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Stylized Facts on Thailand's Residential Electricity Consumption: Evidence from the Provincial Electricity Authority

by

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Stylized Facts on Thailand's Residential Electricity Consumption: Evidence from the Provincial Electricity Authority

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Abstract

This paper documents a few stylized facts of the residential electricity consumption in Thailand. Using an administrative billing records of 16 million residential meters, we find the following stylized facts and potential uses of the data. First, electricity consumption pattern can be used as proxies for household's wealth and wealth inequality since it reflects ownership of durable electrical appliances. Second, bill payment choices suggest that a majority of the households still face non-trivial transaction costs in paying their utility bills. Lastly, the electricity consumption pattern suggests that wealthier households are more sensitive to the temperature change but are less sensitive to the change in price.

Keywords: Electricity consumption, inequality, price elasticity, bill payment
JEL Classifications: Q41, Q48, D63, L94

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1 Introduction and Data

In the digital era like today, electricity has become a necessity to our daily life. Not only does electricity serve our basic needs such as heating, cooling, lighting, and transportation, but it also powers the production process of goods and services. Understanding the pattern of electricity consumption and its driving forces can help us better understand the state of the economy as well as the livelihood of the population.

In Thailand, existing studies that document stylized facts on residential electricity consumption are rare and usually does not include the whole population. For example, Energy Policy and Planning Office (2016) surveyed a small sample of electricity consumers in 2016 about the appliance ownerships and the detailed usage bahavior. Apaitan et al. (2018) analyze the consumption response of small residential meters induced by the Free Basic Electricity (FBE) program. National Statistical Office of Thailand (2017) conducts an annual energy consumption and expenditure survey, which reports the representative households' energy consumption and appliance ownerships.

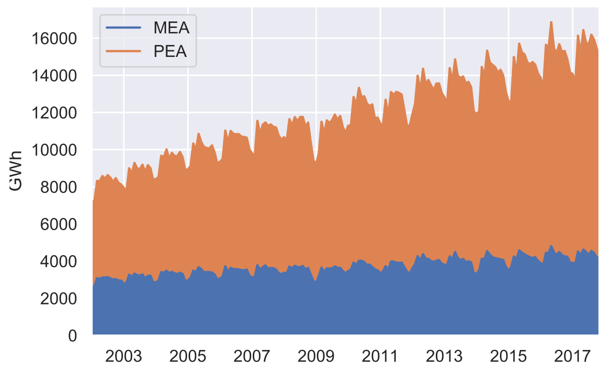
This paper documents stylized facts on residential consumption from billing data. The administrative monthly billing data was provided by the largest retail utility in Thailand, the Provincial Electricity Authority (PEA), who is responsible for around 70% of total electricity sales in Thailand. PEA's service areas include the whole country, except Bangkok, Nonthaburi, and Samut Prakarn. The other retail utility, the Metropolitant Electricity Authority (MEA), accounts for the remaining 30% of the retail sales (figure 1). Due to the data availability, our analyses below mainly use the billing data from PEA's territory.

Within the PEA service areas, residential consumption is the second largest after the industrial Large General Service (LGS) customers (figure 2). Residential consumption share, as well as the number of the meters, has been rising steadily over time from 15 million meters in 2013 to 16.6 meters in 2017 (figure 3).

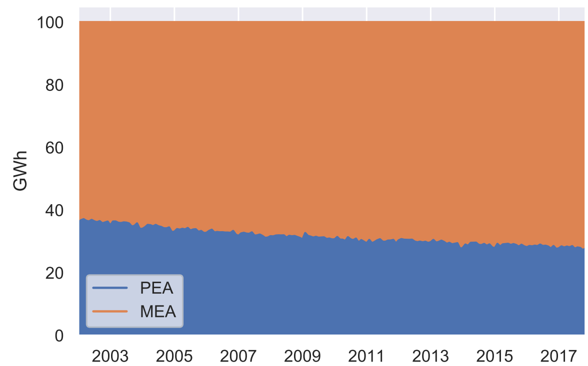
The stylized facts described here are intended to serve as introductions to the data that

Figure 1: Total electricity consumption, 2002–2017

(a) Total consumption



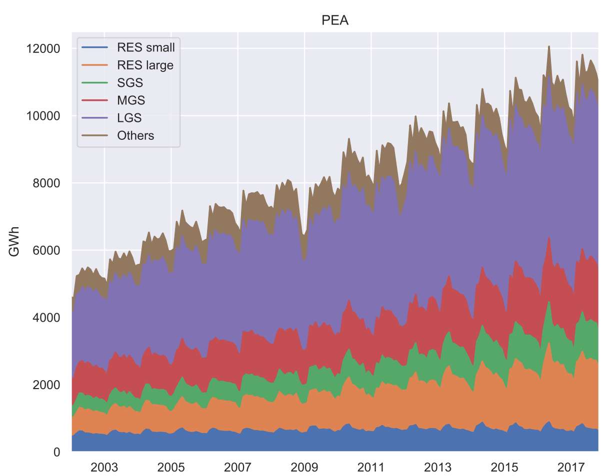
(b) Consumption share



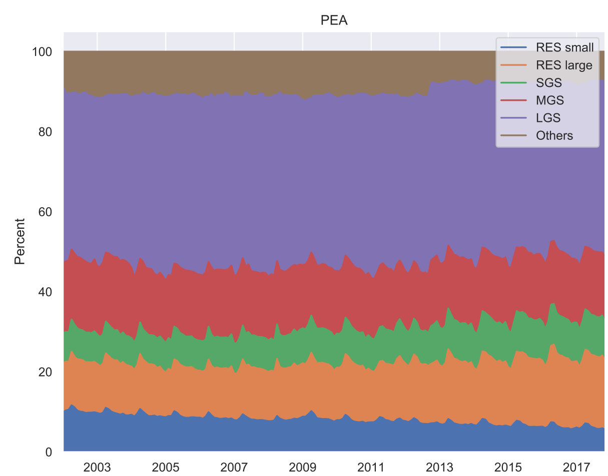
Source: Energy Policy and Planning Office

Figure 2: PEA electricity consumption by customer groups

(a) Total consumption

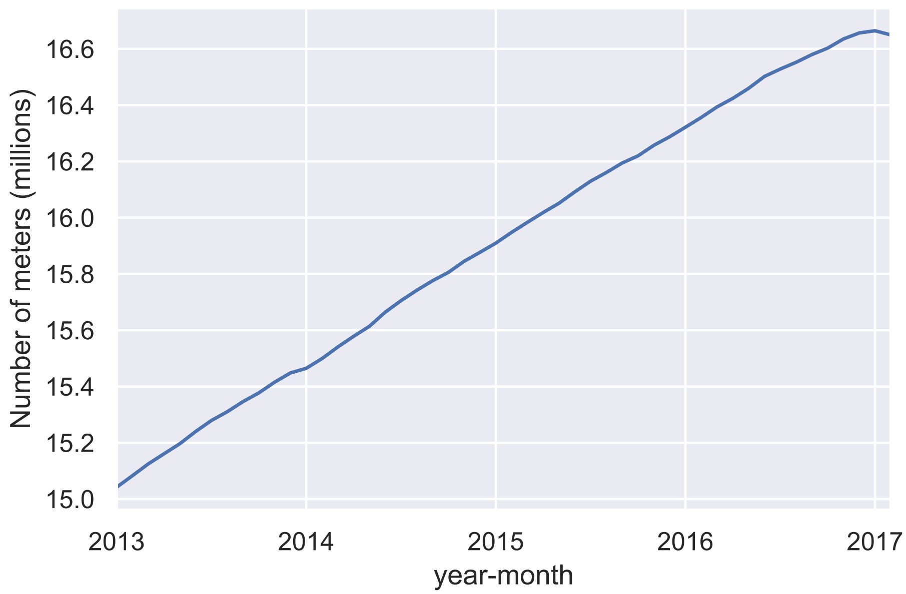


(b) Consumption share



Source: Energy Policy and Planning Office

Figure 3: Number of residential meters in the PEA region



Source: PEA billing data 2013–2017

future and more in-depth studies can be built upon. Our main findings are as follows.

First, average temperature and household income are important determinants of residential electricity consumption. Temperature drives the seasonality of consumption. Household income, on the other hand, drives the longer-term growth in electricity consumption through ownership and usage of various energy-intensive appliances. The relationship between income and electricity consumption implies that the *level* of electricity consumption can provide complementary information on household's wealth. Similarly, consumption *inequality*, which reflects the inequality in energy-intensive appliance ownership, can serve as a proxy for household's wealth inequality.

The impact of temperature on consumption further implies that electricity consumption data during the hottest months should be used to elicit household's wealth level and wealth inequality. This is because the utilization of energy-intensive appliances (e.g. air conditioners), which distinguishes the high-income from the low-income households, will be the highest during this time.

Second, the overall consumption inequality has been rising. Areas with the highest

inequality are major cities and tourist cities. Another alarming finding is that the overall consumption inequality (and thus wealth) has been rising steadily over time. Areas with the most severe inequality are municipal regions of major cities where main highways pass through. These areas, intuitively, have higher proportions of high-income residents compared to the more rural areas. Therefore, there exists a larger within-region difference between the top (high-income) consumers and the bottom (low-income) consumers.

Third, a majority of consumers still pay their bills through counter services, even though the fee-free options has been available. The lack of access to formal financial institutions, as well as high transaction costs are the likely obstacles that prevent consumers from adopting the fee-free payment options through credit cards and bank transfers. It is likely that these obstacles are also present in the bill payment of other utility services. Therefore, the new form of mobile-payment or e-money that does not require an access to formal financial services would provide a significant cost-saving benefit for customers.

Forth, the largest (highest-income) consumers are the most responsive to temperature changes and the least responsive to price changes. Our analysis shows that residential consumers respond to price changes with the average elasticity of -0.08 to -0.1. This implies that, in the future, consumers in the highest-income regions who are the most sensitive to temperature changes will use disproportionately more electricity as a result of climate change. This group of residential customers should therefore be the first target group for energy conservation and energy efficiency measures. However, the low price sensitivity for this customer group suggests that a set of non-price interventions such as a behavioral nudge or those that involve the social norm should be implemented along with traditional price interventions.

This paper is organized as follows. Section 2 discusses the analyses in more detail. Section 3 provides policy implications and conclusions.

2 Stylized facts on Residential Electricity Consumption

Fact #1: Average temperature and household's wealth are important determinants of residential electricity consumption.

Figure 4 plots median daily consumption in kWh and average temperature in degree Celsius from January 2013 to February 2017.

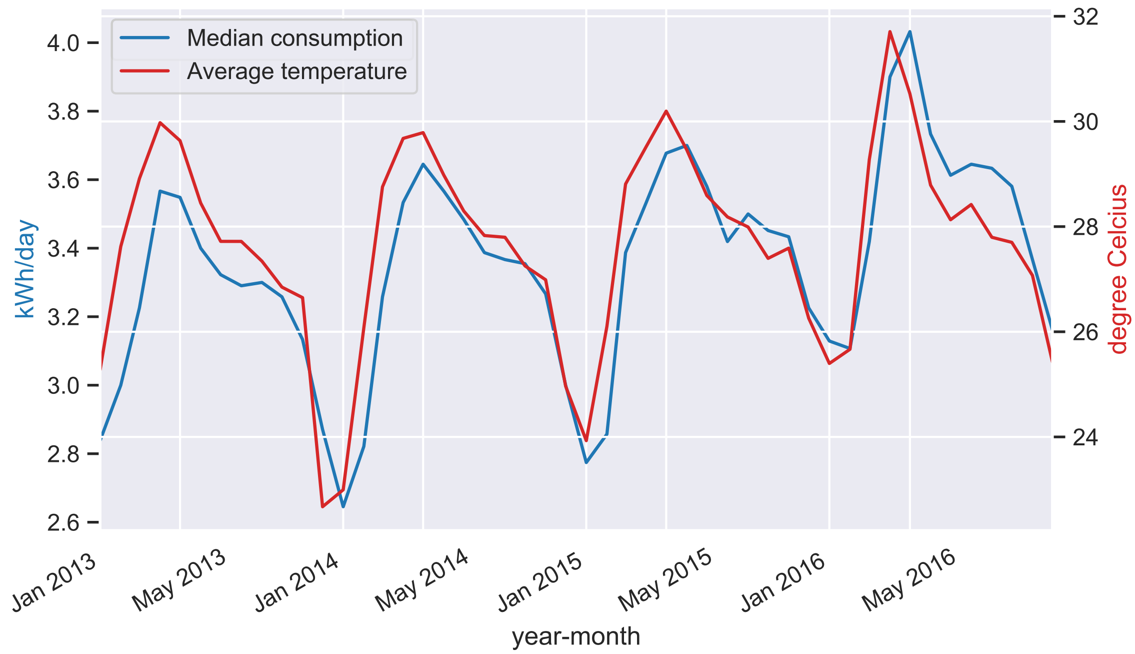
Median daily consumption ranges from under 2.6 units to 4 units per day. This is equivalent to a monthly consumption of 80–120 units or monthly bill payment of 237 bath to 374 baht (including the 7% VAT).

The median daily consumption clearly exhibits a seasonal pattern that tracks the average temperature very closely. The highest daily consumption occurs in May while the lowest daily consumption occurs in January of every year. Furthermore, the median daily consumption shows a slight upward trend over time. The trend reflects both the rising standard of living that accompanies the income growth and the rising temperature as a result of global warming.

Apart from the temperature, household's wealth is another important determinant of electricity consumption. Higher-income households can afford to buy and use more appliances to provide comfort and convenience. Table 1 reports the average ownership of the electricity-intensive appliances: air conditioners and water heaters, by household expenditure quintile. We can clearly see that the ownership of both types of appliance increases monotonically with household income (expenditure).

Figure 5 shows the relationship between the provincial average per-meter electricity consumption and the provincial average household expenditure per capita collected by the National Statistical Office. Due to data limitations, we are unable to credibly estimate income elasticity. However, the figure shows that the province-average electricity consumption are highly correlated with household monthly expenditure at the province level. The overall correlation is as high as 83 percent. The correlation is consistent

Figure 4: Median daily consumption (kWh) vs. Average temperature (degree Celsius), 2013–2017



Source: PEA billing data 2013 – 2017

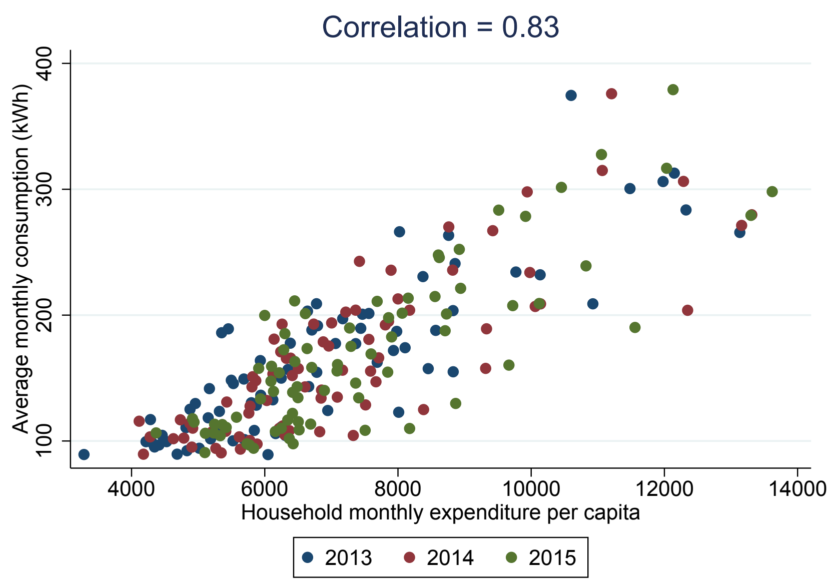
Table 1: Average ownership of air conditioners and electric water heaters in 2014

Quintile	Exp per cap (Baht)	Num. A/C	Num. electric water heater
1	2,603	0.016	0.039
2	4,183	0.085	0.088
3	6,043	0.238	0.151
4	9,035	0.468	0.223
5	18,813	1.04	0.459

Source: Socio-Economic Survey, 2014

with a common finding that the income elasticity of electricity demand is positive and significantly different from zero.[1]

Figure 5: Average consumption vs. average household expenditure per capita



Source: Socio-economic Survey and PEA billing data 2013 – 2015

Fact #2: Residential consumption is concentrated in municipal areas, with median per-meter consumption highest in tourist cities.

Figure 6a displays the geographic distribution of postal-level average consumption between 2013–2017. Notably, total consumption in most provinces is concentrated in just one or two postal codes (dark blue color). These postal codes belong to the densely populated areas of Amphoe Mueangs of each province.

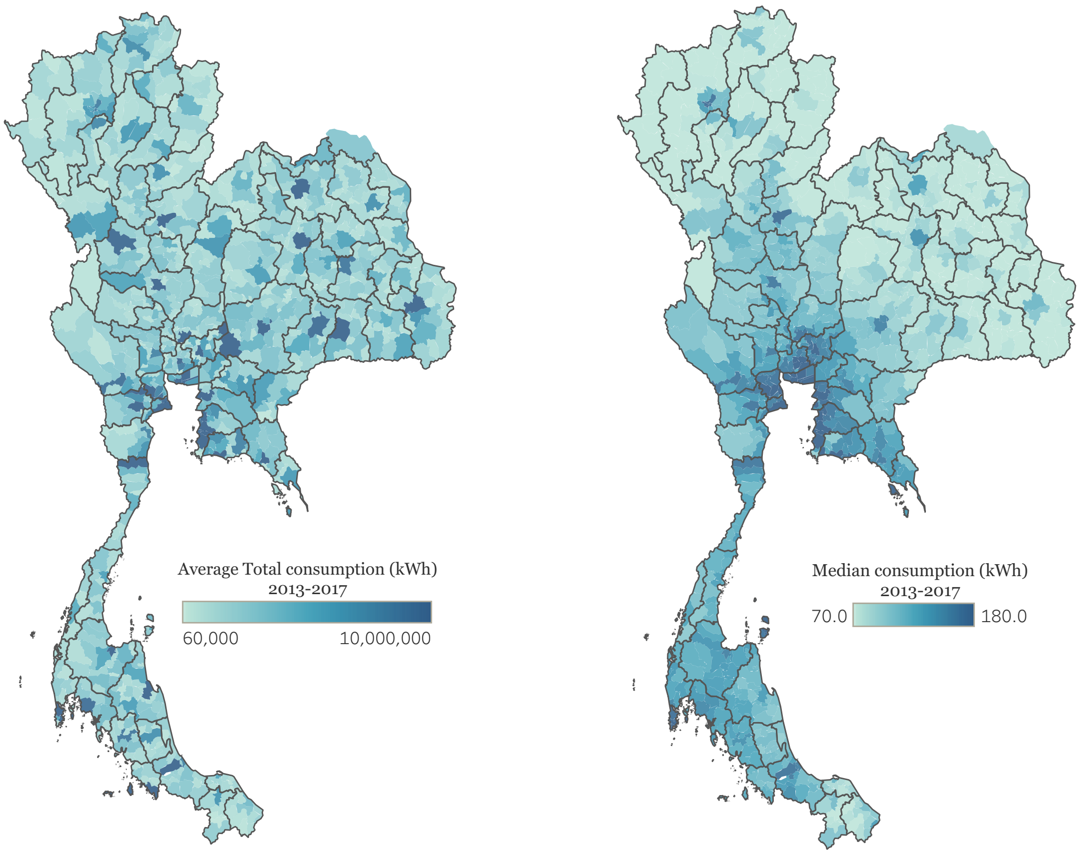
To separate out the impact of the population density on electricity consumption, we further investigate per-meter consumption. Figure 6b shows that the median (per-meter) consumption is highest in Bangkok's vicinity, the Eastern provinces, and tourist provinces such as Phuket and Surat Thani.

[1] See, for example, Kamerschen and Porter (2004); Taylor (1975).

Figure 6: Total and median consumption

(a) Postal-level total consumption 2013–2017

(b) Postal-level median consumption 2013–2017



Source: PEA billing data 2013–2017

Table 2 lists seven postal areas with the highest average per-meter consumption during 2013–2017. Strikingly, most of the listed areas are major tourist cities in the South, such as Phuket, Ko Samui, Ko Pha-ngan, and Pattaya. This finding leads us to speculate that some of the residential meters might belong to the unregistered guesthouses or resorts.

Two exceptions of the top-consuming areas that are not tourist cities are the postal areas that belong to Amphoe Thanyaburi and Amphoe Lam Luk Ka, Pathum Thani province. One possible explanation is that these two areas, being adjacent to Bangkok, are populated by several large housing estates that consume a lot of electricity.

Table 2: Top 7 postal areas with highest median per-meter consumption during 2013–2017

Ranking	Postal Code	Province	Amphoe	Point of Interest
1	83150	Phuket	Kathu	Patong Beach
2	84320	Surat Thani	Ko Samui	
3	83100	Phuket	Mueang	
4	12150	Pathum Thani	Lam Luk Ka	
5	12130	Pathum Thani	Thanyaburi	
6	84280	Surat Thani	Ko Pha-ngan	
7	20150	Chon Buri	Bang Lamung	Pattaya

Source: PEA billing data 2013–2017

Fact #3: Electricity consumption is quite unequal with rising inequality. The inequality is the most severe in major urban areas.

The distribution of monthly residential electricity consumption is rather smooth, left-skewed with a long right tail and a large excess mass at zero unit (figure 7 top panel).

The bottom panel of figure 7 shows the zoomed-in version of the consumption distribution around the mode. Notably, there is a distinct excess mass ("bunching") at the 48$^{\text{th}}$–50$^{\text{th}}$ unit of consumption and a distinct missing mass at the 51$^{\text{st}}$ unit of consumption. The excess mass and the missing mass are the results of behavioral response induced by the Free Basic Electricity (FBE) program. In short, the FBE program creates a significant jump in the marginal price of electricity at the 50-unit threshold. The jump in the marginal price prompted some of the FBE-eligible households to target their consumption right at 50 units in order to receive the FBE benefit. The observed excess mass and missing mass thus indicate that some consumers are responsive to the marginal price change. We explore and discuss this consumption behavior in more details in the following subsection.

The long right-tail of the consumption distribution indicates inequality in consumption. Figure 8 plots the Lorenz curve for the residential consumption in May 2015. The curve indicates that the top 10% highest-consuming meters account for around 40% of the total residential consumption in that month.

To further investigate the pattern of consumption inequality over time and across regions, we uses two convenient measures of inequality: (i) the “ratio index,” and (ii) the Gini coefficient. The ratio index calculates the ratio between consumption at the 90$^{\text{th}}$ percentile and consumption at the 10$^{\text{th}}$ percentile in a particular month. Thus, the ratio index for region i in month t is equal to:

$$ratio_{it} = \frac{q_{it}^{90th}}{q_{it}^{10th}}. \tag{1}$$

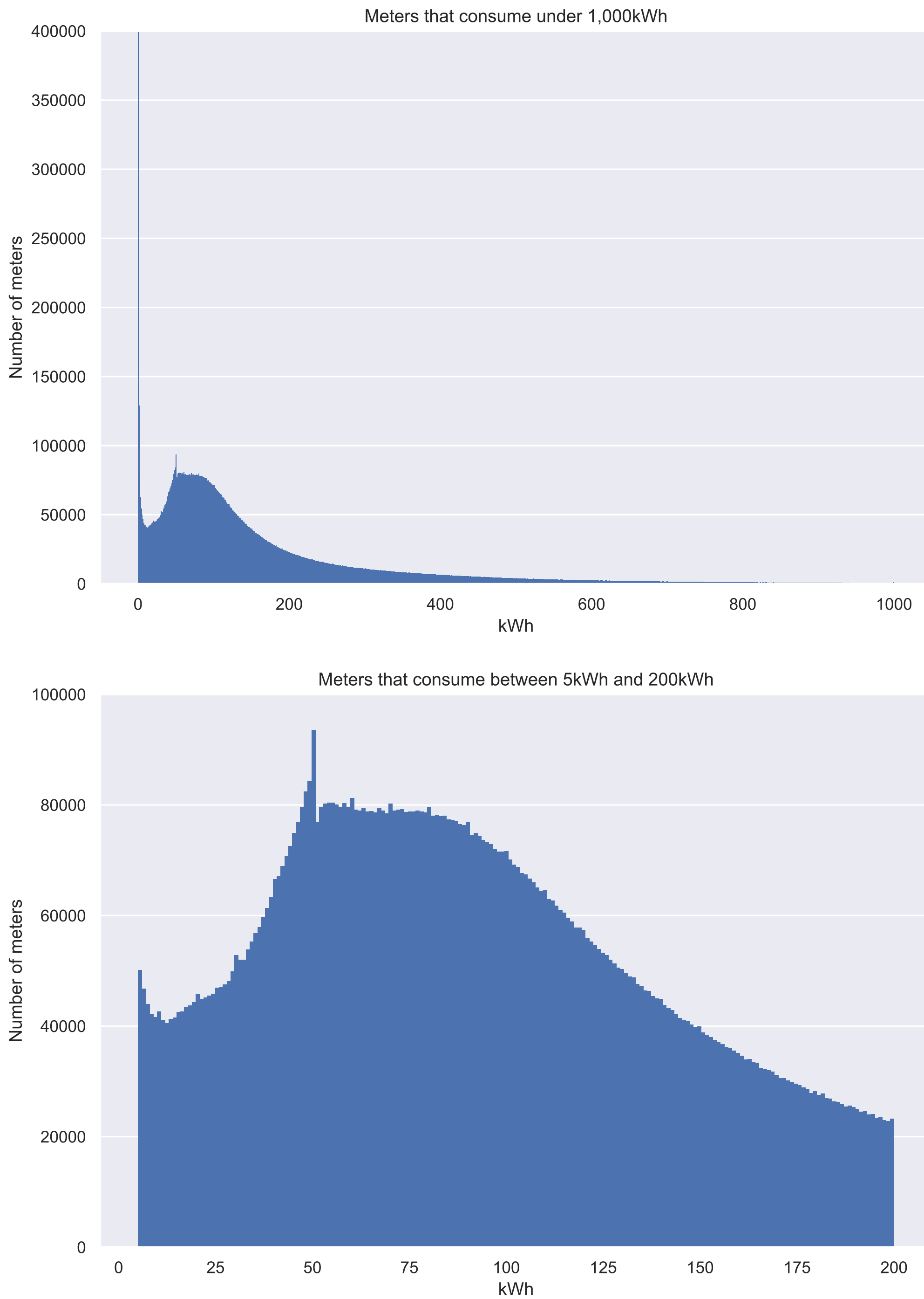
The Gini coefficient measures how much actual distribution deviate from the uniform distribution of consumption. Following Dixon et al. (1987), the Gini coefficient for consumption in region i of month t is calculated using the following expression:

$$G_{it} = \frac{1}{n}(n+1-2\frac{\sum_{j=1}^{n}(n+1-j)y_j}{\sum_{j=1}^{n}y_j}), \tag{2}$$

where $j = 1$ to n is the customer index ranked by consumption in a non-decreasing order ($y_j \leq y_{j+1}$). The Gini coefficient of zero indicates perfect equity, while the Gini coefficient of one indicates perfect inequality. Thus, higher Gini coefficient implies higher inequality.

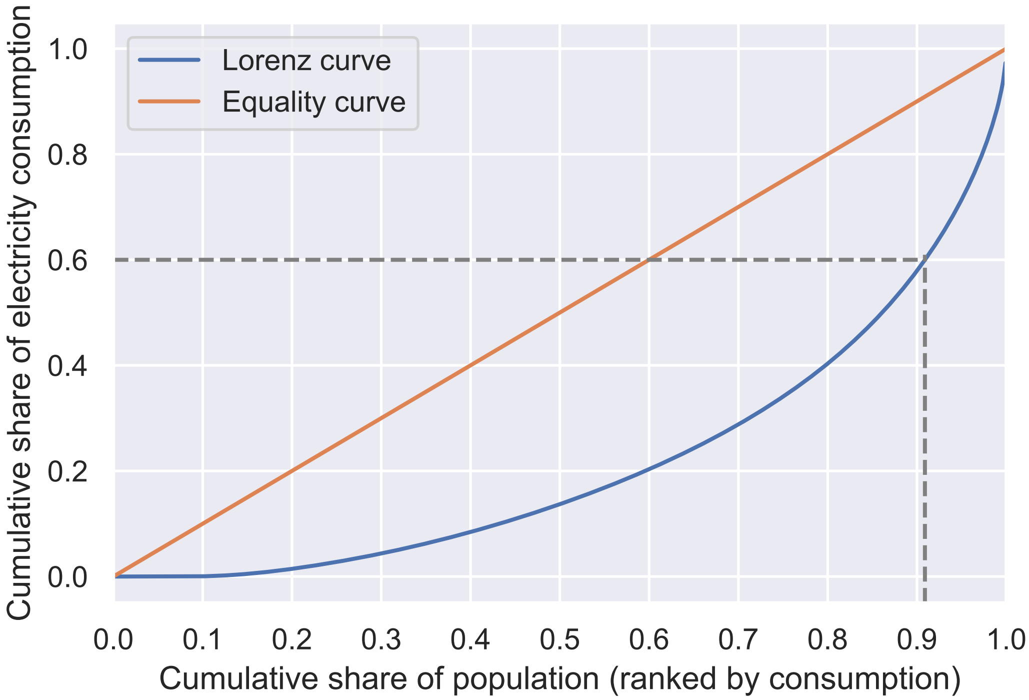
Figure 9 plots the ratio index and the Gini coefficient over time. Both inequality indices clearly exhibit a seasonal pattern similar to the average consumption and the median

FIGURE 7: Consumption distribution for May 2015



Source: PEA billing data for May 2015

Figure 8: Lorenz curve for May 2015



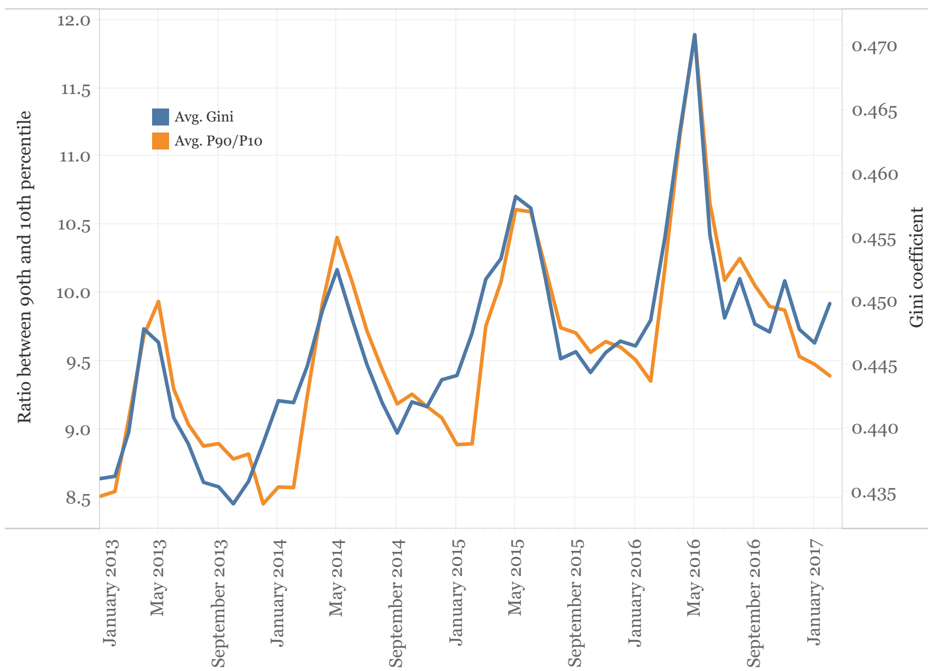
Source: PEA billing data for May 2015

consumption presented above. Specifically, inequality is lowest in the winter months (November through February) and highest in the summer months (April through June). This seasonality implies that the inequality in electricity consumption can serve as a proxy for the inequality in household's appliance ownerships and wealth. As mentioned in the previous subsection, higher-income households can afford luxurious, energy-intensive appliances such as air conditioners and refrigerators for cooling. Both of these appliances are used more intensely during the hot summer months. Lower-income households, on the other hand, cannot afford such appliances. Thus, electricity consumption of high- and low-income households would diverge most in the summer months when the need for cooling is the greatest.

In fact, existing studies from developed countries found that electricity consumption is *more* equally distributed than wealth (Jacobson et al., 2005; Mirnezami, 2014) This is due to two reasons. First, there is a diminishing marginal utility of consuming more electricity.

Second, as household income rises, the householders are more likely to invest in the energy efficiency measures.

Figure 9: Inequality over time



Source: PEA billing data 2013 – 2017

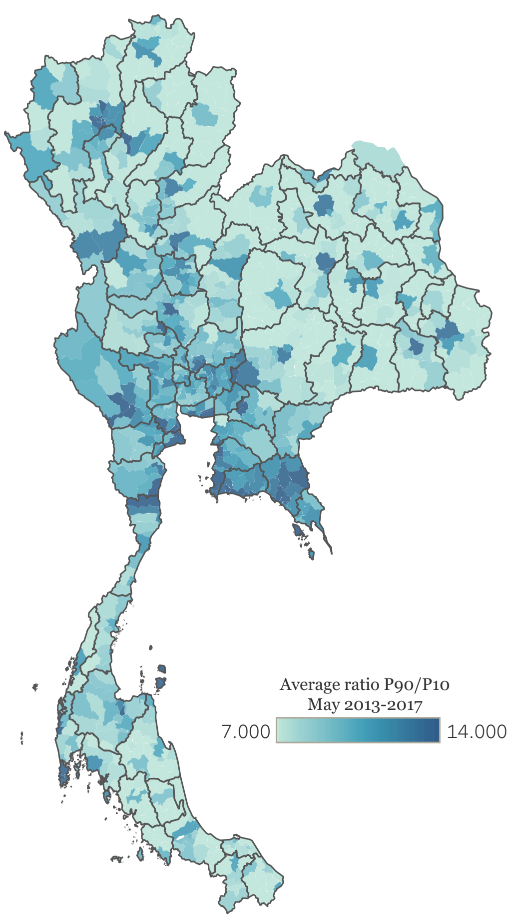
To the extent that the consumption inequality represents a form of wealth inequality, figure 9 reveals an alarming trend that wealth inequality in Thailand has been rising steadily over time. Furthermore, the inequality seems to be concentrated in the Amphoe Mueang districts of each province (darker blue color in figures 10a and 10b).

Fact #4: Bill payment through counter services dominates in most parts, while representative billing dominates in hard-to-reach areas.

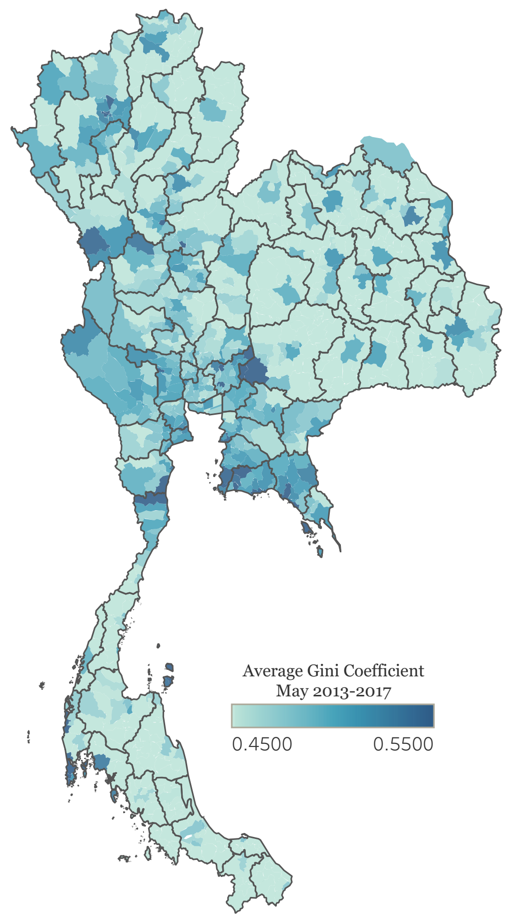
We next turn our attention to investigate how customers pay their electricity bill using the billing records from February 2017. Most residential customers pay their bills through PEA's counter services (free) or dealer's counter services (subjected to fees charged by

FIGURE 10: Consumption inequality

(A) Ratio index, 2013–2017



(B) Gini coefficient, 2013–2017



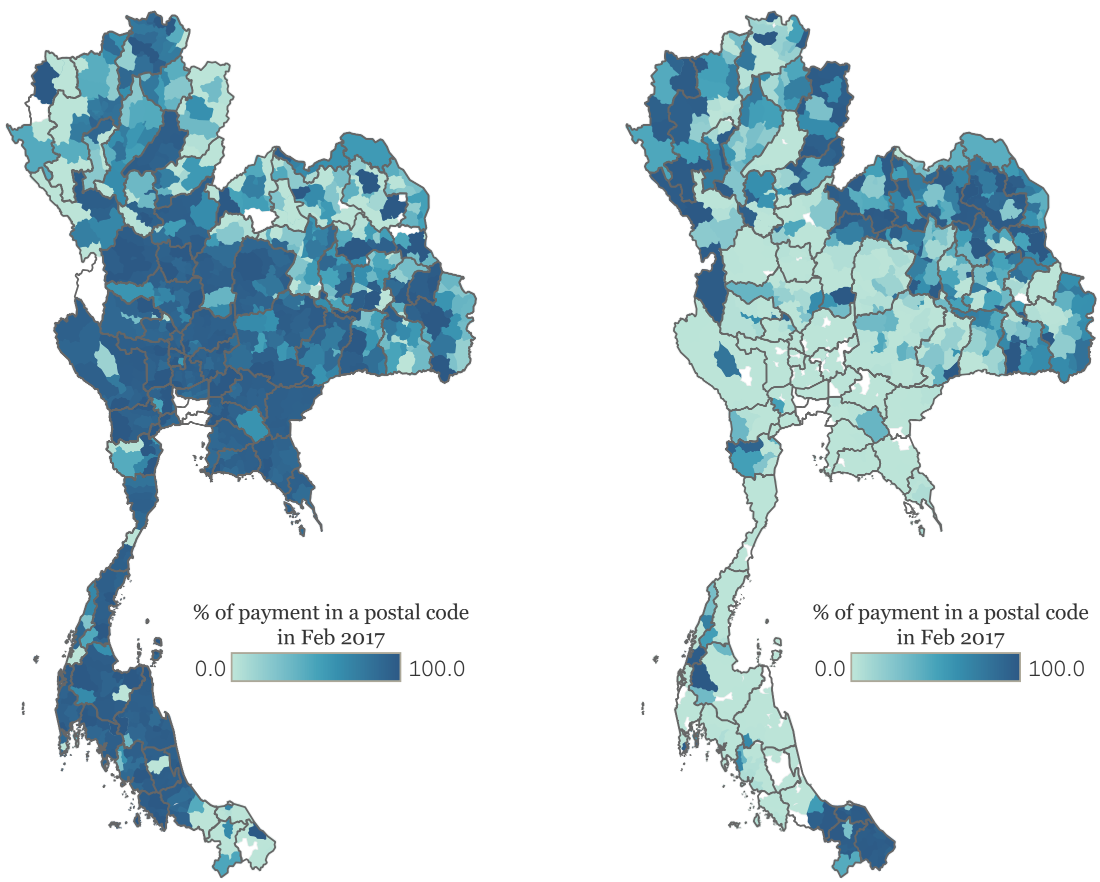
Source: PEA billing data 2013 – 2017

the dealers). Figure 11a reveals that a majority of customers in most part of the country paid their electricity bills through counter service. On the contrary, figure 11b shows that for the remote/mountainous areas and the three southern border provinces, most of the customers paid their bills through PEA's billing representatives.

Figure 11: Most common methods of payment by region, February 2017

(a) Fraction of counter service payment

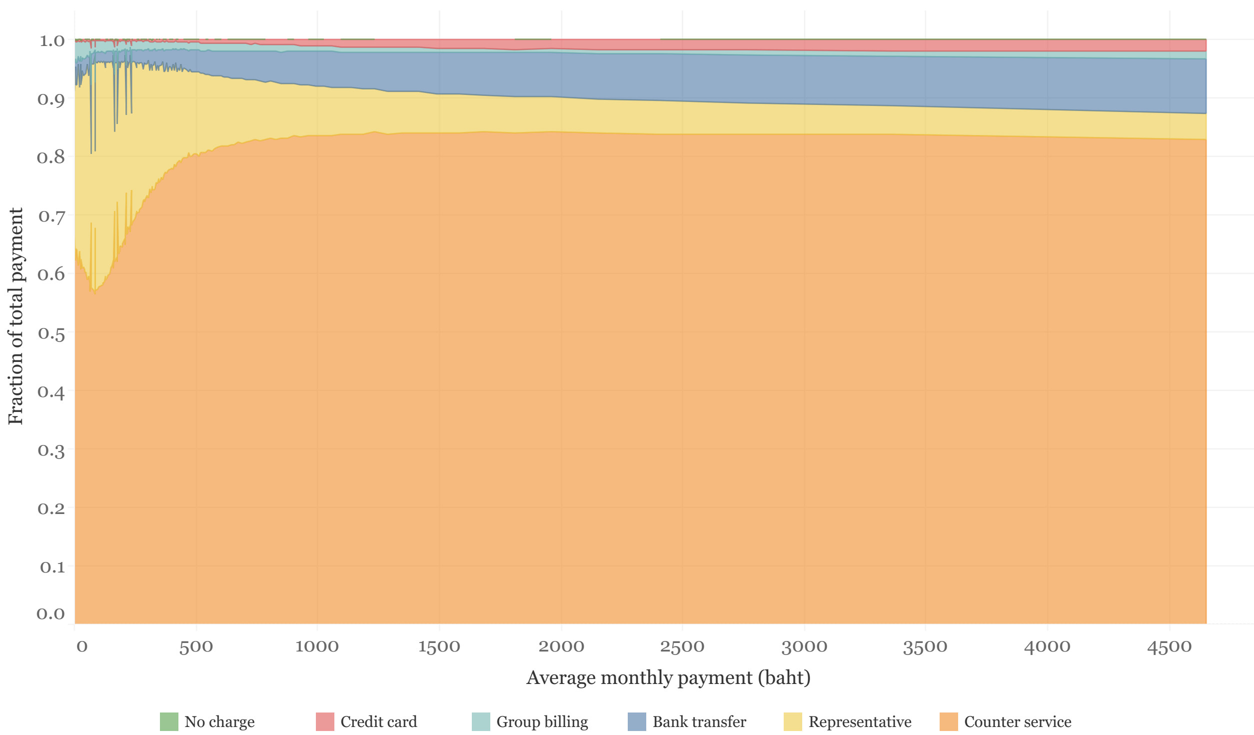
(b) Fraction of representative payment



Source: PEA billing data for February 2017

We next break down the payment method by the average bill amount for February 2017. Figure 12 shows that Group billing and Representative billing are more common among customers with low bill amount who are likely to be low-income families. Counter service payment becomes the major form of payment for customers with bill amount in the medium and high range. Lastly, credit card payments and bank transfers become more and more popular as bill amount increases.[2]

Figure 12: Methods of bill payment vs payment amount, February 2017



Source: PEA billing data for February 2017

The observed bill payment behavior implies the existence of a high transaction cost associated with credit card and bank transfer payment options. In other words, even though credit card and bank transfer options had been available since 1998, they are unpopular due to two apparent reasons. First, a customer needs to have a bank account and/or an approved credit card. These requirements rule out many electricity customers who lack access to the formal financial services. Second, even for a customer with a bank account and a credit card, the process requires the customer to go fill in paperworks at a bank's branch which can be quite time-consuming. Therefore, most customers still prefer to go to counter services nearby (e.g. at convenience store, supermarket, and the PEA

[2]The "Group billing" option in figure 12 refers to a group of meters that request to be billed together. For this group of meters, it is unclear if the payment is done by cash or other methods. The "No charge" option refers to the meters that belong to the eligible veteran families, which are exempted from paying the first 45 units of electricity consumption.

service spots) and pay a small service fee each time they pay their bills.

It is likely that the transaction costs mentioned above are also applicable to payment to other utility services. Therefore, the emerging forms of mobile-payment or e-money that do not require an access to institutional financial services can provide a significant cost-saving potential for utility customers.

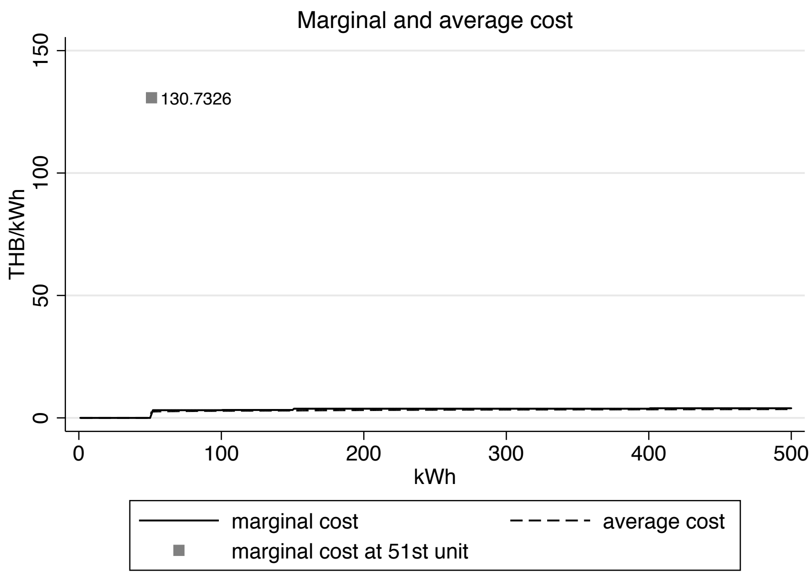
Fact #5: FBE-eligible consumers "bunch" at the threshold point if the price change is large enough.

This section elaborates more on the observed bunching at the threshold points for the Free Basic Electricity (FBE) program. In particular, the FBE program exempts customers who have small 5(15)A meters and use electricity below the threshold level (e.g. 50 units) from paying their bills in that month. If the FBE-eligible consumer exceeds the consumption threshold, he/she has to pay the bill for all the units consumed. The FBE bill exemption rule creates a large notch in the consumer's budget set where the marginal price increases from 0 baht to 130.7 baht (approximately 4.5 USD/unit) when one moves from the 50$^{\text{th}}$ unit to the 51$^{\text{st}}$ unit. Figure 13 depicts the discontinuity in the marginal and average prices.

Under a standard consumer theory, a utility-maximizing consumer would respond to a marginal price change by targeting their consumption at the quantity just below the price change. This is exactly what we observe in the FBE context. Figures 14a–14c plot the consumption distribution for customers with 5(15)A meters for the entire year of 2012 through 2015.

Following a growing list of literature on bunching estimator, Apaitan et al. (2018) use the observed bunching to estimate the price elasticity of consumption for the FBE-eligible customers. Specifically, using a model of consumer's utility maximization and the assumed utility function, Apaitan et al. (2018) derives the relationship that links consumption

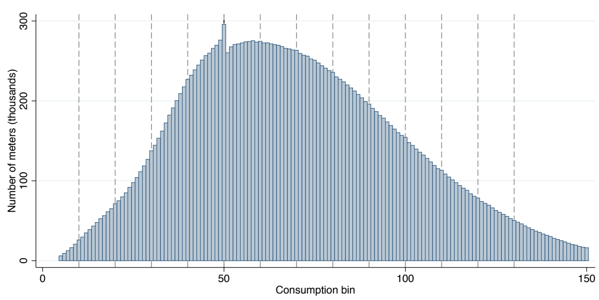
Figure 13: Marginal cost vs. average price



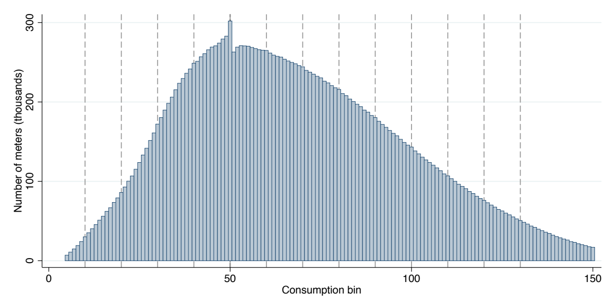
Source: PEA electricity tariff schedule

Figure 14: Bunching behavior among the FBE-eligible meters

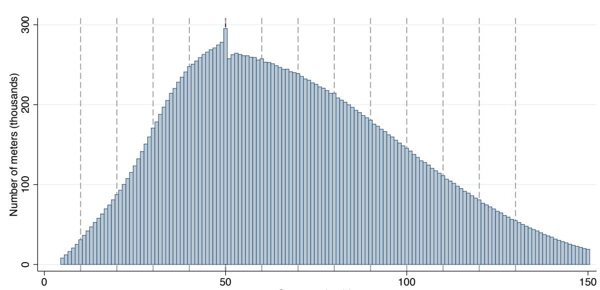
(a) 2013



(b) 2014



(c) 2015



Source: PEA billing data 2013–2015

response to the structural price elasticity:

$$(-e)^{\frac{e}{e+1}} = \frac{q^*}{\bar{q}}, \tag{3}$$

where e is the structural price elasticity of electricity consumption with respect to marginal price, $\bar{q}$ is the FBE threshold where bunching occurs, and q^* is the baseline optimal consumption in absence of the FBE program.

To complement the structural elasticity, Apaitan et al. (2018) also estimate the reduced-form price elasticity with respect to marginal price:

$$e_R = \frac{(\bar{q} - q^*)}{q^*} \Bigg/ \frac{(p^* - p)}{p}\,, \tag{4}$$

where e_R is the reduced-form elasticity, $\bar{q}$ and q^* have the same definitions as above, p^* denotes the implicit marginal price at q^* as a result of the FBE incentive, and p is the actual marginal price at q^* in absence of the FBE program.

Both expressions of the price elasticities require a measure of the consumption response q^*. Apaitan et al. (2018) thus adopt a standard empirical method outlined in Chetty et al. (2011) and Kleven and Waseem (2013), which infer q^* from the excess bunching mass near the consumption threshold. Specifically, the authors estimate the counterfactual consumption density using a polynomial of degree r:

$$N_j = \sum_{i=0}^{r} \beta_i (z_j)^i + \sum_{i=z_l}^{q^*} \gamma_i I[z_j = i] + \nu_j, \tag{5}$$

where N_j is the number of consumers in consumption bin j, z_j is the consumption level of bin j, and $[z_l, q^*]$ is the excluded region.

The counterfactual (predicted) distribution is calculated from:

$$\hat{N}_j = \sum_{i=0}^{r} \hat{\beta}_i (z_j)^i. \tag{6}$$

The resulting excess bunching is simply the difference between the observed distribution and the counterfactual distribution between z_l and $\bar{q}$. The excluded region for the counterfactual estimation starts from the $z_l = 89^{\text{th}}$ (or 49^{th}) consumption bin and ends at the bin where the excess mass equals to the missing mass. In other words, the "end point" q^* is z_u such that

$$\sum_{j=z_l}^{\bar{q}} (N_j - \hat{N}_j) = \sum_{j>\bar{q}}^{z_u} (\hat{N}_j - N_j) \tag{7}$$

The findings from Apaitan et al. (2018) can be summarized as follows.

First, the fact that customers only bunch at the FBE threshold and not at other consumption thresholds of the non-linear tariff schedule suggests that consumers do respond to the marginal price *if the change in the marginal price is large enough*. Thailand's the electricity tariff follows the increasing block price (IBP), which features several consumption range with increasing marginal price. Thus, if consumers are rational and maximizes utility, we should observe the bunching of consumption at *every* threshold before the marginal price rises. In reality, as evident in figures 14a–14c, the overall consumption distribution is smooth except at the FBE threshold. We speculate that the lack of bunching elsewhere is due to the presence of various optimization costs people face to target their consumption correctly. If the gain from bunching is small, as is the case for the small marginal price changes along the normal IBP schedule, most customers would rather ignore it. If the gain from bunching is large, as is the case for the substantial increase in the marginal cost around the FBE threshold, some customers with high elasticity would respond by bunching around that threshold.

Table 3: Price elasticity of residential electricity consumption

Year	Bunching response	Excess bunching	Structural e	Reduced-form e
2013	17.73*	0.039*	-0.129*	-0.154*
	(3.07)	(0.003)	(0.031)	(0.063)
2014	17.65*	0.039*	-0.128*	-0.152*
	(3.04)	(0.002)	(0.031)	(0.063)
2015	18.11*	0.039*	-0.133*	-0.158*
	(1.90)	(0.002)	(0.019)	(0.039)

Note: *Bunching response* is the consumption unit (above the threshold) where bunching ends. *Excess bunching)* is the ratio of the excess bunching mass to the counterfactual density (no-FBE) at the threshold. *Structural e* is the structural price elasticity. *Reduced-form e* is the reduced form price elasticity. Standard errors are in parentheses.Standard errors are calculated using bootstrapping with 500 replications. * indicates statistical significance at the 5% level.

Second, despite the distinct observed bunching at the threshold points, the degree of bunching is small relative to the overall distribution. Table 3 reports the estimation results using data from 2013–2015. The table reveals that the customers in the excess bunching mass at is only 4% of all customers who consume at the threshold. The small bunching mass is due to various forms of optimization frictions such as the lack of knowledge of the FBE program or the difficulty in keeping track of their cumulative consumption.

Third, the estimated structural elasticities, which present the *upper bound* of the structural elasticities, range from −0.129 to −0.133. The complementary reduced-form elasticities are slightly larger and range from −0.152 to −0.158. These price elasticities for the FBE-eligible customers with small meters will be supplemented with the elasticity estimates of the rest of the customers in the next subsection. Together, they give a complete picture of the consumption response among all the residential customers.

Fact #6: Largest (highest-income) consumers are the most responsive to the temperature change and the least responsive to the price change.

In this last subsection, we explores how electricity consumption of the remaining residential customers with large meters responds to the changes in electricity price. The price elasticity of consumption provide valuable information on the potential impact of the climate change and energy policies. For example, the price elasticity can be used to calculate the incidence and distributional impact of an electricity price reform, the effectiveness of a price-based demand response measure, or even to help identify the target group for the energy efficiency incentive. To our knowledge, there does not exist an official estimate for the price elasticity of residential electricity consumption in Thailand.

In general, estimating the price elasticity of electricity consumption is challenging due to the presence of the increasing block price (IBP). Under the IBP, the marginal price that a customer faces is an increasing function of the consumption. The positive relationship between the marginal price and the consumption level will then causes a downward bias in the estimated price elasticity. Thus, various ways to correct for such endogeneity has been proposed.[3]

To circumvent this endogeneity problem, we exploit an exogenous variation in the electricity price coming from the automatic fuel adjustment mechanism (Ft). Specifically, the retail tariff consists of two parts: the base tariff and the automatic fuel adjustment mechanism (Ft). The base tariff has an IBP structure and is revised every 3–5 years. The Ft, on the other hand, is a flat rate per kWh that gets adjusted every 4 months to reflect the deviation of fuel costs from the expected rate as well as additional expenditure from government's energy policy. The Ft rate therefore serves as an exogenous price variation that help us identify the price elasticity of consumption.

This method, however, can only be used to identify the price elasticity of customers with larger meters (who are ineligible for the FBE). This is because the FBE-eligible customers might not be subject to the Ft charge if they consume under the FBE threshold. In other words, the Ft rate is *endogenous* for the FBE-eligible customers and would like cause a downward bias in the price elasticity estimates.

To proceed with the estimation, we construct a panel of 10% random sample of PEA's

[3] For example, see Ito (2014); Reiss and White (2005)

large residential meters between 2012–2015, during which the base tariff remained constant. We then estimate the average price elasticity using the following fixed-effect model:

$$\log(q_{it}) = \beta_0 + \beta_1 \log(Ft_t) + \beta_2 \log(temp_{ct}) + \gamma_i + \epsilon_{it}. \tag{8}$$

Where $\log(q_{it})$ is the natural log of meter i's average daily consumption in month t, $\log(Ft_t)$ is the log of the Ft rate in month t, $\log(temp_{ct})$ is the average temperature in province c in month t, and γ_i is the meter fixed effect.

Threats to identification: Our identification of the price elasticities above relies on the exogenous variations in the Ft rates. By design, every electricity consumer faces the same Ft rate in a particular month. They also experience the same change in the Ft rate from one period to the next. Therefore, our elasticities estimates are identified solely from the change in the Ft over time (and not across customers). The main threat to identification comes from the potential omitted macro variables that could co-move with the Ft rate, but affect the electricity consumption independently of the Ft rate. We attempt to address part of the concern by controlling for the common time trend as well as the province-specific time trends.

Table 4 reports the estimated price elasticity of electricity consumption with respect to the Ft rate. Our preferred specifications are models (3) and (4), which include the common and province-specific time trends. The following findings stand out. First, the estimated impact of the temperature are robust to the specification and are tightly estimated to be around 0.05. In other words, a one degree Celsius increase in the average temperature will raise the average consumption by 0.05% or around 0.14 kWh per month.[4] Second, the estimated price elasticity is tightly estimated to be around −0.08. Therefore, a 1% increase in the average Ft rate will reduce the average consumption by around 0.22 kWh per month. Adding the time trends reduces the elasticity estimates, but the results do not differ between common and province-specific time trend specifications.

[4] Average consumption of the large customers during the sample period was around 280 kWh per month.

Table 4: Price elasticity of residential electricity consumption

	(1)	(2)	(3)	(4)
temp	0.0505***	0.0494***	0.0497***	0.0499***
	(346.70)	(340.33)	(345.44)	(347.53)
log(ft)		-0.137***	-0.0808***	-0.0803***
		(-35.13)	(-21.06)	(-20.91)
constant	0.492***	0.605***	1.026***	1.024***
	(122.76)	(124.89)	(33.00)	(33.00)
Common time trend	No	No	Yes	No
Province time trend	No	No	No	Yes
N	8,369,154	8,369,154	8,369,154	8,369,154

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

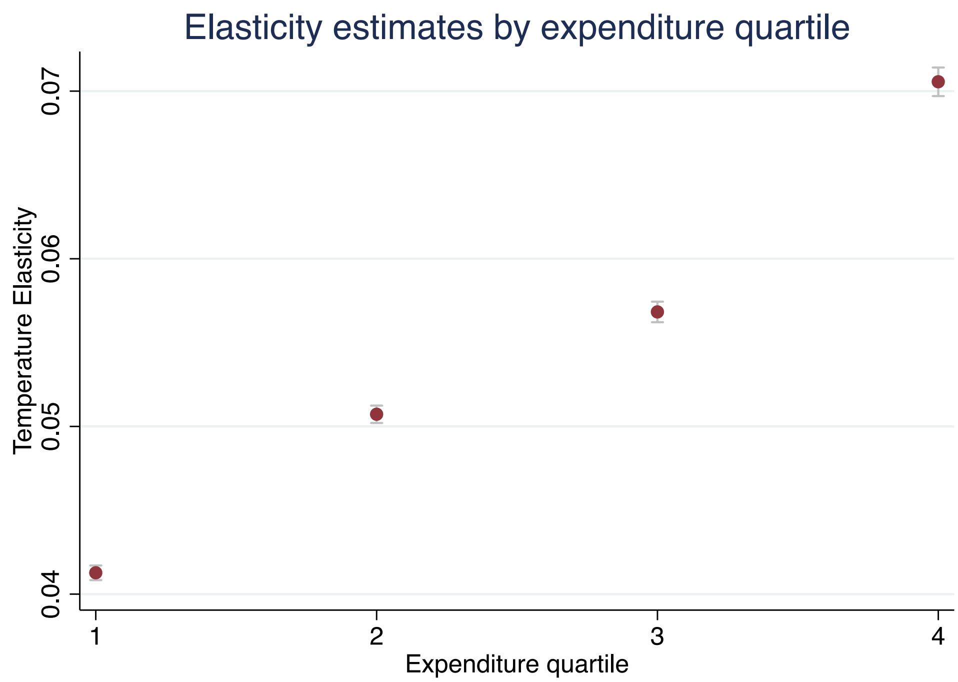
We next explore how temperature and price responses vary with average household expenditure. To do so, we group the sample into quartiles based on the province-average household expenditure per capita between 2013–2015. We then re-estimate equation 8 for customers in each expenditure quartile. Figures 15a and 15b report the estimates, which reveal the following results.

First, customers in higher-income provinces are more responsive to increase in the average temperature. Customers in the 4$^{\text{th}}$ income quartile are almost twice as responsive as those in the 1$^{\text{st}}$ income quartile. This result is consistent with table 1: higher-income households own and probably use more energy-intensive appliances. Thus, they are able and willing to increase electricity consumption by much more than lower-income households. Second, customers in higher-income provinces are less responsive to the increase in the Ft rate. Price elasticity estimates for provinces in the 4$^{\text{th}}$ quartiles is not statistically different from zero.

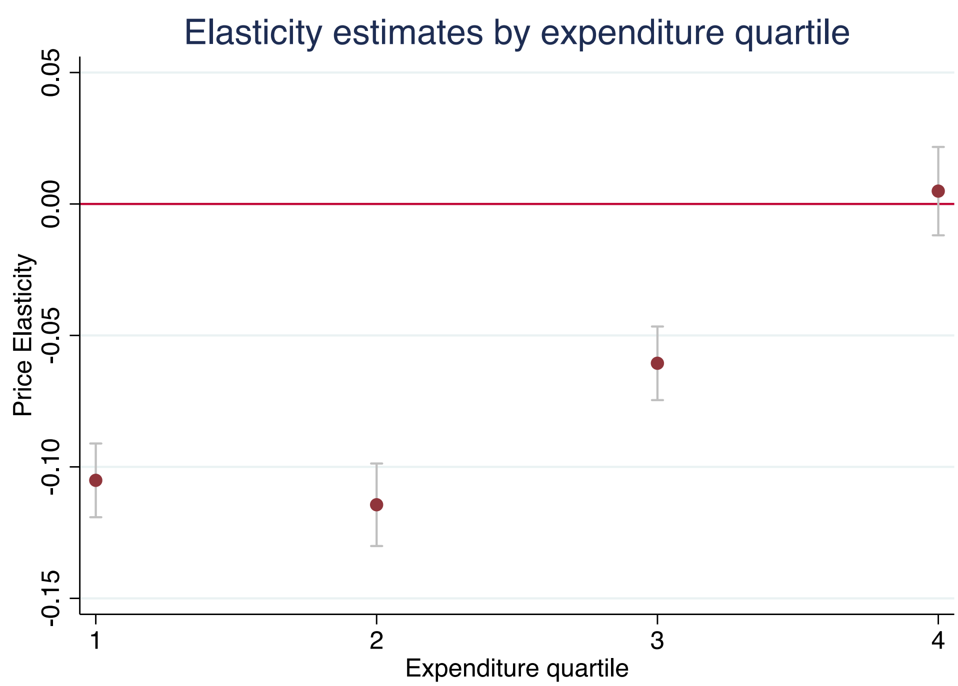
Our elasticity estimates lie towards the low end when compared to the previous studies that used micro-data to estimate the short-run price elasticity. For example, Reiss and

Figure 15: Temperature and price responses by expenditure quartile

(a) Temperature elasticities



(b) Price elasticities



Note: The vertical bars indicate the 95% confidence interval for the elasticity estimates. Source: Author's estimation

White (2005) estimate the price elasticities to range from −0.29 to −0.49 with lower-income consumers being more price responsive. Deryugina et al. (2017) use billing data and find one-year price elasticity of −0.16 and three-year price elasticity of −0.27. Our elasticity estimates are closest to Ito (2014), whose estimate the elasticity with respect to average price is around −0.054, and to Blázquez et al. (2013), who find the short-run price elasticity to be −0.07 in Spain.

3 Policy Implications and Conclusions

This paper documents the stylized facts on the residential electricity consumption in Thailand. We use a large administrative dataset on residential electricity consumption in the Provincial Electricity Authority service area. The sample includes more than 16 million meters from every provinces except Bangkok and vicinity. The stylized facts described in the paper provide policy implications on at least three aspects.

First, the electricity billing data provides a measure for tracknig household wealth dispersion and wealth inequality. The government can use electricity consumption data, especially in the summer months, to provide a high-resolution and up-to-date indicator for the wealth distribution and inequality. Our analyses reveal an alarming inequality situation that is rising steadily and concentrated in the major cities.

Second, innovative the utility bill payment methods can provide a substantial cost-saving benefits to consumers. Traditional fee-free payment options such as credit card and bank transfer prove to have a high transaction cost and is inaccessible by many of the utility customers. Therefore, a majority of the customers have been paying their bills through the dealer-operated counter services and facing a small fee. The rise of the mobile payment and e-money that does not require an access to the financial institutions offers a substantial cost-saving benefits to utility customers.

Third, the price-based instrument might not be an effective tool to encourage en-

ergy conservation in the residential sector. Our analyses suggest that as the average temperature rises, future electricity consumption will come disproportionately from the higher-income households. However, the low price elasticity of this group of customer can compromise the effectiveness of the price-based mechanism to promote electricity conservation and energy efficiency. Therefore, policymakers should also consider a set of non-price mechanisms such as a behavioral nudge and the social norm instruments to invoke household's energy conservation behaviors.

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