size of household members who fall in the corresponding group. In this approach, the variable household size corresponds to the concept of doubling the number of household member while keeping family composition constant. Therefore, the approach can eliminate the impact of difference in members' preference in household consumption.

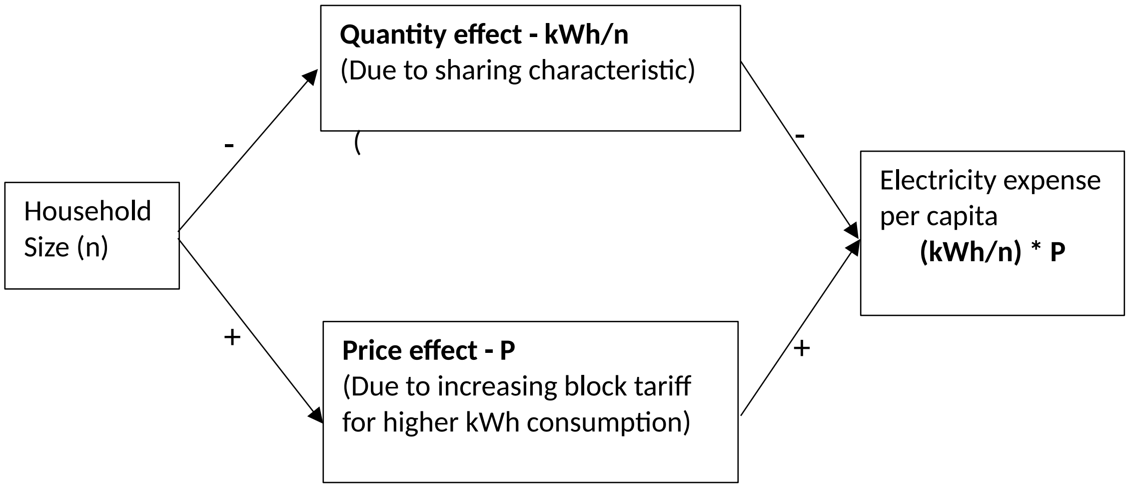
Of all approach above, Deaton and Paxson (1998)'s approach has an important side effect advantage. In addition to identifying the impact of household size, it allows to investigate the differences in preference between a certain group of the (k-1) groups with the base group (the k^{th} group). Therefore, this paper will apply Deaton and Paxson (1998)'s approach. Each household will be separated to three groups including children who is less than 15, adults from 16 to 59 and elders who is over 60. Two variable children ratio and elder ratio will be employed to represent for household composition. The coefficients of the variables indicate whether there is difference in consumption between a child or an elder and an adult.

Economy of scale for household electricity consumption

Electricity consumption has high potential for economies of scale in household consumption since it is a typical public goods. People do not consume electricity directly but indirectly via appliances which can be share among household members such as lighting or cooling devices. When a household's size increase, the household can maximize the use of share goods including electricity use (Ironmonger, Aitken and Erbas, 1995), thus decrease the amount of electricity consumption per capita.

So far, researchers have found empirical evidences for economies of scale in household electricity consumption. Ironmonger, Aitken and Erbas (1995) investigated the data of Australia in 1987 and 1990 and found that as household size increases, energy-efficiency increases and electricity expense per cap decreases. Filippini and Pachauri (2004) found in India that houses with larger and younger household heads have lower electricity consumption than those have fewer members and older household heads. However, whether the economies of scale exists or not is still in question because electricity in many countries including Vietnam, has increasing block tariff instead of "bulk buy" price as other goods. The increasing block tariff means that the higher level of consumption, the higher price the household has to pay. When a household becomes larger, its demand for electricity increases. This leads to an increase in price which can offset the economy of scale from saving in quantity.

Figure 1. **Economies of scale's channels of household electricity consumption**



Note. *kWh – Household consumption of electricity in kWh; P – Electricity price*
kWh/n – Electricity consumption per capita in kWh
Source. *Authors compiled*

The diagram shows the two effects of changing in household size on electricity expense per capita. The first effect is quantity effect due to the sharing characteristic. When household size increases, the household electricity consumption in kWh increases however, due to sharing characteristic, the electricity consumption per capita in kWh decreases. The second is price effect. When the household size increase, the household electricity consumption in kWh increases. Thus, the price each member has to pay increases due to increasing block tariff. If quantity effect dominates, households enjoy economies of scale. If price effect dominates, there is diseconomies of scale.

This paper will use VHLSS data from 2010-2014 to test which effect is stronger for household electricity consumption in Vietnam.

3. Data and Methodology

Model specification

The paper will employ econometric model with OLS estimator to test the economies of scale in electricity consumption. The model is based on Engel curve function for electricity and includes not only variables of electricity expense and household size but also some other well-known control variables for electricity consumption such as household income, dwelling and climate conditions.

$$\mathit{ln}\ \text{elec\_share}_i = \beta_0 + \beta_1 \mathit{ln}\ \text{size}_i + \beta_2 \text{children\_ratio}_i + \beta_3 \text{elder\_ratio}_i + \beta_4 \mathit{ln}\ \text{inc\_ave}_i + \beta_5 \mathit{ln}\ \text{cdd25} + \beta_6 \text{rent}_i + \beta_7 \mathit{ln}\ \text{sqm}_i + \beta_8 \text{y2012}_i + \beta_9 \text{y2014}_i + \sum \beta_k \text{citycode}_{ki} + \varepsilon_i$$

in which:

elec_share	= the share of electricity expenditure last month (of the survey month) on household's monthly income
size	= total number of household members
children_ratio	= fraction of members below 15-year old over size
elder_ratio	= fraction of members over 60-year old over size
inc_ave	= household's monthly per capita income
cdd25	= cooling degree days of the month previous to survey month
rent	= 1 if the household pay rent; =2 if the household owns the dwelling
sqm	= total area of the dwelling in term of square meter
y2012, y2014	= dummy variables for year of 2012, 2014
citycode_k	= vector of dummy variables for each city with Ha Noi is the base

In the model, the dependent variable is the share of electricity in monthly household income. As Deaton and Paxson (1998) indicated, to calculate economy of scale, we compare expense per capita of different households at given income per capital. It will be equivalent to compare the ratio of the expense per capita over income per capital which is exactly the share of electricity expense on total income.

The variables size represents for household sizes. The variable size represents for the concept of doubling the household while keeping the same household composition which is control by children_ratio and elder_ratio variables. If the coefficient of variable size (β_1) is positive, households have economy of scale in electricity consumption. If it is negative, there is a diseconomy of scale in electricity consumption.

Variables children_ratio and elder_ration represents for household composition. Household composition is classified to 3 types of members. Children are members who are less than 15-year old. Elders are members who are over 60-year old. Adults are members from 16 to 59. The coefficients of the two variables will reveal the difference in electricity demand between a child/an elder and an adult.

Variable inc_ave controls for households' wealth. The variable ensures for the concept that doubling a household means doubling both people and resource (Deaton and Paxson, 1998).

Cdd25 represents for climate condition which can impact on electricity demand. Cooling degree day (cdd) is the amount of temperature that need to be cooled down to reach a certain base temperature for every day of a month. In this paper, cdd25 is calculate for the base of 25oC. The formula of cdd25 is the following

Cdd25 = ∑(tavg-25) for all days of a month which have average daily temperature (tvag) higher than 25oC.

Dummy variables for years and cities capture unobserved factors which vary across year and geographic location.

Data

The data for cdd comes from Global Historical Climatology Network (GHCN) of National Centers for Environmental Information (NOOA); GHCN provides daily temperature of 15 weather stations in Vietnam. The cdd25 is calculated for each station. Each household is assigned the cdd25 of the nearest station to its ward.

Other data such as electricity expense, income, household demographic, dwelling condition are extracted from Vietnam Household Living Standard Survey (VHLSS) of three years 2010, 2012 and 2014. Since 2002, for every 2-year, VHLSS was conducted national wide by General Statistics Office of Vietnam (GSO) to collect data on income and expense of Vietnam household covering many areas such as demographics, education, medical care, employment, income, expense, etc. provided by GSO.

The model will run only for households living in urban area due to nature of electricity price policy in Vietnam. Vietnamese government has two different tariff schedules for urban and rural areas. Urban area has one explicit retail increasing block tariff which applies to individual household. By contrast, rural area does not have uniform tariff schedule for households. Instead, rural area has a whole sale increasing block tariff which apply for whole sale organizations. These organization then apply their own price policy for retail households. Some organization may adapt the wholesale price. However, some other can apply one price policy.
All the variable in money term has unit of million VND and adjusted to 2010 price by consumer price index (cpi). Data descriptive is detailed in appendix.

4. Results and discussion

The model passes all diagnostic tests for OLS detailed in appendix B.

Table 1. **OLS Estimate results**

lelec_share	OLS model
ln inc_ave	-0.4789***
	(-59.08)
ln size	-0.3278***
	(-27.20)
children_ratio	0.0392
	(1.54)
elder_ratio	0.0057
	(0.31)
ln cdd25	0.0351***
	(8.90)
rent	0.1060***
	(4.67)
ln sqm	0.2840***
	(35.18)
N	14,764
F	91.41
Adj R-squared	0.3030

Note: *t statistics in parentheses; * p<0.05, ** p<0.01, *** p<0.001*
The table only display estimated results for some selected variables.
Source. *Authors estimate*

Control variables

Overall, the estimated result for control variables are as expected. First, the result shows that if income per capita increases one per cent, the share of electricity expense will decrease 0.47 percentage point. It implies that electricity demand is inelastic with respect to income which is similar to Alberini and Filippini (2011). Alberini and Filippini (2011) explains that income is highly correlated with other characteristics of household such as size, number of floors or availability of appliances.

Second, the coefficient of climate condition (cdd25) is positive and significant meaning that electricity share in income will increase if weather becomes hotter. It is reasonable because Vietnam is a tropical country with hot weather. When the average temperature increases, especially in summer, households may have to devote more income for cooling effort such as using fans or air conditioners. In addition, the result can also be explained by urban heat island effect since the model only run for urban area.

Third, coefficients of dwelling condition (sqm and rent) show that the higher the total area, the higher electricity share in income and households who rent houses also have higher electricity share. The estimated results for the total area (sqm) is similar to Kavousian *et al*. (2013). Kavousian *et al*. (2013) argues that a larger dwelling requires more energy for cooling/heating because it has large volume to condition and have higher loss with outside. For the rent variable, it may be strange at first glance since people rent house normally are not wealthy people. However, in Vietnam, people who rent a house normally live with landlord and have to pay highest block prices. Thus, the coefficient of the rent variable is reasonable.

Household composition

Table 1 shows that there are no significant differences in electricity demand between an adult and a child or an elder. This result contradicts to Brounen et al. (2012). Brounen et al. (2012) analyzed data of 300,000 Dutch households in 2008-2009 and found that elder households consume two to 4 per cent less electricity than middle-aged married couples do. They explained that though elders stay more time at home but use less energy-consuming appliance. In addition, they also found that in comparison to electricity consumption of middle-aged married couples, families with children have lower per capita electricity consumption in kWh. Families with children less than four year old have higher per capita consumption while families with children from five to 12 and above 12 year old has increasing higher per capita consumption than middle-aged married couples do. They explained by “Nintendo-effect” where older children use intensively television, gaming devices and personal computers.

In Vietnam, the indifference in demand between an adult and an elderly person may come from the fact that elderly people have higher saving attitude. In this case, the saving attitude obviates any increase electricity consumption that incurs from their longer time stay at their residential. The saving attitude comes from two sources. First, elderly people who are over 60 in 2014 have passed both two wars in Vietnam when living standard is extremely low. Thus, saving attitude is built in their daily activities. Second, at the age of 60, elderly people get retired. Their retired salary is considerably low in comparison to their income at work. They need to saving money to cope with unexpected events.

The indifference in demand between an adult and a child may come from the fact that the “Nintendo-effect” does not work in Vietnam. Children in Vietnam also play game intensively, however, instead of playing at home as in European countries, they go to gaming centers which are popular in Vietnam. Their electricity expenditure for gaming then is not included in households’ electricity bills. Sanquist et al. (2012) investigated lifestyle factors in US residential electricity consumption. They identified five lifestyle factors associated with air conditioning, laundry usage, personal computer usage, climate zone of residence and television use. The key different factor between a child and an adult in Vietnam is personal computer usage for gaming. Thus, if children go out for playing game, it should be no difference in electricity demand between a child and an adult.

Household sizes – economies of scale
With regards to the focus variable of the paper, estimated result shows that when a household double keeping the same composition and resources, the share of electricity expense decrease 32.78 percentage point. This implies that in general, household consumption on electricity still enjoy economy of scale regardless of increasing block tariff. In other words, quantity effect of an increase in household size dominates the price effect.

The result may come from the fact that a large fraction of sample are households with small and medium sizes. Households with less than or equal four members account for 73 per cent of the sample. Households with less than or equal six members account for 95 per cent of the sample. It is worthy to note that the increasing block tariff increases at increasing speed. This means the price effect on small or medium size households is smaller than on large size household. In this case, with large fraction of sample are small and medium size, it is reasonable to have quantity effect dominate price effect.

Robustness check
A local regression estimate is employed to do robust check for the result. The idea is to regress electricity expense share in household income (elec_share) on monthly income per capita (inc_ave) for different type of households.

$$\text{Elec\_share} = f(\text{inc\_ave}) + u_i \quad \text{where } f(.) \text{ is not specified.}$$

Household types are designed to incorporate the idea of doubling a household keeping its composition constant. In this paper, a household composition has the pattern of children/adults/elders. For example, we will have household types as households of (0, 1, 0), (0, 2, 0), (0, 3, 0) or (1, 1 ,0), (2,2,0), (3, 3, 0). This method allows us to compare whether a larger household type has smaller electricity share at any given income per capita level.

Local regression smoother is a non-parametric method which let data suggests appropriate function form of f(.) instead of imposing a structure on data as parametric method. The procedure is detailed in Fan and Gijbels (1991). First, dividing inc_ave to 50-point equally periods. At any point inc_ave_m, run a local weighted average of elec_share on the neighborhood of inc_ave_m. The closer inc_ave_i to inc_ave_m, the higher weight inc_ave$_i$ has. There is no or little weight assigned for inc_ave$_i$ which is far from inc_ave$_m$. The regressions are then used to calculate the expected value of elec_share at each point of inc_ave$_m$.

Technically, $\widehat{elec_{share}}$ (inc_ave$_m$) is estimated by minimizing with respect to a and b

$$\frac{1}{Nh}\sum_{1}^{N} K\left(\frac{inc_{avei}-inc_{avem}}{h}\right)\left(elec_{sharei}-a-b\left(inc_{avei}-inc_{avem}\right)\right)^2$$

With $K(z)=\begin{cases}\frac{3}{4}\left(1-z^2\right), if\,|z|<1\\ 0, otherwise\end{cases}$

The estimator is

$$w_i\,.\,elec_{sharei}/❑\sum_{i=1}^{N} w_i$$

$$elec_{share}\left(inc_{avem}\right)=\hat{a}=\sum_{i=1}^{N}❑$$

$$\widehat{❑}$$

With $w_i=K\left(\frac{inc_{avei}-inc_{avem}}{h}\right)[s_{n,2}-\left(inc_{avei}-inc_{avem}\right)s_{n,1}]$

Where

$$inc_{avei}-inc_{avem}$$

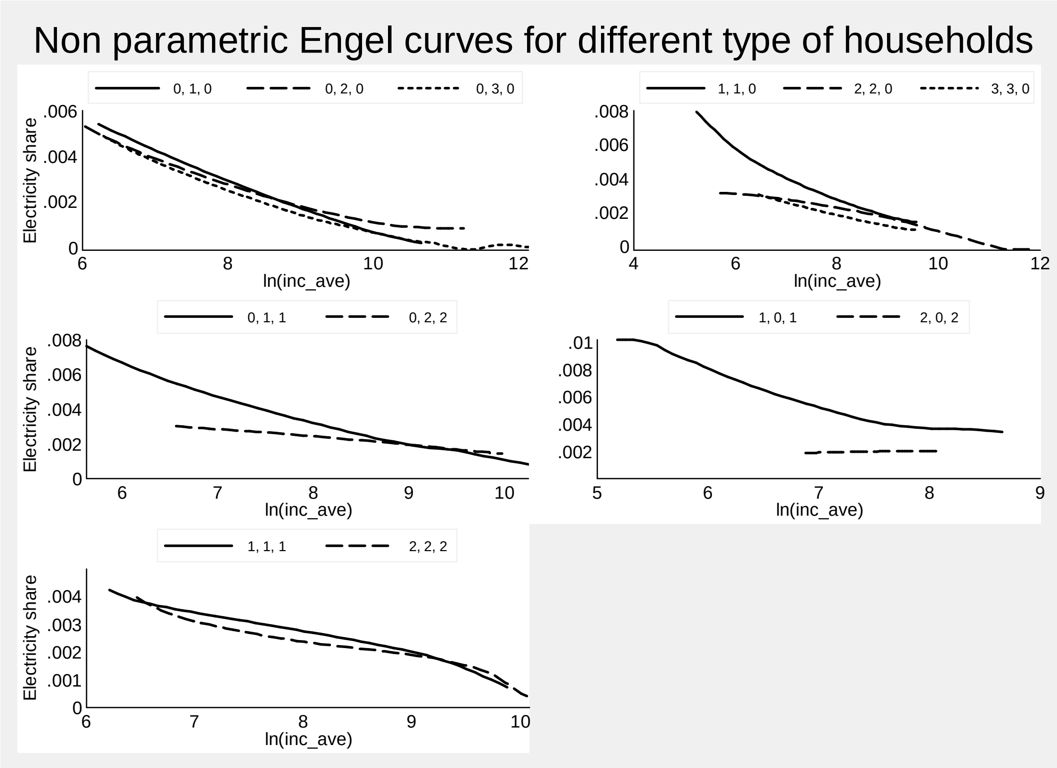
¿

$$K\left(\frac{inc_{avei}-inc_{avem}}{h}\right)$$

$$s_{n,l}=\sum_{i=1}^{N}❑$$

The full procedure will calculate the bootstrap estimates of standard error. However, this part is only for doing robust check for OLS estimate results, thus, we only use the local linear regression estimates to visualize the relationship between elec_share and inc_ave for different type of household.

Figure 2. **Non-parametric Engel curve for different type of households**



Note. *Legends are the compositions of (children, adults, elders)*
Source. *Authors estimate*

In general, the visualization of local linear regression supports for the econometric estimates. Figure 2 shows that the local linear smoother lines of larger families are higher than that of smaller families for major range of income per capita. This means that at a given income per capita, electricity share of smaller households is higher than that share of larger households or economies of scale exists.

However, the visualization also reveals an interesting trend. There are cross points between the lines at high level of income per capita. This suggests that the economies of scale may not exist for rich families. This may come from the fact that rich families already consume electricity at high blocks. Under the situation that the electricity price increases at increasing speed, the higher block a household consumes, the higher price effect which cancel out all economies of scale from quantity effect.

5. Conclusion

This study has illustrated the economies of scale in household electricity consumption using VHLSS data 2010, 2012, 2014. Electricity has high potential for economies of scale since it is a “public goods” which the consumption of one member does not rule out the consumption of others. Thus, an increase in household size creates a quantity effect where kWh consumption per capita decreases. However, the electricity tariff in Vietnam is progressive. In this case, an increase in household size creates a price effect where the higher using block is, the higher price applied. The higher price may rule out the saving from quantity effect. The economies of scale exists if the quantity effect dominates the price effect.

Estimated result from econometric model provides empirical evidence that in general, there is economies of scale for household electricity consumption. When a household doubles while keeping the same composition and resources, the share of electricity expense in household income decrease 32.78 percentage point. This may come from the fact that the electricity tariff increase at increasing speed and most households in the sample are at small and medium size. The households usually consume at small or medium blocks where the price gap between blocks are not too high. Therefore, when household sizes increase, price effect is relatively smaller than quantity effect.

Robust check with non-parametric method reveals an interesting trend. In general, the robust check estimates support for the economies of scale in household electricity consumption. However, for certain household types, economies of scale is not valid at high level of income per capita. The reasons may be the high consuming level of rich household. They usually consume electricity at high block where price gaps between blocks are large. Thus, when household sizes increase, price effect is large and cancel out the saving from quantity effect.

The results implied that there is still a room for government in adjusting the electricity tariff without making penalty for low income and large household. Besides, it also suggests a hypothesis that worth to test in future. Th economies of scale in household consumption can be moderated not only by a progressive tariff schedule but also by how quickly the tariff increase.

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Appendix A. Data description

Table 2. **Household size (unit: number of members)**

Size	Freq.	Percent	Cum.
1	948	5.53	5.53
2	2,393	13.95	19.47
3	3,597	20.97	40.44
4	5,601	32.65	73.08
5	2,585	15.07	88.15
6	1,302	7.59	95.74
7	433	2.52	98.26
8	170	0.99	99.25
9	78	0.45	99.71
10	29	0.17	99.88
11	11	0.06	99.94
12	6	0.03	99.98
13	4	0.02	100
Total	17,157	100	

Table 3. **Household composition**

Variable	Obs	Mean	Std. Dev.	Min	Max
children_ratio	17157	0.202318	0.20052	0	1
elder_ratio	17157	0.149135	0.272658	0	1

Table 4. **Household income and dwelling condition**

Variable	Obs	Mean	Std. Dev.	Min	Max
inc_ave	17157	3.261219	2.650165	0.045	46.766
sq_m	17146	90.06876	61.16	4	720

Note. Unit of inc_ave: million VND/month; sq_m: squared meters.

Table 5. **Rent**

Rent	Freq.	Percent	Cum.
Yes	834	4.86	4.86
No	16,312	95.14	100
Total	17,146	100	

Table 6. **Climate condition**

Variable	Obs	Mean	Std. Dev.	Min	Max
cdd25	17157	69.80727	51.60391	0	202.7778

Appendix B. Diagnostic test for the OLS model

Test of the functional form of the conditional mean

Ramsey RESET test using powers of the fitted values of lelec_share
Ho: model has no omitted variables
F(3, 14689) = 2.26
Prob > F = 0.0791

Heteroskedasticity test

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
Ho: Constant variance
Variables: fitted values of lelec_share
chi2(1) = 0.16
Prob > chi2 = 0.6875

Multicolinearity test

Table 7. **Multicolinearity test**

Variable	VIF	1/VIF
lsize	1.6	0.626362
lsq_m	1.54	0.650555
linc_ave_cpi	1.44	0.694256
Rent	1.35	0.742249
elder_ratio	1.3	0.766568
Children_ratio	1.36	0.734318
lcdd25	1.21	0.829684

Note. Table shows results of selected variables

Normal distribution of residuals

Figure 3. **Normal distribution of residuals**