# Bunching for Free Electricity

Tosapol Apaitan[1], Thiti Tosborvorn[2], Wichsinee Wibulpolprasert[3]

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[1]Bank of Thailand, Email: TosapolA@bot.or.th.
[2]Bank of Thailand, Email: ThitiT@bot.or.th.
[3]Thailand Development Research Institute, Email: wichsine@alumni.stanford.edu.

# Challenges in studying households' electricity consumption

- Residential sector is the third largest consumer of electricity in Thailand
- Yet, electricity consumption behaviors of the Thai households are rarely studied
- Understanding the factors that affect household electricity consumption will help inform policy on the following dimensions:
  1. Welfare impact of electricity price change
  2. Program design to encourage energy efficiency and conservation

# This paper

1. Characterize stylized facts on residential electricity consumption
2. Explore the consumption response to exogenous price change created by the Thailand's Free Basic Electricity program
    - Free if usage is under threshold, pay for everything if above
    - Very large exogenous price jump ("notch")

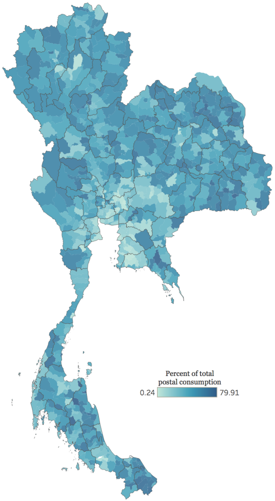
- **Research questions:**
    - How do consumer respond to a financial notch created by the FBE?
    - What can the behavioral response reveal about price elasticity?
    - Policy implications?

# A quick stylized facts on residential electricity consumption in Thailand

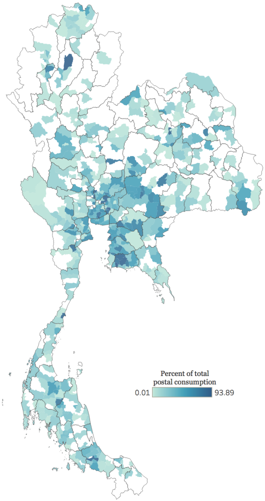
1. In most region of Thailand, residential consumption constitute a major share of total electricity consumption
2. Residential consumption is highly seasonal with a peak in May
3. Inequality in residential consumption is also seasonal with a peak in May
4. Residential consumption is highly correlated with household expenditure
5. Residential electricity consumption is relatively unresponsive to price changes

# Stylized fact #1: Residential electricity consumption dominates in most of Thailand

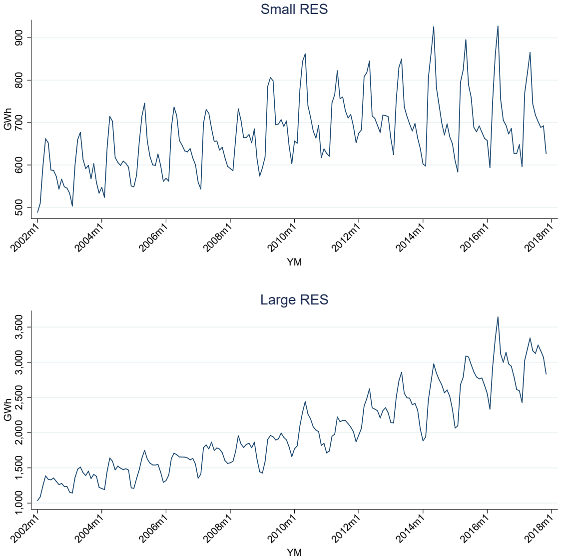
(a) RES consumption share




(b) LGS consumption share

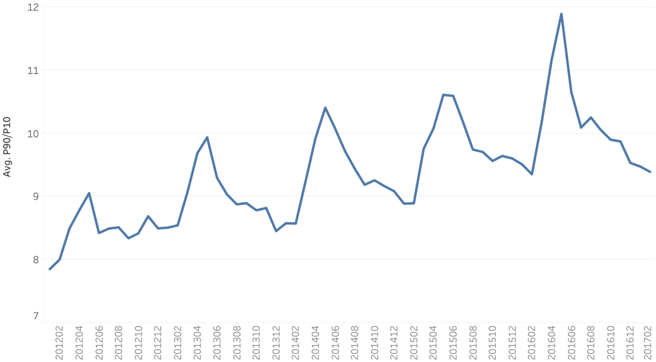


# Stylized fact #2: Residential consumption is highly seasonal with a peak in May



# Stylized fact #3: Inequality in residential consumption is also seasonal with a peak in May

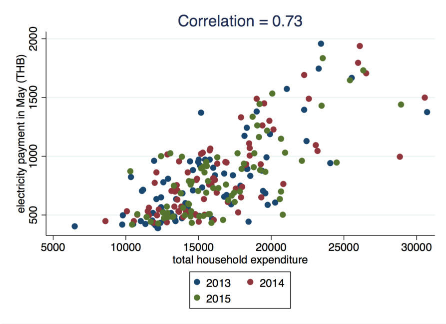
Figure: Ratio between 90th percentile and 10th percentile consumption



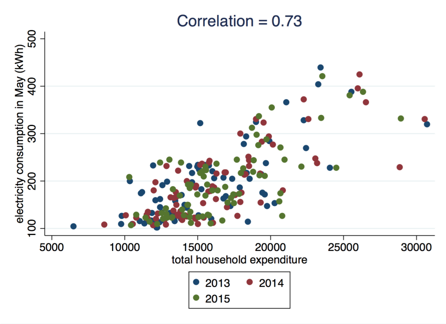

- Consumption in May reflects inequality in electrical appliances (implies wealth inequality)

# Stylized fact #4: Residential consumption is highly correlated with household expenditure

(a) Electricity expenditure (THB)




(b) Electricity consumption (kWh)



# Stylized fact #5: Residential consumption is relatively unresponsive to price change

1. Price elasticity estimates from a panel data regression: -0.03 to -0.06
2. Price elasticity estimates from the observed bunching response are even lower: -0.01 to -0.03

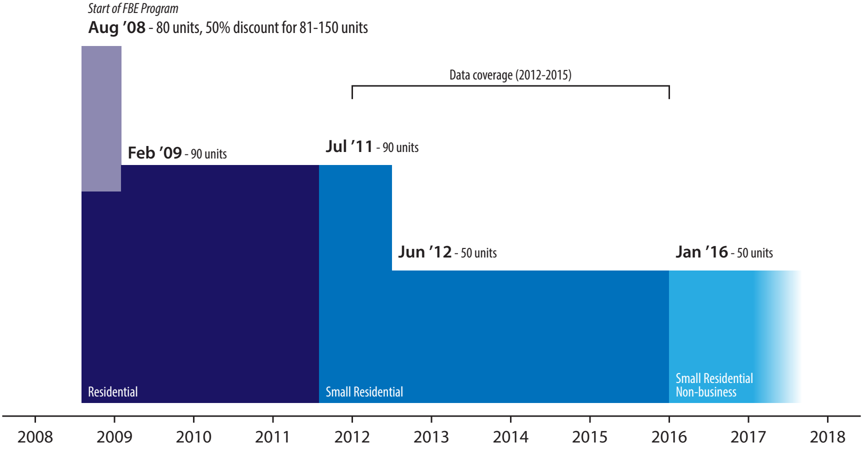
**The remaining of the presentation will focus on consumers' response to price changes.**

# Data

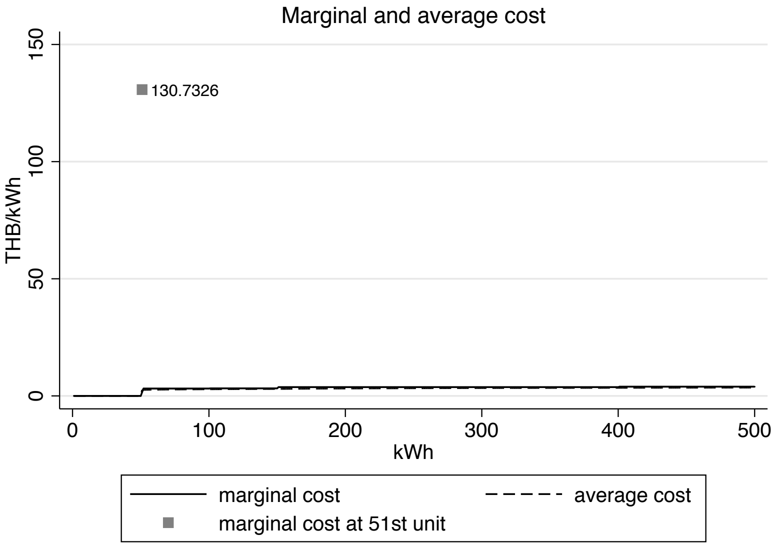
- Meter-level monthly billing data from the Provincial Electricity Authority (PEA)
- PEA account for more than 70% of total consumption in Thailand
- Analysis period is from January 2012 to December 2015

# Thailand's Free Basic Electricity (FBE) Program

- Main objective of the FBE: subsidize cost of living for lower income households
- Full subsidy for those who are eligible, none for others



# FBE creates a large marginal price jump at the threshold

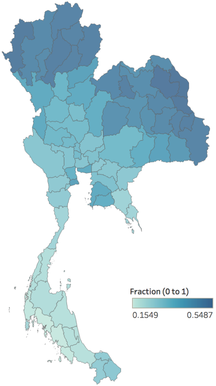


# The FBE incentive should lead to two types of responses

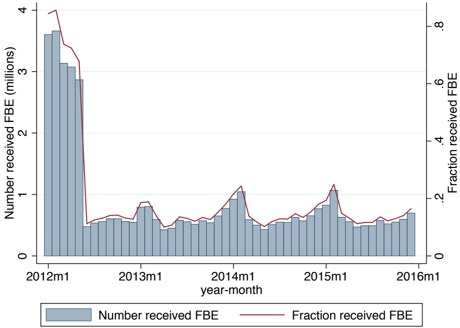
1. **Bunching from below**: everybody who used to consume below $\bar{q}$ should move up to $\bar{q}$
   - unable to quantify with the current data
   - likely to be small since electricity consumption is constrained by the stock of appliance
2. **Bunching from above**: those between $\bar{q}$ and "marginal buncher" who used to consume at $q^*$ should now consume $\bar{q}$

# Descriptive evidence #1: FBE beneficiaries are concentrated in the North and Northeast region and is seasonal

(a) Fraction of FBE-eligible meter that received benefit Jan 2015

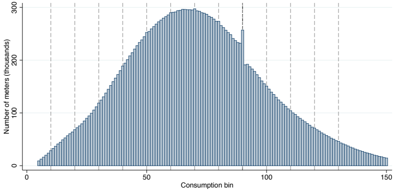



(b) Seasonality of FBE benefits

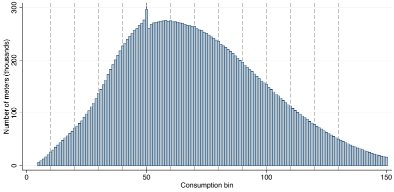


# Descriptive evidence #2: Obvious bunching and missing mass

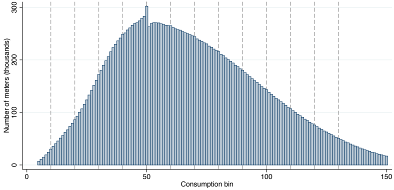
(a) 2012 (90 units free)



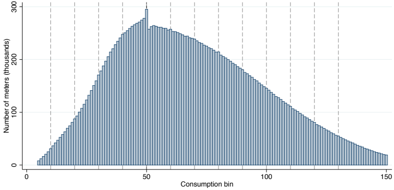

(b) 2013 (50 units free)




(c) 2014 (50 units free)




(d) 2015 (50 units free)



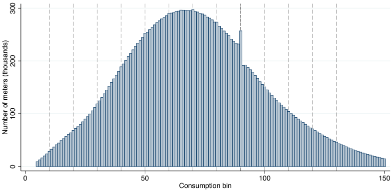
# Descriptive evidence #3: Bunching is difficult

Distribution of the number of months when a meter consumes at the notch point or receives free electricity in 2013

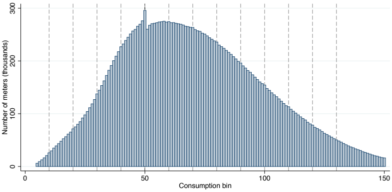
| Number of months | **Exact bunching** | | **Free electricity** | |
|---|---|---|---|---|
| in 2013 | No. meters | Percent | No. meters | Percent |
| 0 | 3,718,881 | 86.71 | 2,001,171 | 46.66 |
| 1 | 465,009 | 10.84 | 353,102 | 8.23 |
| 2 | 85,392 | 1.99 | 253,213 | 5.9 |
| 3 | 14,978 | 0.35 | 193,318 | 4.51 |
| 4 | 2,941 | 0.07 | 157,233 | 3.67 |
| 5 | 889 | 0.02 | 131,847 | 3.07 |
| 6 | 391 | 0.01 | 120,215 | 2.8 |
| 7 | 213 | 0 | 116,329 | 2.71 |
| 8 | 139 | 0 | 117,376 | 2.74 |
| 9 | 91 | 0 | 124,703 | 2.91 |
| 10 | 52 | 0 | 142,400 | 3.32 |
| 11 | 45 | 0 | 175,133 | 4.08 |
| 12 | 33 | 0 | 403,014 | 9.4 |
| Total | 4,289,054 | 100 | 4,289,054 | 100 |

# Descriptive evidence #4: Bunching increases with financial incentive and FBE program awareness

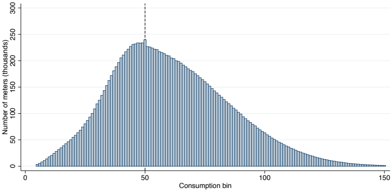
(a) 90 units free (2012)



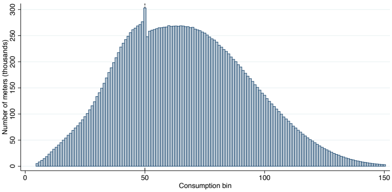

(b) 50 units free (2013)



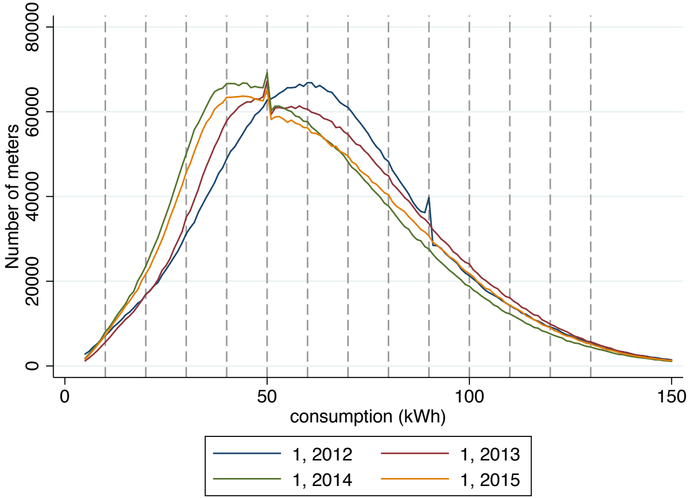

(c) Rural area (2013)




(d) Urban area (2013)



# Descriptive evidence #5: Bunching varies across month and exhibits learning



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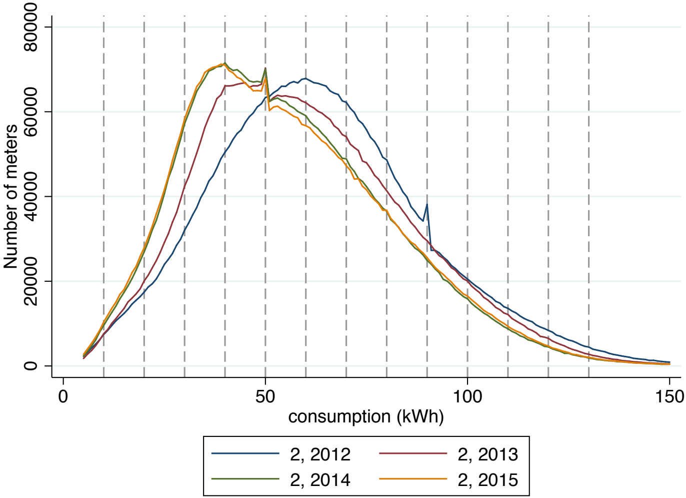

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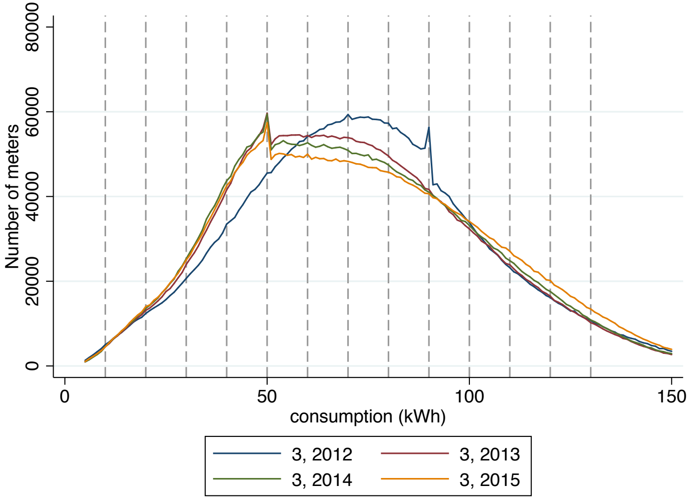

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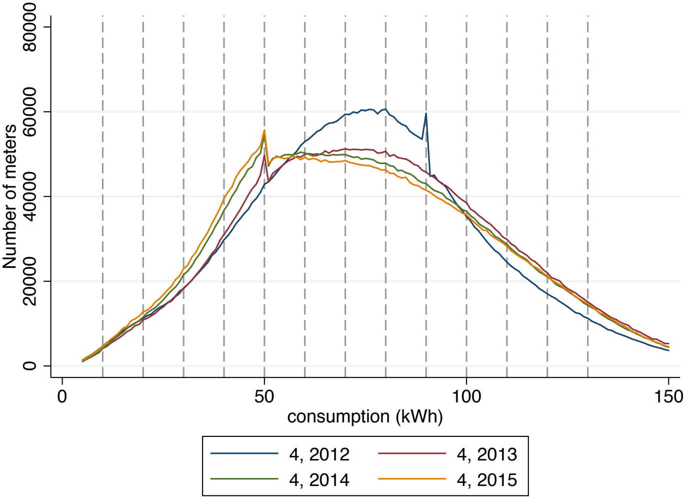

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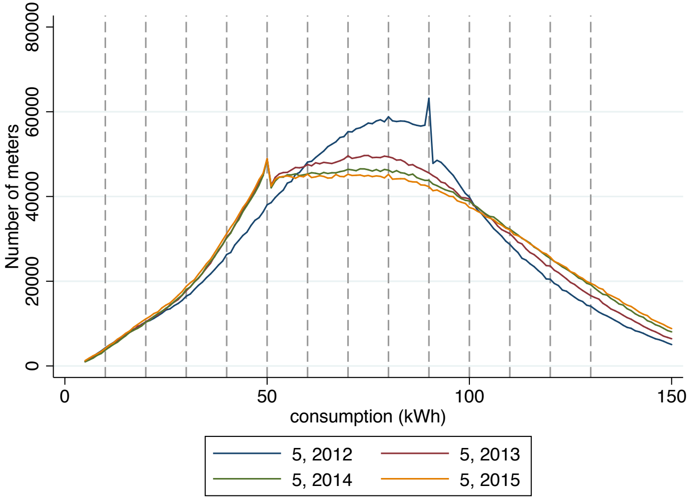

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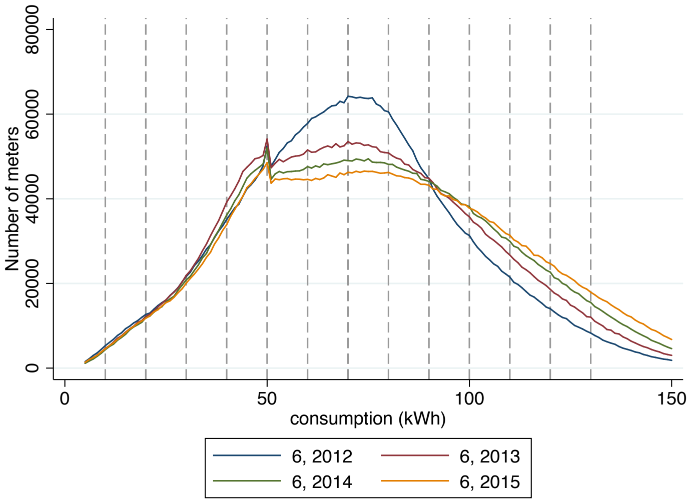

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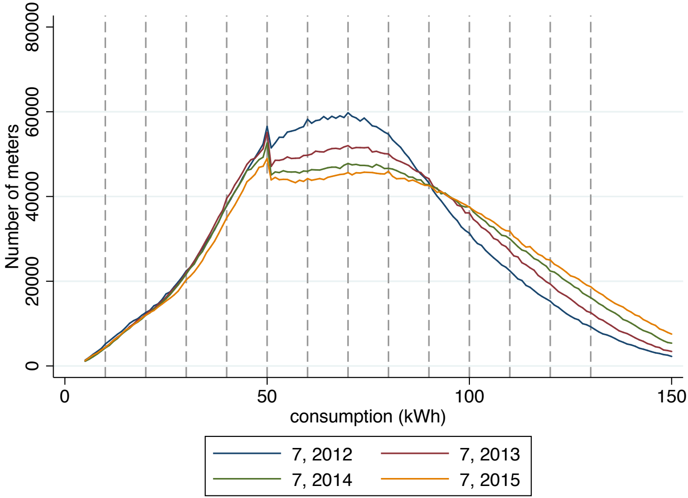

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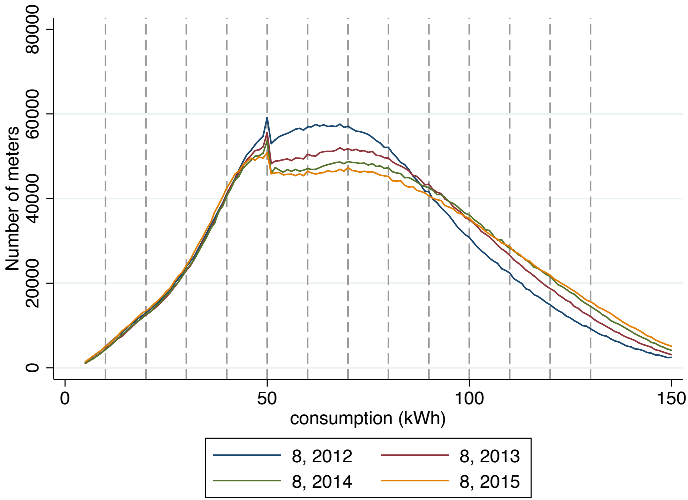

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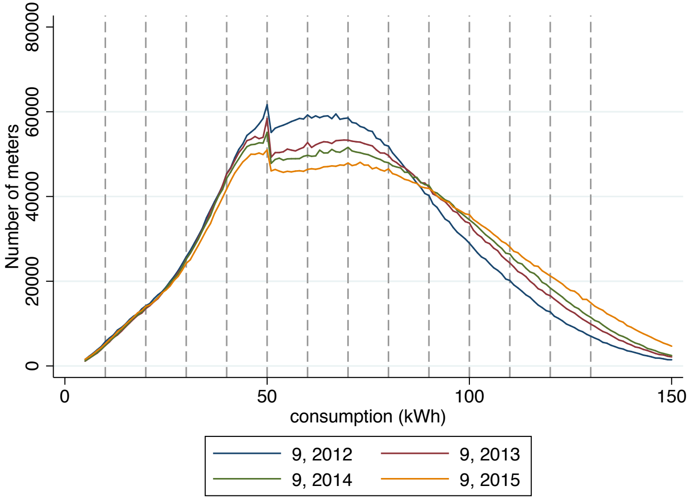

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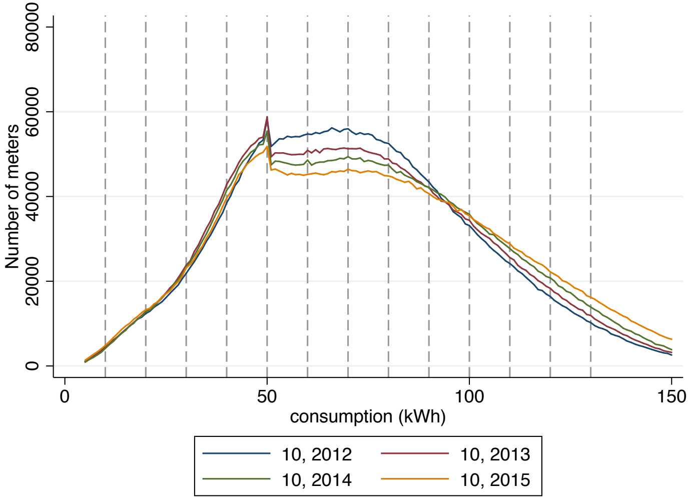

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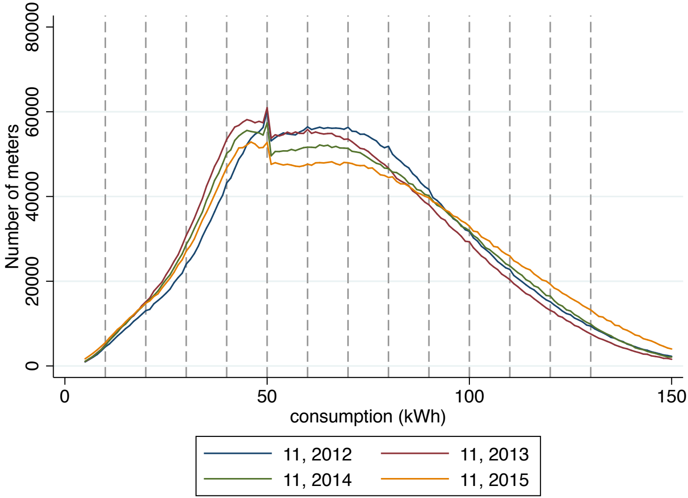

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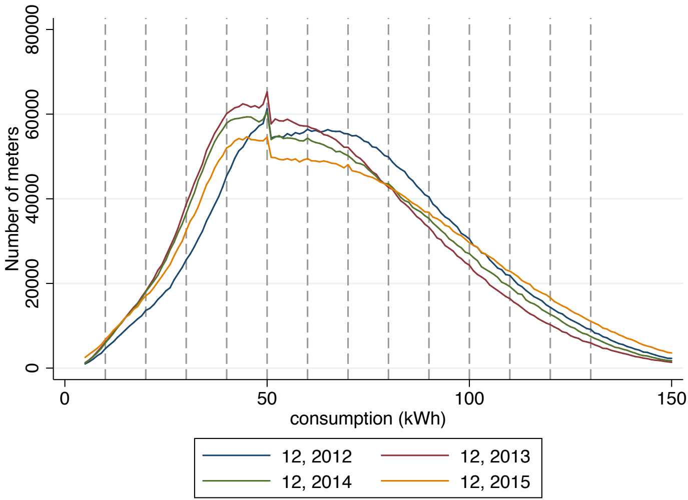
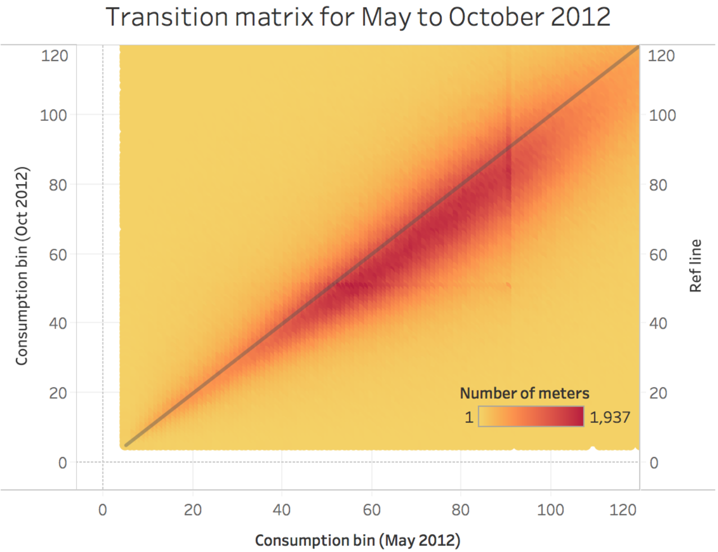
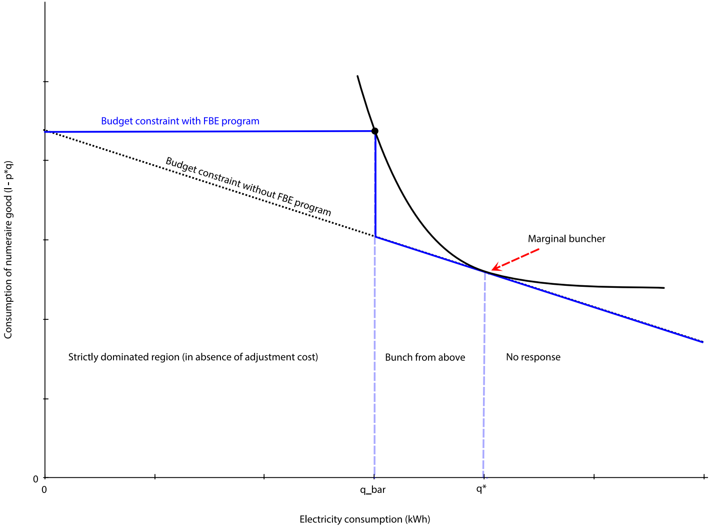


# Descriptive evidence #6: Bunching comes from above and below the threshold



# Linking the observed bunching to price elasticity

## The FBE creates a notch in the consumer's budget set



# Linking the observed bunching to price elasticity

- Two goods: electricity ($q_i$) and numeraire ($\eta_i$)
- Parameters: taste for electricity ($\alpha_i$) and price elasticity ($e$)
- Isoelastic quasi-linear utility function

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

- Budget constraint

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

# Linking the observed bunching to price elasticity (cont.)

- Interior solution: $q_i = \alpha_i p^e$
- Marginal buncher is indifferent between consuming $q^*$ and $\bar{q}$
- This gives us the relationship between consumption response and price elasticity:

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

**Intuition: bunching end point ($q^*$) reflects price elasticity**

# Estimating bunching and price elasticity

Use the method outlined in Kleven and Waseem (2013) to estimate $q^*$ and excess bunching

- Pick an excluded region $[z_l, q^*]$
- Approximate the distribution using a polynomial of degree $r$ over the non-excluded region

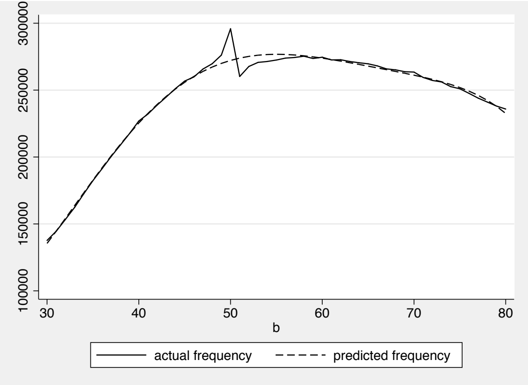
$$N_j = \sum_{i=0}^{r} \beta_i (z_j)^i + \sum_{i=z_l}^{q^*} \gamma_i I[z_j = i] + \nu_j \tag{1}$$

- Calculate counterfactual (predicted) distribution:

$$\hat{N}_j = \sum_{i=0}^{r} \hat{\beta}_i (z_j)^i. \tag{2}$$

# Estimating bunching and price elasticity

- Solve for the ending bin $q^*$ using iterative process that equate the excess mass with the missing mass
- Calculate structural elasticity $e$ using expression from earlier




- $q^*$ represents the consumption response of the highest-elasticity consumer $\rightarrow$ the *upper bound* of the average elasticity

# Estimation results: Overall

1. "End Ponit" $= q^*$ or the largest consumption response observed in the data
2. "Excess Bunching" $= \frac{\#actual - \#counterfactual}{\#counterfactual}$

# Estimation results: Overall

| Year | End Point | Excess Bunching | Estimated Elasticity |
|---|---|---|---|
| 2012 | 95.35* | 0.115* | −0.013* |
| | (1.48) | (0.004) | (0.005) |
| 2013 | 53.90* | 0.056* | −0.018 |
| | (2.52) | (0.003) | (0.018) |
| 2014 | 56.05* | 0.061* | −0.032* |
| | (1.36) | (0.003) | (0.010) |
| 2015 | 54.70* | 0.060* | −0.023 |
| | (1.97) | (0.004) | (0.014) |

[1] Standard errors are in parentheses. Standard errors are calculated using bootstrapping with 500 replications. Data is limited to January–May of every year.

[2] The * indicates statistical significance at the 5% level.

# Estimation results: Urban vs. Rural

| Group | Year | End Point | Excess Bunching | Estimated Elasticity |
|---|---|---|---|---|
| Rural Area | 2013 | 52.52* | 0.019* | −0.011 |
| | | (2.15) | (0.003) | (0.015) |
| | 2014 | 52.83* | 0.022* | −0.012 |
| | | (2.78) | (0.003) | (0.019) |
| | 2015 | 52.99* | 0.020 | −0.013* |
| | | (3.11) | (0.046) | (0.021) |
| Urban Area | 2013 | 53.03* | 0.077* | −0.013* |
| | | (0.37) | (0.004) | (0.002) |
| | 2014 | 53.29* | 0.081* | −0.015* |
| | | (0.99) | (0.004) | (0.007) |
| | 2015 | 53.01* | 0.068* | −0.013* |
| | | (0.79) | (0.005) | (0.005) |

[1] Standard errors are in parentheses. Standard errors are calculated using bootstrapping with 500 replications. Data is limited to January–May of every year.

[2] The * indicates statistical significance at the 5% level.

# Summary

- The FBE triggers obvious excess bunching
- However, bunching implies small underlying price elasticities
- Small excess bunching and elasticity are due to various sources of frictions:
    - Consumers face **uncertainty** on consumption shocks and/or cannot keep track of their cumulative consumption
    - Consumers are **not aware** of the FBE incentive and/or ways to save energy

Next steps:

1. How to quantify bunching from below?
2. How to quantify or explicitly model the sources of frictions?
3. Using learning dynamic to confirm the role of consumer's awareness?

# Policy implications

**From the Perspective of FBE Program Administrator:**

- FBE aims to redistribute wealth to the low-income households
- Bunching response represents a “leakage” of the subsidy
  $\rightarrow$ Bad for the policy
- Although evidence shows bunching, the degree is very small
- Advantage of using necessity good as a threshold

# Policy implications

**From the Perspective of Electricity Pricing Design:**

- Using financial incentive to encourage conservation might not be practical because would require an unrealistically large financial incentive
- Roles for other interventions to remove frictions...
  - Information campaign on how to save energy
  - Smart app/meter that lets people keep track of their energy usage
  - Behavioral nudges to make consumers more aware of their energy usage

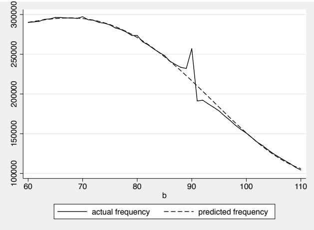
Thank you

Backup Slides

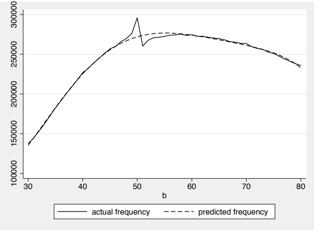
# Estimation Results: Overall

## Actual and counterfactual densities (January–December of each year)

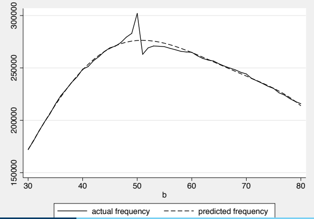
(a) 2012 (50 units free)



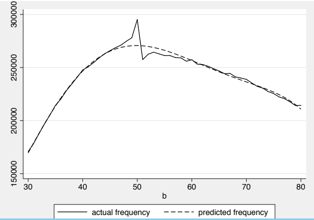

(b) 2013 (50 units free)




(c) 2014 (50 units free)




(d) 2015 (50 units free)



# Estimation Results: Overall

| Year | End Point | Excess Bunching | Estimated Elasticity |
|---|---|---|---|
| *January – December* | | | |
| 2013 | 53.81* | 0.058* | −0.018 |
| | (2.06) | (0.003) | (0.014) |
| 2014 | 54.10* | 0.060* | −0.020* |
| | (1.41) | (0.004) | (0.010) |
| 2015 | 53.87* | 0.052* | −0.018 |
| | (2.39) | (0.005) | (0.017) |

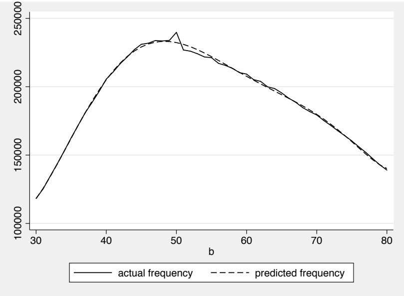
[1] Standard errors are in parentheses. Standard errors are calculated using bootstrapping with 500 replications. Data is limited to January–December of every year.

[2] The * indicates statistical significance at the 5% level.

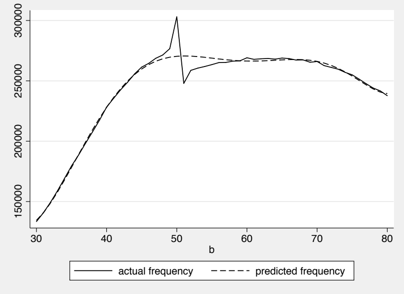
# Estimation Results: by urbanization status

Bunching is more obvious among consumers in the urban area, who are better informed about the FBE program

(a) Rural area (2013)




(b) Urban area (2013)

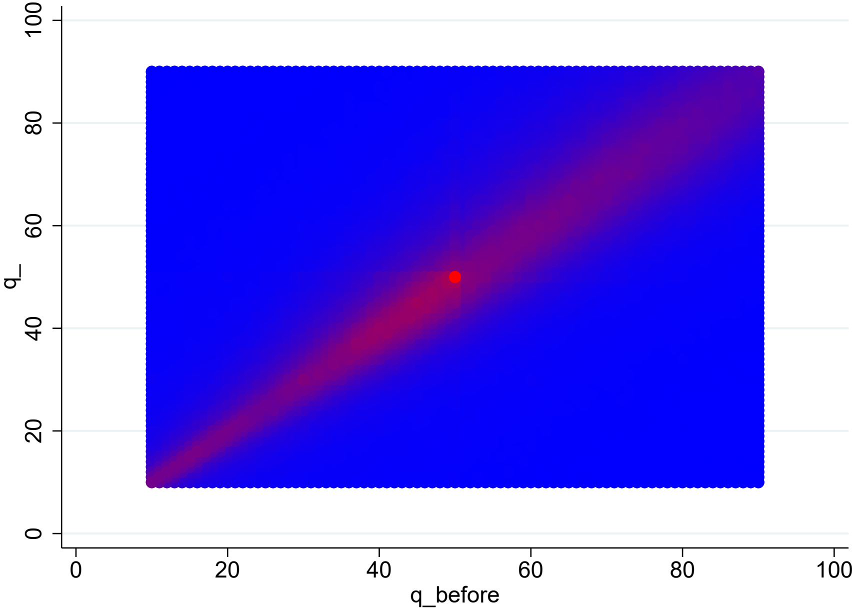


# Discussions

- Without adjustment cost, there should not be any consumers below the threshold (i.e. "strictly dominated region")
- In reality, we still observe a mass of consumers under the threshold $\rightarrow$ the presence of optimization friction or adjustment cost
- However, we cannot quantify the friction since the strictly dominated region is so wide that we cannot credibly estimate the counterfactual distribution using the cross-sectional data
- Moreover, we lack the pre-FBE data so we cannot use that as a counterfactual distribution either

# Manipulated by meter surveyors?

- Unlikely
- Meter surveys are done by noting the cumulative usage, so need to note last month's number as well
- Meter surveyors are rotated every few months, unlikely to collude with households
- Since meter surveys are done cumulatively, if there's collusion, it's more likely that consumption in the month *after* consuming at the threshold would be higher



100
80
60
40
20
0
q_
0
20
40
60
80
100
q_before