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Bunching for Free Electricity

by

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Bunching for Free Electricity

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Abstract

This paper documents the impacts of Thailand's Free Basic Electricity program on electricity consumption behavior. Under the program, households who use less than 50 units are exempt from paying their electricity bill in that month, while households who use more than 50 units have to pay for the full amount. The program thus creates a large notch in the household's budget set. In contrast to existing literature that finds little or no bunching, we observe a distinct bunching of electricity consumption around the threshold. Nonetheless, the excess bunching is still small compared to the overall distribution. We provide possible explanations on the role of various optimization frictions.

Keywords: Price elasticity, bunching, electricity consumption, free basic electricity

JEL Classifications: D12, L94, Q21, Q41, Q48

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1 Introduction

Non-linear price schedule is a common practice for utility services. Under the assumption that consumers respond to marginal price, increasing-block pricing is a standard tool that many utilities use to encourage energy conservation by reflecting the increasing marginal cost of production. However, many recent studies have pointed out the lack of evidence that consumers respond to marginal price. An important indicator used in such studies is the lack of bunching at kink points of the price schedule. Borenstein (2009) and Ito (2014) attribute the lack of bunching as either coming from consumers' having near zero elasticity, or responding to an alternative price. As outlined in Ito (2014), the presence of uncertainty about consumption shocks may also lead consumers to form and respond to the expected marginal price. Additionally, if the cognitive cost of understanding the complex increasing-block pricing is high, consumers may resort to using the average price as an approximation of the marginal price.

It is important to note that, in the aforementioned studies, the authors estimate demand elasticity in the context of relatively small marginal price changes. For example, while Ito (2014) finds no bunching when the price increase is as high as 80 percent, this increase translates to only approximately 10 cents per unit. In these settings, the cognitive cost of optimizing with respect to the increasing-block price might still outweigh the benefits from saving the money, justifying the use of the average price as a proxy for the marginal price. While existing studies document the lack of consumers' response to small marginal price change, no study has been done on the consumers' response to a more extreme marginal price change.

This study utilizes a unique feature of the price structure created by Thailand's Free Basic Electricity (FBE) program. The program exempts consumers who consume below the threshold level of electricity (e.g. 50 units) from paying their bill in that month. However, if the consumer exceeds the threshold, he/she has to pay the bill for all the units consumed. Such incentive creates a large "notch" in the consumer's budget set and a sharp increase in the marginal price from 0 THB to 130 THB (approximately 4 USD) when one moves from the 50th unit to the 51st unit.

This paper adds to a growing list of studies that uses the observed bunching at the kink/notch point to estimate various behavioral responses. Seminal papers led by Saez (2010) and Chetty et al. (2011) laid out a theoretical framework on the relationship between observed bunching and labor supply elasticity as well as devised a simple empirical method to credibly quantify such excess bunching. As summarized in Kleven (2016), bunching analysis in other settings include, for example, estimating behavioral response to electricity price (Ito, 2014), mortgage interest rate (Best and Kleven, 2017), pensions level (Brown, 2013), health insurance contract (Einav et al., 2017).

Our study also contributes to another strand of literature that aims to quantify the price elasticity of electricity consumption. In general, estimating causal impact of the price change on electricity consumption is not straightforward. First, estimating the relationship between the observed consumption at different observed marginal prices using cross-sectional datawill suffer a reverse causality problem. This because observed consumption is the result of consumers' endogenously choosing their optimal consumption in response to the existing price schedule. Remedies to such problem include estimating a structural model (Reiss and White, 2002) or a panel data model that exploits exogenous change in the price schedule over time (Alberini et al., 2011; Ros, 2015; Campbell, 2018; Borenstein, 2009). Second, even if there is an exogenous price schedule change, comparing the consumption pre- and post-policy change in a panel data model is often not credible due to lack of a suitable control group to control for unobserved confounder. Only under a rare circumstances as laid out in Ito (2014) can one observe both exogenous price change and appropriate control group to infer a credible causal relationship. By using the observed excess bunching of consumers around the notch point, our study offers an alternative and arguably more credible way of estimating the price elasticity from the cross-sectional data.

The study features four main results. First, there is an observable bunching of consumption around the notch point in every period of the analysis. The result indicates that some consumers still respond to marginal price when the price increase is large enough, and that the findings in earlier studies might be due to the small size of the price increase. Second, the excess bunching becomes larger as the financial incentive increases. This is because a larger financial incentive can induce more consumers to overcome the aforementioned frictions. Third, even though the sample exhibits distinct bunching at the notch points, the degree of bunching is small relative to the overall distribution. Fourth, the estimated elasticities from the bunching observation are very small and are not always statistically different from zero.

The small excess bunching and the corresponding elasticity can result from various optimization frictions. First, targeting consumption at the notch point is difficult since consumers face substantial uncertainly on consumption shocks and/or may not be able to keep track of their cumulative consumption in a month. Second, some consumers may not be aware of the FBE program and thus did not respond to the incentive. We show evidence supporting the presence of both form of optimization frictions.

Our results contribute a new evidence on consumption response in the context of an extreme marginal price change. In contrast to existing studies that find little or no response to the increasing-block price, our findings confirm that, in the context of FBE, some consumers *do* respond to such price schedule if the financial incentive is large enough. However, the large amount of price incentive required to induce a meaningful consumption response might render the increasing marginal price approach infeasible in practice.

This paper is organized as follows. Section 2 describes the background of the FBE program and its impact on the consumer's budget constraint. In section 3, we develop a simple theoretical model of price response that links the observed bunching to the price elasticity of electricity. Section 4 provides the data source and descriptive statistics. Section 5 presents the estimation of excess bunching and price elasticity. Last, section 6 offers policy implications and conclusions.

2 Background on the FBE Program

The Free Basic Electricity (FBE) program in Thailand was first introduced in 2008 as a temporary measure to subsidize the cost of living for lower income households during the economic downturn. At the program's introduction, residential meters that used less than 80 units (kWh) per month were exempted from paying that month's bill, while residential meters that used between 80 and 150 units received a 50 percent discount on their electricity bill. In early 2009, the program's eligibility changed to exempting residential meters that used less than 90 units per month from paying the bill. This is equivalent to a saving of up to 253 THB or 7.9 USD.[1] Consumers who exceed the free electricity threshold need to pay their full bills starting from the first unit. Between 2009 to present, the eligibility rule has periodically been changed to ensure that subsidy burden remains managable. Most recently, the threshold was lowered to 50 units, which is equivalent to a saving of up to 130 THB or around 4.1 USD. Table 1 summarizes the various changes to the program.

TABLE 1: The evolution of the FBE program

Period	Meter type	Free Threshold
Aug 2008 – Jan 2009	Residential	80 units[1]
Feb 2009 – Jun 2011	Residential	90 units
Jul 2011 – May 2012	*Small* residential	90 units
Jun 2012 – Dec 2015	*Small* residential	50 units
Jan 2016 – Present	*Small* residential, non-business	50 units[2]

[1] Consumers who consume between 81–150 units get a 50% discount.

[2] To be eligible, the consumer must be below the threshold for three consecutive months.

The FBE eligibility rule creates a sharp discontinuity in the marginal and average price schedules that the consumer faces. Figures 1a and 1b show that the marginal and the

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[1] We assume a currency conversion rate of 32 THB per 1 USD.

average price for all units under 50 are both zero since each unit of electricity is free. At the 51st unit, the marginal price significantly increases from zero to 130 THB (approximately 4.1 USD) since the consumer needs to pay starting from the first unit. On the other hand, the average price jumps by only around 2.8 THB (around 1 cent), since the total cost is spread among the first 50 units. After the 51st unit, the marginal and average price schedule reflect the regular increasing block price schedule for residential consumers.

3 Bunching Model and Estimation

3.1 Bunching model

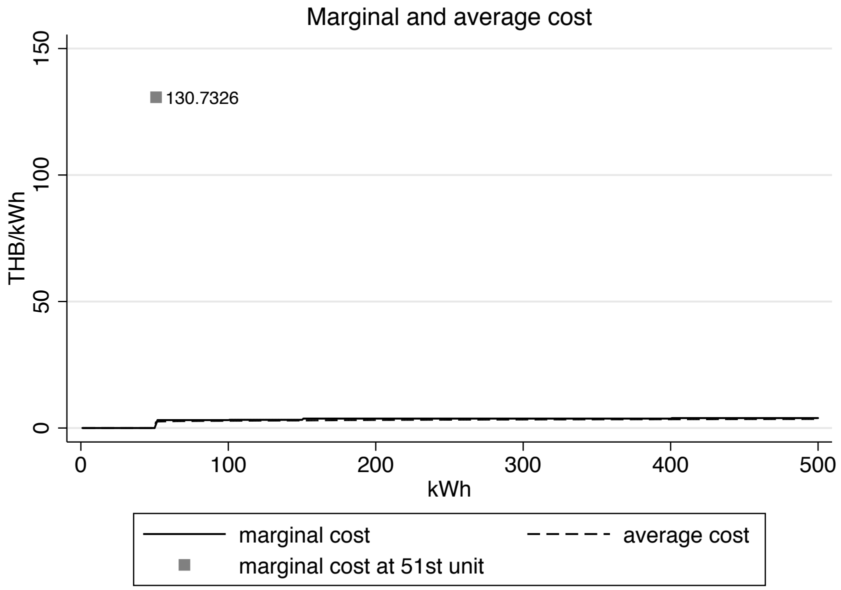
In our model, we assume that the consumer chooses between two goods: electricity and the numeraire good. Figure 2 shows the consumer's budget constraint. The horizontal axis represents the consumption of electricity (in kWh) and the vertical axis represents the consumption of the numeraire good. The FBE program allows the consumer to consume electricity for free up the threshold amount $\bar{q}$. After that, the program causes the budget constraint to drop to the one without the program, creating a notch in the consumer's budget constraint.

For simplicity, we will abstract from the marginal price increases beyond the threshold and assume that a consumer has to pay a constant marginal price p per unit if he/she consumes more than the threshold.

Theoretically, the incentives created by the FBE program should lead to two types of responses. First, in absence of the optimization frictions, the zero marginal cost of electricity for the first $\bar{q}$ units should induce all consumers whose baseline consumption were below $\bar{q}$ units to increase their consumption to $\bar{q}$. In other words, consumption below $\bar{q}$ is the strictly dominated region. We call this the "response from below." Second, given the FBE-induced notch in the budget constraint, there should exist a marginal buncher who is indifferent between the interior solution (q^*) and the notch point ($\bar{q}$). Assuming no

Figure 1: Marginal vs. average price

(a) Overview



(b) Zoomed in

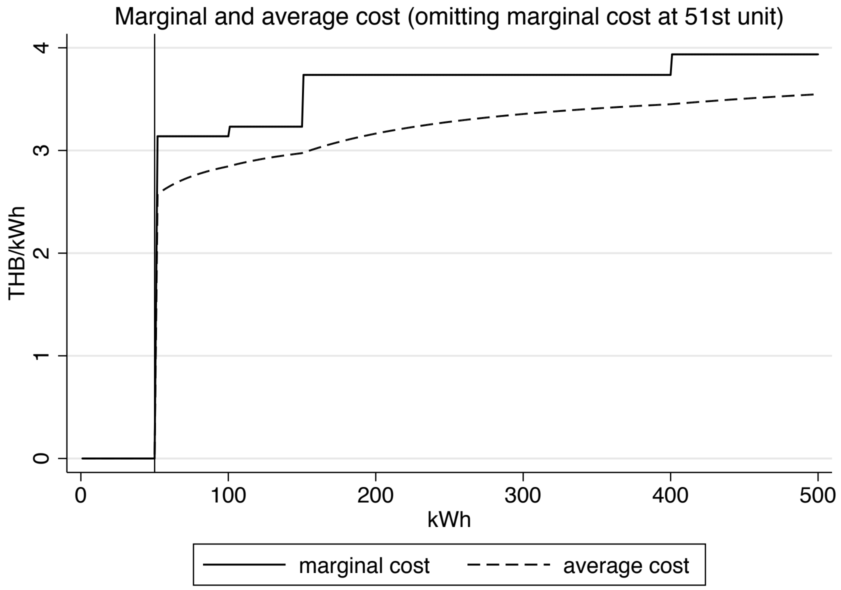
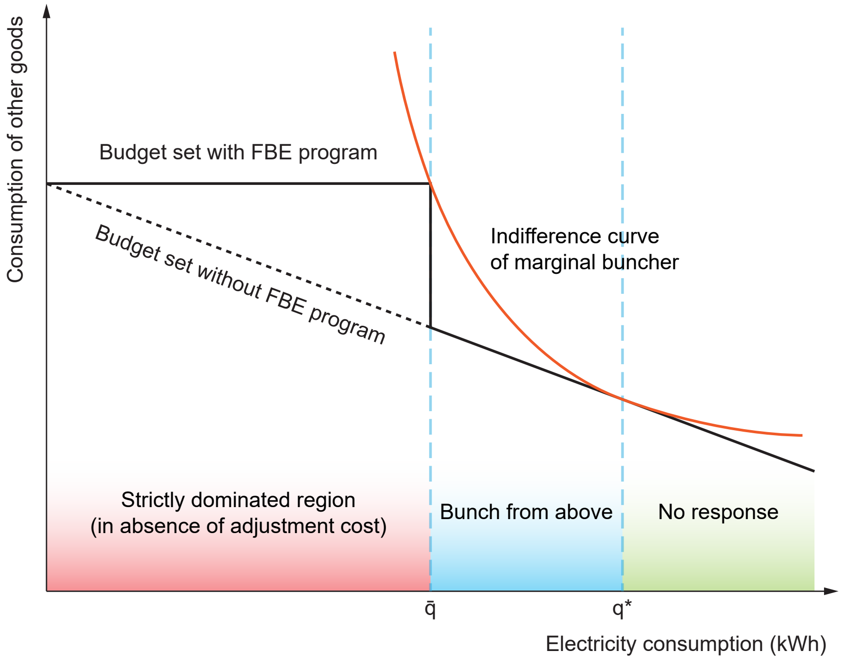


FIGURE 2: Consumer's budget set under the FBE program



frictions or uncertainties, all consumers whose interior solution lies between $\bar{q}$ and q^* will necessarily bunch at $\bar{q}$. We call this second type of response the "response from above."

In practice, the *first type of response (from below)* is unlikely to contribute to the excess bunching at $\bar{q}$. This is because there is a cost to consuming more electricity, especially for lower income households, i.e. cost of buying more electrical appliances. If the response from below exists at all, we expect it to cause only a small increase in consumption. As shown in section 4, we still observe a distribution of eligible consumers who consume under the threshold $\bar{q}$.[2]

The second type of response (from above), on the other hand, would create a distinct excess bunching at $\bar{q}$ because these consumers have no incentive to reduce consumption too far below $\bar{q}$. In the following text, we describe a simple theoretical framework that relates the observed "bunching from above" to the average price elasticity.

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[2] Unlike the application in Kleven and Waseem (2013), we cannot quantify the size of the friction (i.e. the adjustment cost) in this case because the strictly dominated region spans all the way from zero unit to $\bar{q}$ units. Therefore, no credible counterfactual distribution can be estimated.

Formally, let q_i and η_i be consumer i's consumption of electricity and numeraire good, respectively. Parameter α_i represents consumer-specific taste for electricity, and e is the constant price elasticity. Assume that the consumer's preference is characterized by an isoelastic quasi-linear utility function:

$$U(q) = \frac{\alpha_i}{1+1/e}\left(\frac{q_i}{\alpha_i}\right)^{1+1/e} + \eta_i. \tag{1}$$

The consumer chooses electricity and numeraire good consumption that maximizes his/her utility $U(q)$ subject to a budget constraint

$$I \geq \begin{cases} pq_i + \eta_i & \text{if } q_i > 50, \\ \eta_i & \text{if } q_i \leq 50, \end{cases}$$

where p is the per-unit price of electricity and I is monthly income.

Assuming interior solution and no uncertainty, the optimal consumption level is $q_i = \alpha_i p^e$. Thus, parameter α_i is the preferred consumption level if he/she is perfectly inelastic ($e = 0$) and can afford to consume at the interior solution.

By definition, the marginal buncher whose interior solution is $q^* = \alpha^* p^e$ is indifferent between consuming at the interior solution q^* and at the notch point $\bar{q}$. Substituting in the optimal consumption $q_i = \alpha_i p^e$, we have that the marginal buncher's utility at the interior solution q^* is

$$U(q^*) = -\frac{\alpha^*}{1+1/e}\left(\frac{p^{e+1}}{e}\right) + I, \tag{2}$$

and the marginal buncher's utility at the notch point $\bar{q}$ is

$$U(\bar{q}) = \frac{\alpha^*}{1+1/e}\left(\frac{\bar{q}}{\alpha^*}\right)^{1+1/e} + I. \tag{3}$$

Using the indifference condition $U(q^*) = U(\bar{q})$ and the first order condition $q^* = \alpha^* p^e$, we arrive at a relationship that links consumption response to price elasticity:

$$(-e)^{\frac{e}{e+1}} = \frac{q^*}{\bar{q}}. \tag{4}$$

3.2 Estimating reduced-form elasticities

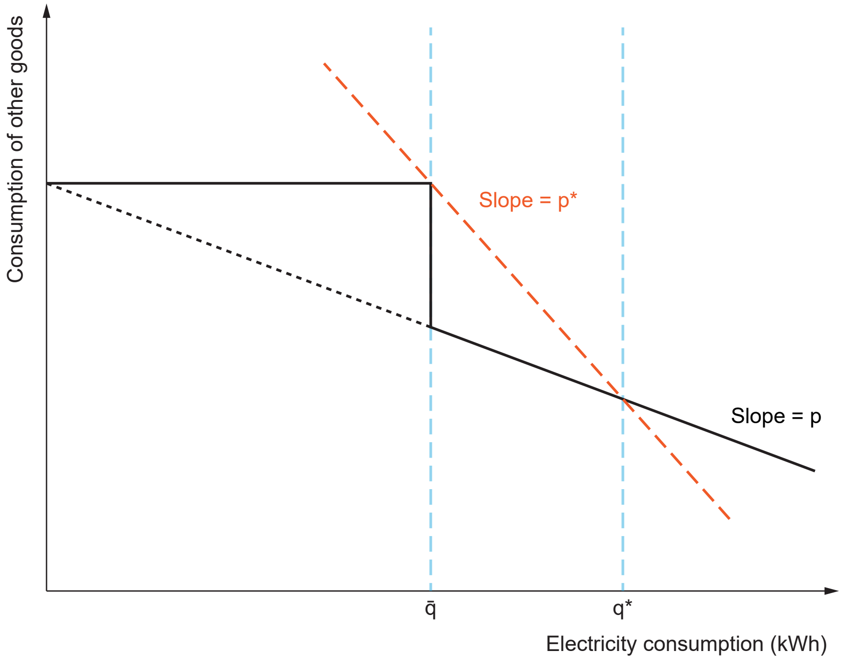
In this subsection, we derive an expression for estimating the reduced-form price elasticities that does not rely on a parametric assumption on the utility function.

The basic idea is to approximate the change in the implicit marginal price and compare it to the change in consumption that results from the notch. We define an implicit marginal price for each consumption unit (q) *above* the FBE threshold ($\bar{q}$) as

$$p^*(q^*) = \frac{TC(q^*) - TC(\bar{q})}{q^* - \bar{q}} = \frac{TC(q^*)}{q^* - \bar{q}}.$$

The implicit marginal price is depicted as a dash line in figure 3.

Figure 3: Implicit marginal price for reduced-form elasticity



Using the definition of elasticity defined in Saez (2010) and assuming a small change in the implicit marginal price at the notch point, the reduced-form elasticity with respect to the implicit marginal price is defined as

$$e_R = \frac{(\bar{q} - q^*)}{q^*} \bigg/ \frac{(p^* - p)}{p} \, . \tag{5}$$

Note that the expression for the reduced-form elasticity depends on both the changes in price and quantity, while the structural elasticity derived above only depends on the quantity change. This means that when the observed consumption response is large, the implicit marginal prices p^* will be small, and the reduced-form elasticity will be larger than the structural elasticity in absolute term and vice versa.

3.3 Estimating excess bunching and consumption response

In order to estimate elasticity, we need to estimate excess bunching and consumption response q^*. To do so, we use an empirical method outlined in Chetty et al. (2011) and Kleven and Waseem (2013). Specifically, we estimate the counterfactual density using a polynomial of degree r:

$$N_j = \sum_{i=0}^{r} \beta_i (z_j)^i + \sum_{i=z_l}^{q^*} \gamma_i \mathbb{I}[z_j = i] + \nu_j, \tag{6}$$

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

The counterfactual (predicted) distribution for any particular bin j is calculated from:

$$\hat{N}_j = \sum_{i=0}^{r} \hat{\beta}_i (z_j)^i. \tag{7}$$

The resulting excess bunching is simply the difference between the observed distribution and the counterfactual distribution between z_l and $\bar{q}$ (FBE threshold).

Suppose that the excluded region for the counterfactual estimation starts from the z_l^{th} consumption bin. We identify the "end point" q^* to be the bin that makes the excess mass equals to the missing mass. In other words,

$$\sum_{j=z_l}^{\bar{q}} (N_j - \hat{N}_j) = \sum_{j>\bar{q}}^{q^*} (\hat{N}_j - N_j). \tag{8}$$

We can then use this q^* to estimate the price elasticity from equation (4). As described in Kleven and Waseem (2013), this method yields an *upper bound of the bunching response* in the case of heterogenous structural elasticity. In other words, q^* represents the response of the highest-elasticity consumer in absence of frictions. Note that the FBE notch does not create a strictly dominated region similar to the notch in Kleven and Waseem (2013). As a result, we cannot identify the impact of the optimization frictions and provide a lower bound on structural elasticity in a similar fashion.

Lastly, standard errors for the excess bunching, end point, and the elasticity estimates are computed using bootstrap method outlined in Chetty et al. (2011) and Kleven and Waseem (2013).

3.4 Identification

Due to the lack of pre-FBE data, we identify excess bunching, ending bin, and elasticity using a cross-sectional billing data. In other words, the counterfactual distribution is calculated using data within the post-FBE period. Thus, the identification relies on the accuracy of the estimated counterfactual distribution. In this regards, we acknowledge a potential threat to the identification that the shape of the counterfactual distribution might not be correct.

Estimating the shape of the counterfactual distribution can be challenging if the bunching happens in the area with curvature. This is the case for our the FBE program during the 50-unit free period since the threshold occurs near the mode of the distribution. We alleviate this concern by conducting sensitivity estimations using various degrees of polynomials and excluded ranges.

4 Data and Descriptive Statistics

4.1 Data

We obtain individual meter's monthly billing data from the Provincial Electricity Authority of Thailand (PEA). The PEA is a state-own public utility that sells power to retail customers throughout Thailand, except in Bangkok and its vicinity. The data in this study accounts for more than 70 percent of electricity consumption in Thailand.

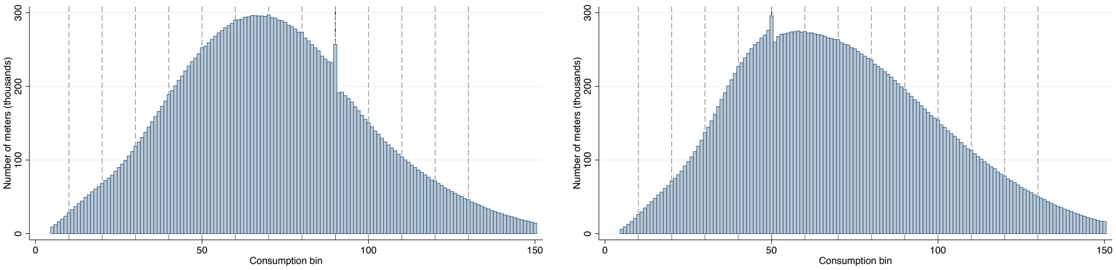
The main variable of interests include monthly electricity consumption, billing amount, and meter size. Due to data availability, the analysis periods are limited to January 2012 through December 2015. We perform our analyses using two versions of the data. The first version is an unbalanced panel data over the 48-month analysis period. The average number of observations in the unbalanced panel data are 8.3 million FBE-eligible meters per month. The second version is a balanced panel data set that contains the same set of unique meters over the 48-month analysis period. This version of the data aims to eliminate the effect of the entries (of new meters) and exits (of existing meters). Our balanced panel sample contains 4.3 million unique FBE-eligible meters in each month.

4.2 Descriptive evidence on bunching

Figures 4a–4d plot the histograms of consumption for January–May of each year. We restrict the data to the first 5 months to account for the fact that the free electricity threshold was 90 units until May 2012, before being lowered to 50 units afterwards.

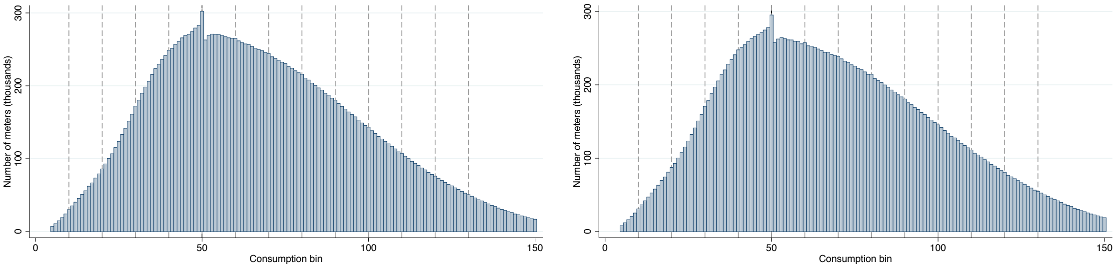
We observe distinct bunching of consumption at the notch points in every period (month) of the billing data. The distribution of consumption is smooth overall except at the notch points (90 units in 2012 and 50 units afterwards). Further, the histograms also indicate that excess bunching may start around 5 units below the threshold.

Figure 4: Histogram of consumption (January–May of each year)



(a) 2012 (90 units free)

(b) 2013 (50 units free)



(c) 2014 (50 units free)

(d) 2015 (50 units free)

Despite the observed bunching, the excess masses seem small relative to the overall distribution. The small responses reflect a difficulty in targeting consumption at the notch point, which may be due to low elasticity and various form of optimization frictions. The following observations highlights the difficulty in targeting.

First, very few customers can consume exactly at the notch point for several months in a year. Table 2 shows the number of times in 2013 that a meter consumes at the notch point (49–50 units, "exact bunching") and the number of times in 2013 that a meter receives free electricity ($\leqslant$ 50 units, "free electricity"). Most (99.9%) of the meters did not consume at the notch point more than 3 times in 2013.

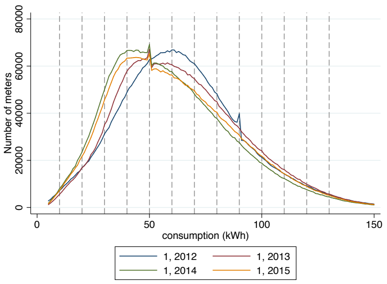
Second, most households that receive free electricity will either received the benefit for either 1–2 months or for all months. The meters that received free electricity for 1–2 months did so during the winter months when the baseline demand is low ("seasonal buncher"). Those that received the free electricity for 12 months are likely to be low income families whose baseline demands are well below the free electricity threshold.

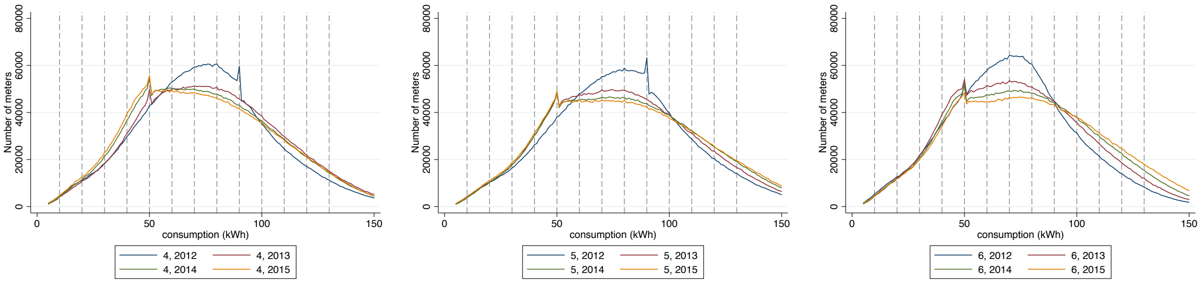
Table 2: Distribution of the number of months when a meter consumes at the notch point or receives free electricity

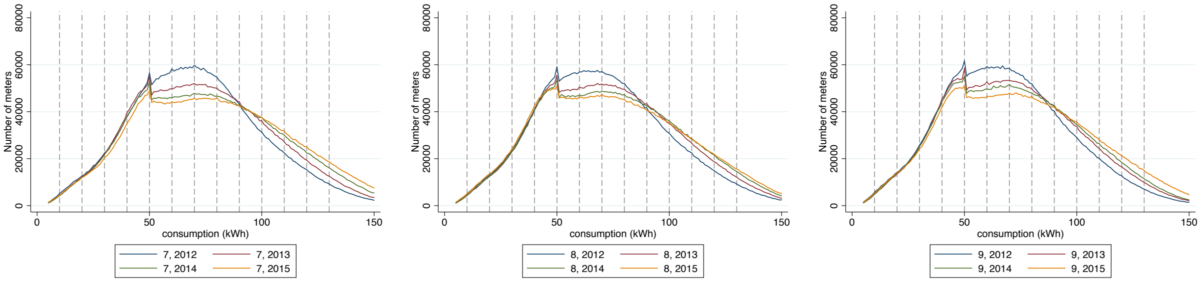
Number of months in 2013	**Exact bunching** No. meters	Percent	**Free electricity** No. meters	Percent
0	3,718,881	86.71	2,001,171	46.7
1	465,009	10.84	353,102	8.2
2	85,392	1.99	253,213	5.9
3	14,978	0.35	193,318	4.5
4	2,941	0.07	157,233	3.7
5	889	0.02	131,847	3.1
6	391	0.01	120,215	2.8
7	213	0	116,329	2.7
8	139	0	117,376	2.7
9	91	0	124,703	2.9
10	52	0	142,400	3.3
11	45	0	175,133	4.1
12	33	0	403,014	9.4
Total	4,289,054	100	4,289,054	100

Interestingly, a closer look at the monthly bunching pattern reveals that the consumption distribution and the excess mass differ substantially across months. Figure 5 shows consumption distribution by month for years 2012–2015. The bunching mass and bunching end point seem smaller during the winter months (November to February) when there are also more consumption mass to the left of the notch point. The consumption pattern is consistent with the average temperature pattern as depicted in figure 6. Milder temperature in the winter months results in the lower baseline consumption, making it easier for households to stay to the left of the notch point. Thus, households did not have to reduce consumption by much in order to stay below the FBE threshold.

Figure 5: Histogram of monthly consumption, 2012–2015


(a) January (b) February (c) March


(d) April (e) May (f) June


(g) July (h) August (i) September

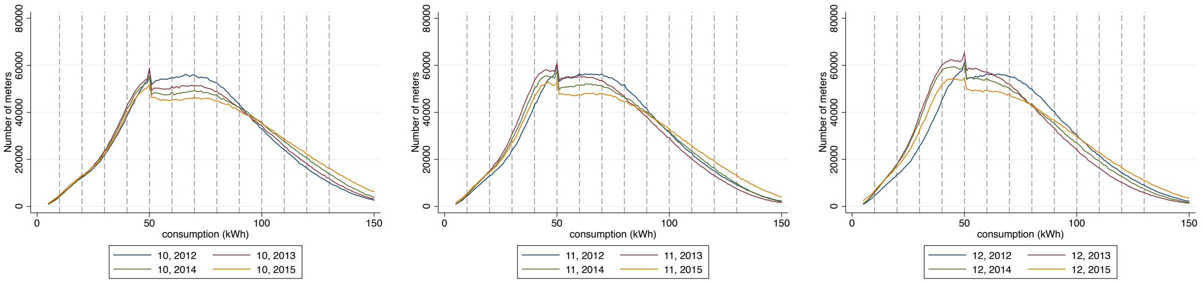
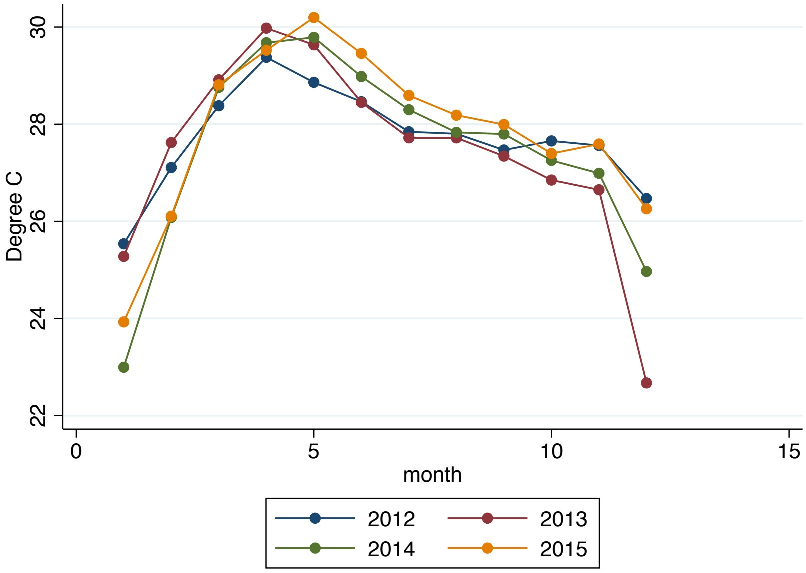

(j) October (k) November (l) December

Figure 6: Average temperature across years



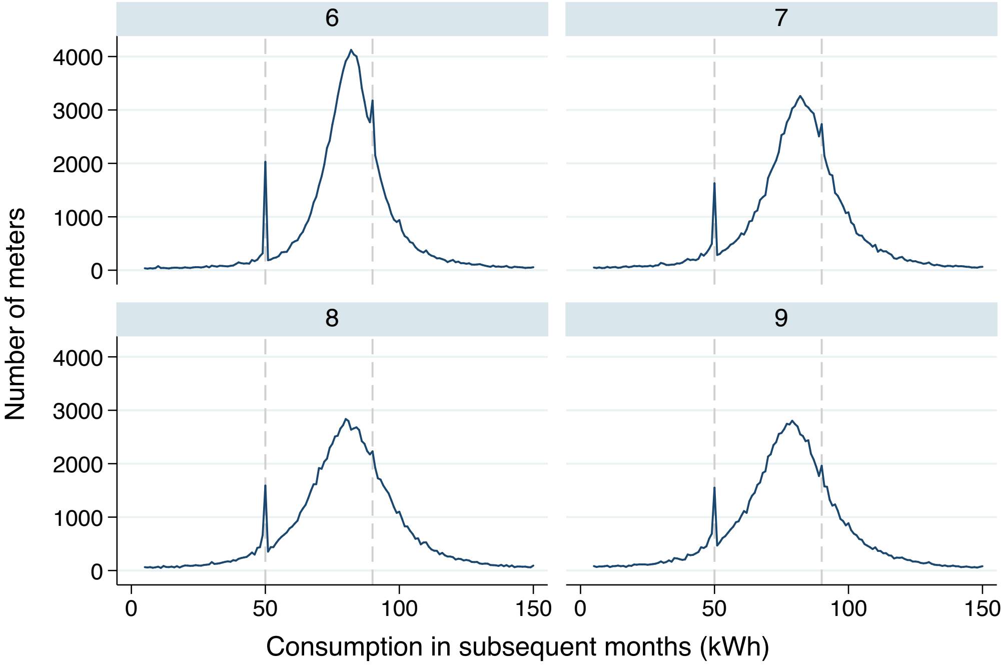
4.3 Optimization frictions on excess bunching

The small observed excess bunching in the previous subsection may be explained by the presence of optimization frictions. First, targeting consumption at the notch point is costly since consumers face substantial uncertainly on consumption shocks and/or may not be able to keep track of their cumulative consumption in a month. Figures 4a–4d show that the excess bunching was larger during the 90-unit scheme (2012) than during he 50-unit scheme (2013 through 2015), suggesting that a sufficient financial incentive can induce more consumers to overcome this optimization cost As described in section 2, the saving at the 90th unit is twice as large as the saving at the 50th unit (7.9 USD vs. 4.1 USD). We quantify this observation in section 5.

Another form of friction is inattention, as some consumers may not be aware of the FBE program and thus did not respond to the incentive. Figure 7 reveals that when the FBE threshold was first changed from 90 units to 50 units in June 2012, a significant number of consumers who used 90 units in May 2012 still bunch at 90 units in June 2012. The number of consumers in these bins, i.e. the “laggards,” decrease as time passes

(July–September 2012). This descriptive dynamic may suggest that some of the customers did not learn about the policy change right away and thus did not respond to the new incentive until later on.

Figure 7: Consumption in subsequent months conditioning on using 90 units in May 2012



5 Results

5.1 Excess bunching and elasticity: overall results

Figures 8a–8d plot the observed density against the estimated counterfactual density using unbalanced panel data from the first 5 months of every year. Figures 9a–9d plot the difference between the two densities. In all the graphs, we notice that excess bunching starts as far as 7 units below the threshold and feature sharp spikes at the threshold. The missing masses, on the other hand, are more diffused above the threshold. The bunching end points extend as far as 20 units above the threshold.[3]

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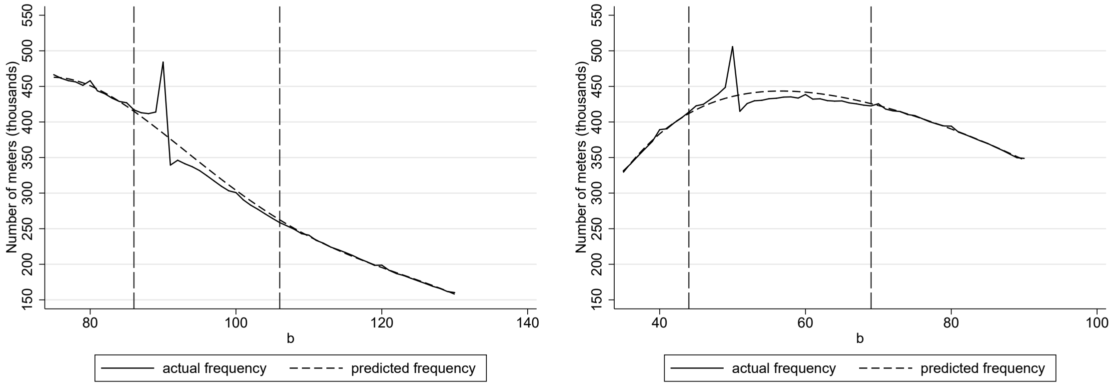
[3] We also notice an evidence of bunching at reference points, which are at the multiples of 10 units (e.g. 40, 60, 70, 80, and so on). This could happen due to meter inspectors' imprecision. The existence of these

Figure 8: Actual and counterfactual densities (January–May of each year)

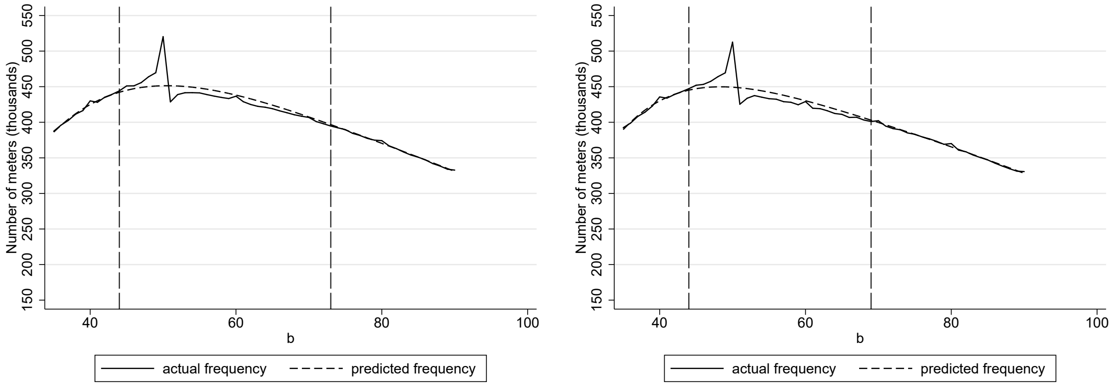
(a) Year 2012 (90 units free)

(b) 2013 (50 units free)



(c) 2014 (50 units free)

(d) 2015 (50 units free)

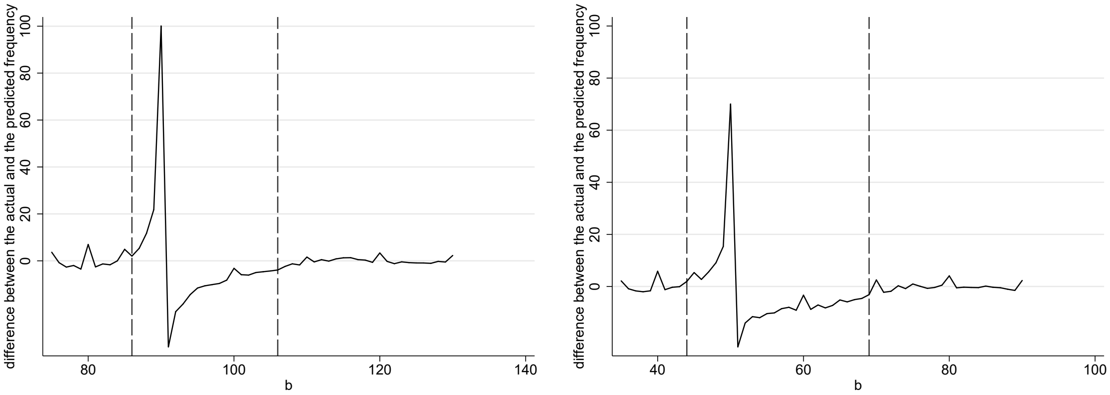


Note: The counterfactual distribution is estimated using the 5th-degree polynomial.

Figure 9: Difference between the actual and counterfactual densities (January–May of each year)

(a) 2012 (90 units free)

(b) 2013 (50 units free)



(c) 2014 (50 units free)

(d) 2015 (50 units free)

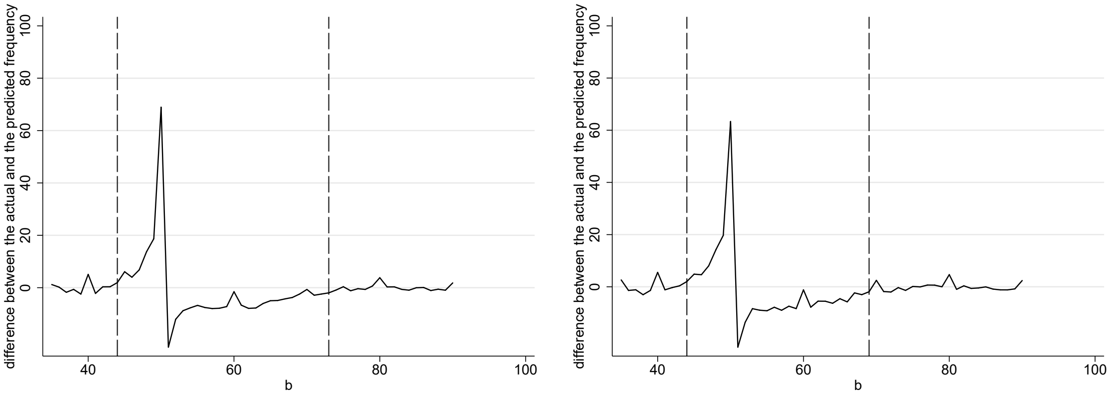


Table 3 reports the overall estimation results across years. The first column, *Bunching Response*, shows the consumption bin, q^*, above the threshold which makes the missing mass equals to the excess mass. The second column, *Excess Bunching*, presents the fraction of meters in the excess mass compared to the counterfactual frequency at the notch point. The last two columns, *Structural Elasticity* and *Reduced-form Elasticity*, are the structural and reduced-form price elasticity computed from equations (4) and (5).

The top panel restricts the data to January through May of every year. The results for 2012 represent consumer's responses during the 90-unit free scheme, while the results for 2013–2015 represent the responses during the 50-unit free scheme. The bottom panel contains data for the full year of 2013–2015 and thus represents only the response during the 50-unit free scheme.

All the estimates for bunching response, excess bunching, and price elasticities in table 3 are statistically different from zero at the 5 percent significance level.

Using the data for January through May (top panel), we can see that the bunching responses range from 15 units to 22 units above the threshold. Excess bunching is largest at 7.3 percent in 2012, and remains at around 4 percent in 2013–2015. The bunching response in 2012 (90-unit free scheme) was smaller than the responses during 2013–2015 (50-unit free scheme), while the excess mass in 2012 was twice as large. In other words, bunching is sharper and larger during the 90-unit free scheme. Recall that the notch size—the monetary incentive to stay below the threshold—during the 90-unit free scheme was twice as large (253 THB in 2012 versus 130 THB afterwards). This larger incentive provides an additional "push" for more consumers near the threshold to overcome the frictions and bunch in 2012.

Estimation using data from January through May reveals that the associated price elasticity ranges between −0.032 and −0.243. The estimated reduced-form elasticities

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reference point bunching will result in an overestimation of the excess bunching and the bunching end points.

Table 3: Baseline estimated excess bunching and elasticities

Year	Bunching response	Excess bunching	Structural elasticity	Reduced-form elasticity
January–May				
2012	15.03*	0.073*	−0.104*	−0.032*
	(2.93)	(0.002)	(0.028)	(0.016)
2013	18.00*	0.041*	−0.132*	−0.156*
	(2.13)	(0.002)	(0.021)	(0.044)
2014	22.41*	0.040*	−0.175*	−0.243*
	(2.63)	(0.002)	(0.027)	(0.056)
2015	18.32*	0.039*	−0.135*	−0.162*
	(2.79)	(0.002)	(0.028)	(0.057)
January–December				
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 elasticity* is the structural price elasticity. *Reduced-form elasticity* 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.

are generally larger than the elasticity estimated using structural model.[4] The exception was for January through May of 2012, when the reduced-form elasticity was significantly smaller at −0.032. This is due to two reasons. First, the percent change in the consumption is smaller in 2012 since it was based on the threshold of 90 units. Second, change in the implicit marginal price was larger in 2012 since it was based on the total cost at 90 units.

The bottom panel of table 3 shows that when we average out the effect from weather by pooling data across the 12 months, the estimated end points, excess bunching, and elasticities become much more similar across years. The estimated elasticities using the full-year sample are within the range of the elasticities implied by the restricted sample (January through May), ranging between −0.128 and −0.158. Again, the reduced-form elasticities are consistently larger than the structural elasticity in absolute term. Note that the price elasticities we estimate here represents the response of the highest-elasticity consumer. This means that the average price elasticity in the population will be even lower, assuming heterogenous elasticity.

Table 4: Elasticity estimates from existing studies

Study	Elasticity estimates	Country
Reiss and White (2002)	−0.08 to −1.02	US
Borenstein (2009)	−0.05 to −0.13	US
Alberini et al. (2011)	−0.67 to −0.86	US
Ros (2015)	−0.20 to −0.35	US
Campbell (2018)	−0.82 to −0.25	Jamaica

In all the cases, our estimated elasticities implied by equation (4) are on the lower side compared to the elasticities estimated in other studies using panel data (table 4).

The small estimated price elasticities in our context could be explained by our study's focus on the lower range of the demand curve where consumption quantities are close to subsistence level (by design of the program to support lower-income households), and where the demand is relatively inelastic. On the other hand, the studies mentioned above

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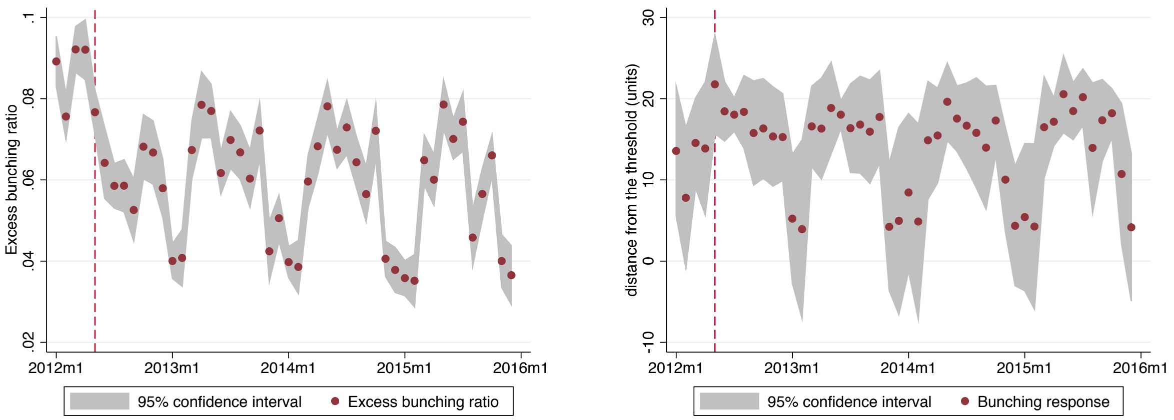
[4] This results from the fact that the reduced-form elasticity expression was partially scaled by the percent change in the implicit marginal price as explained in section 3.

use the entire distribution of electricity consumption.

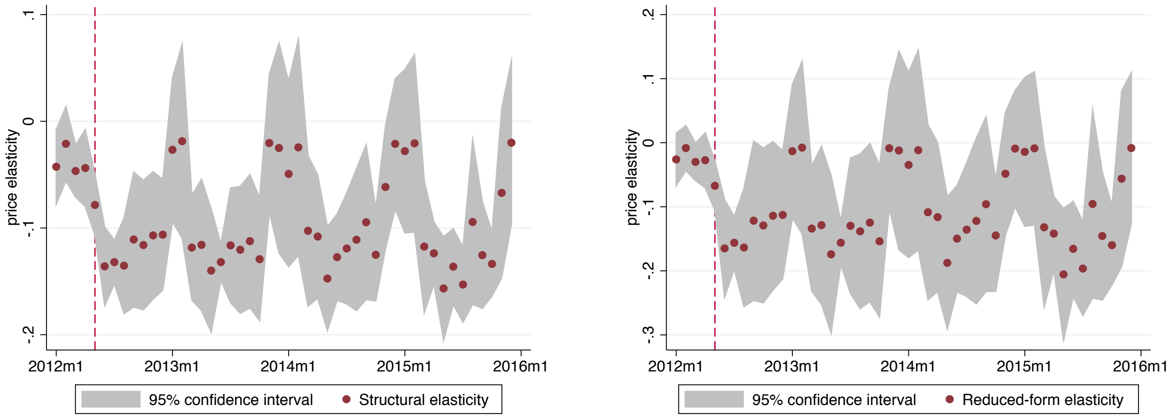
5.2 Seasonality in bunching

Figures 10a–10d shows estimation results for all 48 months in the data.

Figure 10: Estimation results by month


(a) Excess bunching ratio

(b) Structural bunching response


(c) Structural elasticities

(d) Reduced-form elasticities

The excess masses, the bunching responses, and the associated price elasticity show a remarkable seasonal pattern. the estimated bunching masses and the bunching responses are generally small and not statistically different from zero during winter months, and are much larger and statistically different from zero for the rest of the year. The seasonality in the excess mass and the bunching responses lead to the seasonality in the estimated price elasticities. Consistent with the explanation in section 3, the reduced-form elasticities are larger than the structural elasticities (in absolute term) in the summer months and become smaller than the structural elasticities in the winter months.

A closer look at the monthly consumption distribution in figure 11 explains the observed seasonal pattern.[5] The winter months (November through February) feature a mild or moderate temperature. Thus, the consumption distribution skews leftward with the mode below 50 units. A majority of consumers already consume below the FBE threshold in absence of the FBE program. This leaves only a small number of the price-elastic consumers who need to distort their consumption to stay below the threshold, resulting in the small excess mass and the bunching end point.

On the other hand, when temperature rises for the rest of the year, the consumption distribution becomes more and more right-skewed and flattens at around 60–70 units. More of the price-elastic consumers would have consumed above the 50-unit thresholds during these months in absence of the FBE program. In particular, these price-elastic consumers have baseline consumptions that spread over a wider consumption range compared to the winter months. This leads to a larger bunching response (end point) and the excess mass.

The large bunching response during the hottest months (April and May) also reflect the strongest bunching efforts from the price-elastic consumers. Therefore, these responses represent the upper bound of the structural consumption responses and the associated price elasticities.

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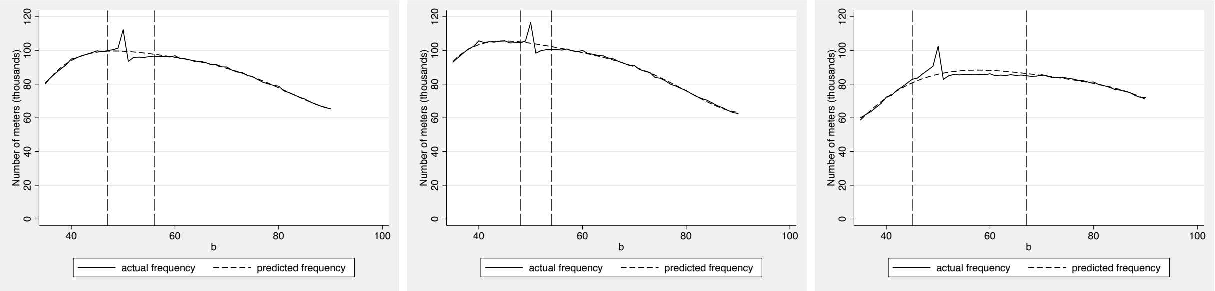
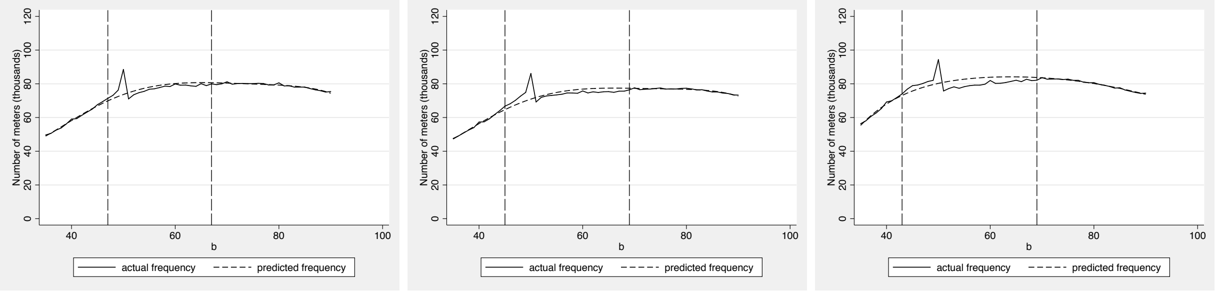
[5] We only show the results for 2013. The distributions for 2014 and 2015 exhibit a similar pattern and are reported in appendix A.

Figure 11: Histogram of monthly consumption, 2013

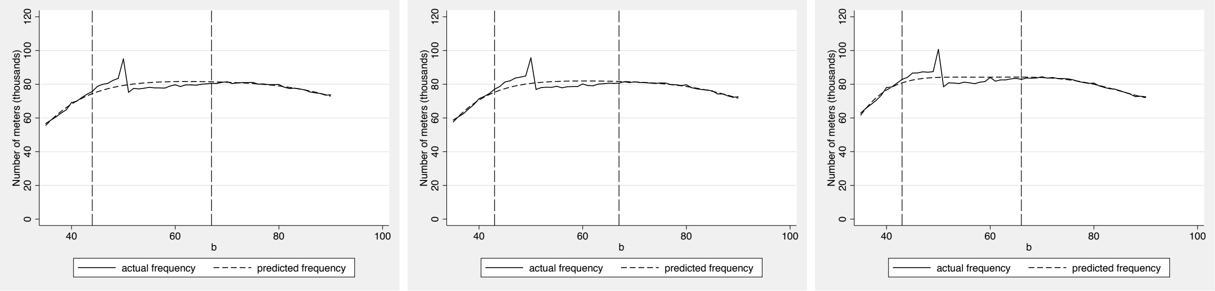
(a) January (b) February (c) March



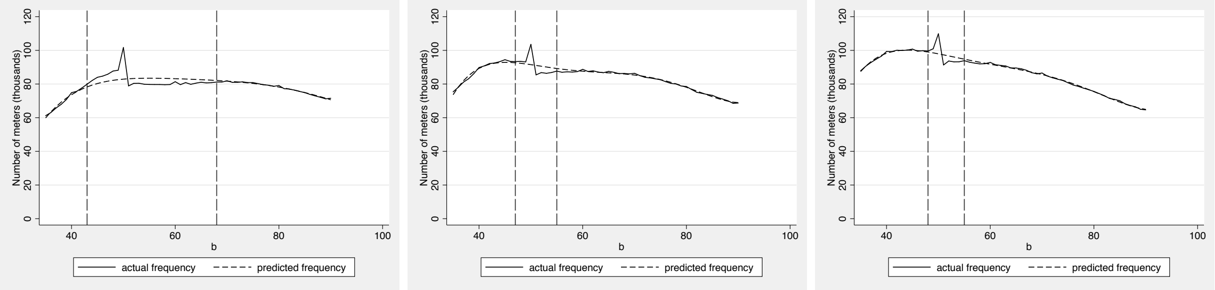
(d) April (e) May (f) June



(g) July (h) August (i) September



(j) October (k) November (l) December



5.3 Bunching and subsidy burden

Behavioral response in the form of bunching increases the number of consumers who receive the FBE subsidy and the overall subsidy burden. We refer to the additional subsidy due to bunching as the "subsidy leakage." Table 5 calculates the increase in subsidy leakage per year that result from the excess bunching at the FBE threshold.

Bunching caused the number of FBE recipients to increase by 340,000–350,000 meter-month between 2012–2015. For simplicity, we assume that all of these meters reduced their consumption from 91 (51) units to 90 (50 units). This leads to an increase in the subsidy burden (leakage) of approximately 62.5 million THB in 2012 and 42–45 million THB in 2013–2015.

The subsidy leakage is quite small compared to the overall subsidy budget of the FBE program, which is around 2–3 billion THB per year. This is consistent with the observation that the excess bunching is small relative to the overall distribution. Thus, one important policy implication from this finding is that the low price elasticity of electricity consumption can be beneficial for the quantity-targeted subsidy. In other words, using consumption of inelastic necessity goods (such as electricity) as criteria for providing subsidy can minimize leakage and increase the effectiveness of the subsidy.

Table 5: Estimated excess burden from bunching

Year	Bunching meters (thousand meters)	Burden (million THB)
2012	345.6	62.57
2013	336.6	42.95
2014	355.7	45.38
2015	341.1	43.52
Total	1,379.0	194.43

6 Policy Implications and Conclusion

This paper analyzes the behavioral response of electricity consumption to a unique subsidy program in Thailand, namely the Free Basic Electricity (FBE) program. The FBE program creates a large notch in the consumer's budget set in which a consumer would save between 4.1–7.9 USD per month as he/she reduces electricity consumption below the notch point. Unlike existing studies that examine electricity consumption response to the non-linear price schedule and find no bunching, we observe distinct excess bunching at the notch point for all years of the sample.

Our first finding is that, while we observe distinct bunching at the notch points across all years of the sample, the degree of bunching is small relative to the overall distribution. The small excess bunching can result from various form of optimization frictions. First, targeting consumption at the notch point can be costly since consumers face substantial uncertainly on consumption shocks and/or may not be able to keep track of their cumulative consumption in a month. Second, some consumers may not be aware of the FBE program and thus did not respond to the incentive. We show evidence supporting the presence of both form of optimization frictions.

The second finding is that the excess bunching becomes larger as the financial incentive increases. This is because a larger financial incentive can induce more consumers to overcome the aforementioned frictions.

Lastly, the estimated elasticities are very small compared to existing literature that uses panel data. This is because our sample only includes consumers at the lower end of the consumption range.

The policy implications of the findings are twofolds. First, from the perspective of electricity pricing design, the study shows that some consumers do respond to marginal price if the incentive is large enough. The finding suggests that it is possible to use a subsidy/rebate to encourage electricity conservation. However, achieving a non-trivial amount of reduction requires a large amount of financial incentive, which might render such policy cost-ineffective.

The second policy implication is from the point of view of the FBE program administrator, whose goal is to support targeted lower income households with minimum leakage. While bunching at the notch point represents a leakage of the subsidy to the non-target population, the degree of bunching and leakage is moderate at most. The degree of leakage is limited by the fact that electricity is somewhat a necessity and thus its consumption is more costly to manipulate. Furthermore, there exists various form of optimization frictions as described above. The results therefore points to the practicality of using necessity consumptions (e.g. water, electricity) as a screening criteria for subsidy targeting, since they provide an accurate proxy for wealth and could not be easily manipulated.

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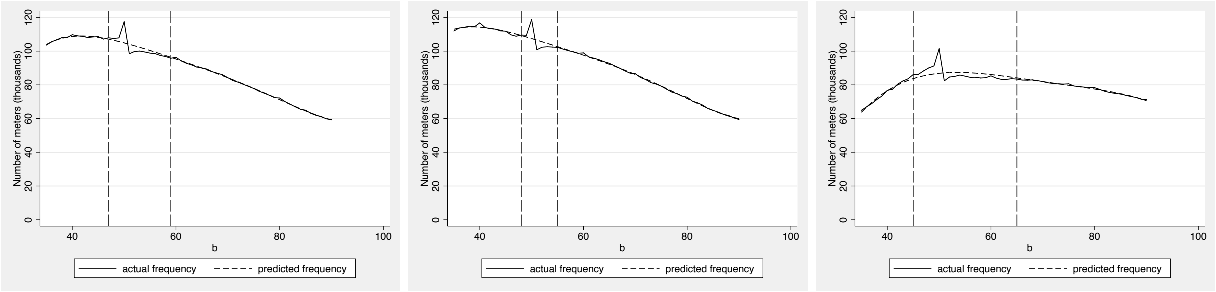
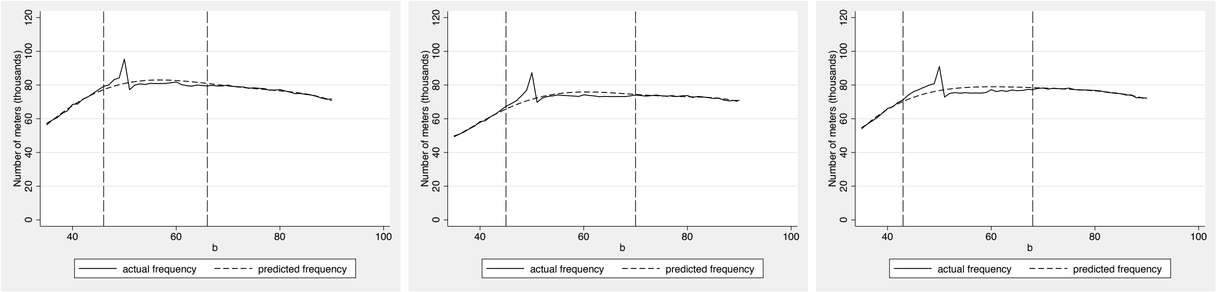
A Monthly Consumption Profiles

Figure 12: Histogram of monthly consumption, 2014

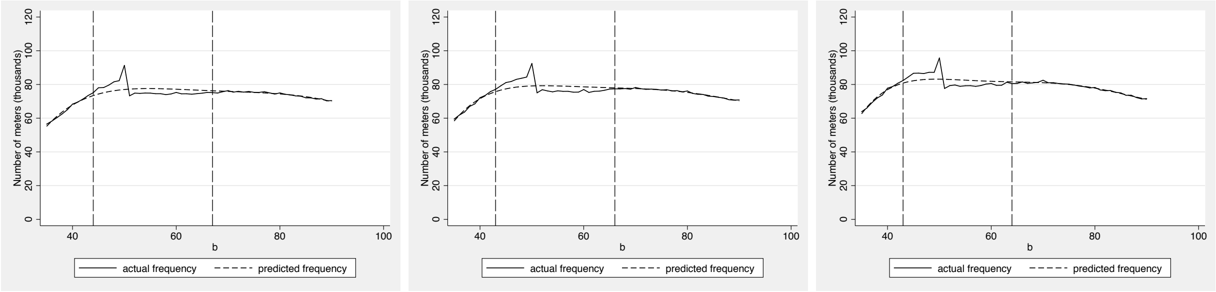
(a) January (b) February (c) March



(d) April (e) May (f) June



(g) July (h) August (i) September



(j) October (k) November (l) December

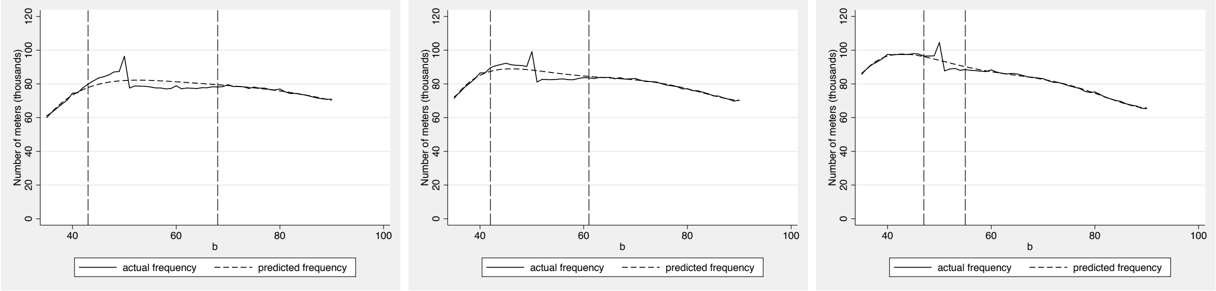
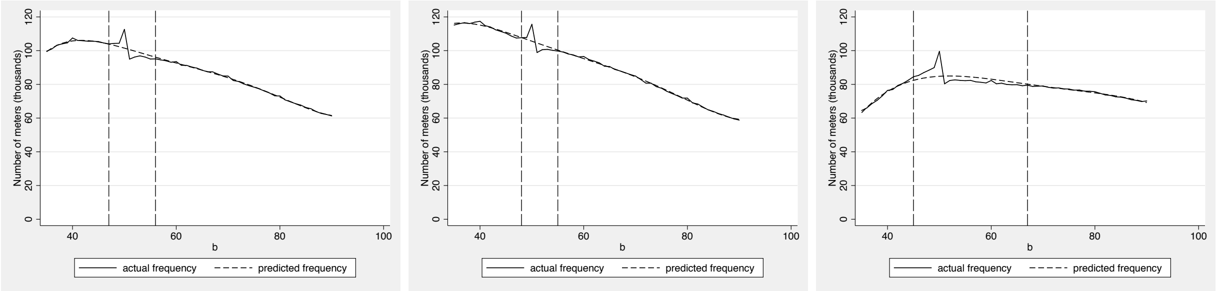
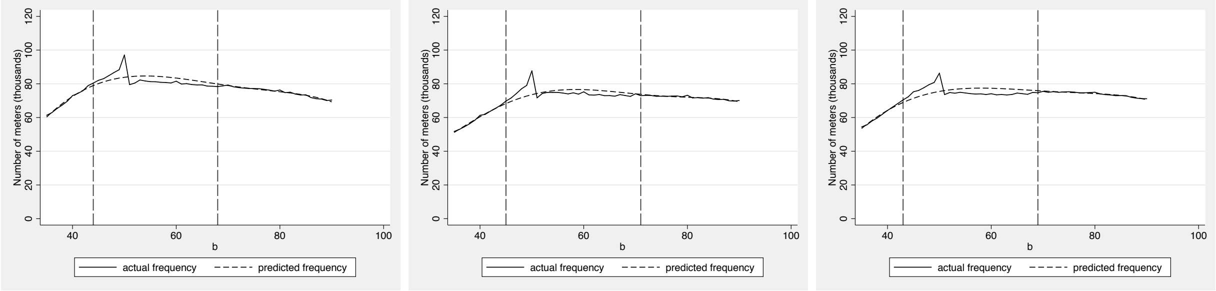


Figure 13: Histogram of monthly consumption, 2015

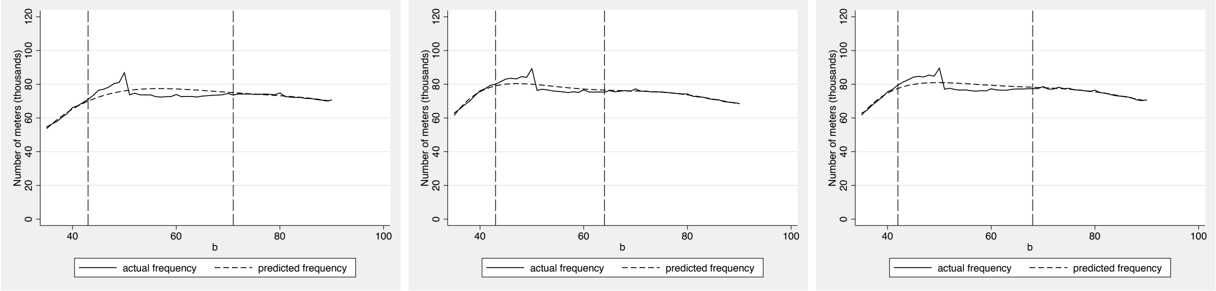
(a) January (b) February (c) March



(d) April (e) May (f) June



(g) July (h) August (i) September



(j) October (k) November (l) December