Real-Time Pricing for Everyone: Evidence from the Spanish Electricity Market

Natalia Fabra, David Rapson, Mar Reguant, and Jingyuan Wang

01/2019

Energy transition underway

- Real need to reduce Green House Gas emissions (GHGs).
- Electricity sector ($\approx$35-40% of CO_2 emissions) has been **most active** in making the transition.
- **Renewable power** generation is the main source of emissions reductions.
- Ambition to move towards **carbon-free electricity** by 2050.

Integration of renewable energy sources

- The intermittency of renewables puts **limits to decarbonization**:
  - Potential mismatch between supply and demand requires back-up capacity.
  - Total costs increase, until better battery solutions are found.
- Changing the the supply-demand paradigm in electricity?
  - So far, supply follows demand
  - Instead, can demand follow supply?

Demand response as a solution to intermittency?

- Questions on the **real possibilities**:
  - Electricity demand quite inelastic (0.1-0.3).
  - Consumers typically exposed to constant electricity prices.
  - If exposed to **dynamic pricing**, will consumers respond?

Demand response as a solution to intermittency?

- Questions on the **real possibilities**:
  - Electricity demand quite inelastic (0.1-0.3).
  - Consumers typically exposed to constant electricity prices.
  - If exposed to **dynamic pricing**, will consumers respond?
- Well known properties of **dynamic pricing**:
  - Energy conservation in high-priced hours.
  - Load-shifting from high-priced to low-priced hours.

  $\rightarrow$ Greater investment and productive efficiency.
  $\rightarrow$ Reduced market power.

Demand response: existing evidence

- Large **theoretical literature**: Borenstein (2005), Joskow and Tirole (2006, 2007)...
- **Field experiments** on electricity demand response
  - Jessoe and Rapson (2014); Allcott (2011), Faruqui and Sergici (2010); Wolak (2010); Ito *et al.* (2018); Bolinger and Hartman (2018)...
  - Limited evidence of true real-time pricing (hourly price changes, instead of critical events or time-of-use).
  - Limited external validity (subjects participating in the experiments did so voluntarily).
- **Simulation** studies on the role of demand response in enabling zero-carbon generation
  - Imelda, Fripp and Roberts, 2018; Coffman et al., 2018.

This project: Real-Time Pricing in Spain

- April 2014: In Spain, RTP becomes the **default option for all households** (below 10 kW).
  - "The case of Spain with a regulated default dynamic price contract is unique" (EC 2019)

This project: Real-Time Pricing in Spain

- April 2014: In Spain, RTP becomes the **default option for all households** (below 10 kW).
  - "The case of Spain with a regulated default dynamic price contract is unique" (EC 2019)

- Electricity **marginal price** composed of two parts:
  - **Energy component**: passthrough of hourly wholesale electricity market price (**RTP**), or time-invariant (non-RTP).
  - **Network component**: regulated costs charged at the margin; peak/off-peak prices (**TOU**) or time-invariant (non-TOU).

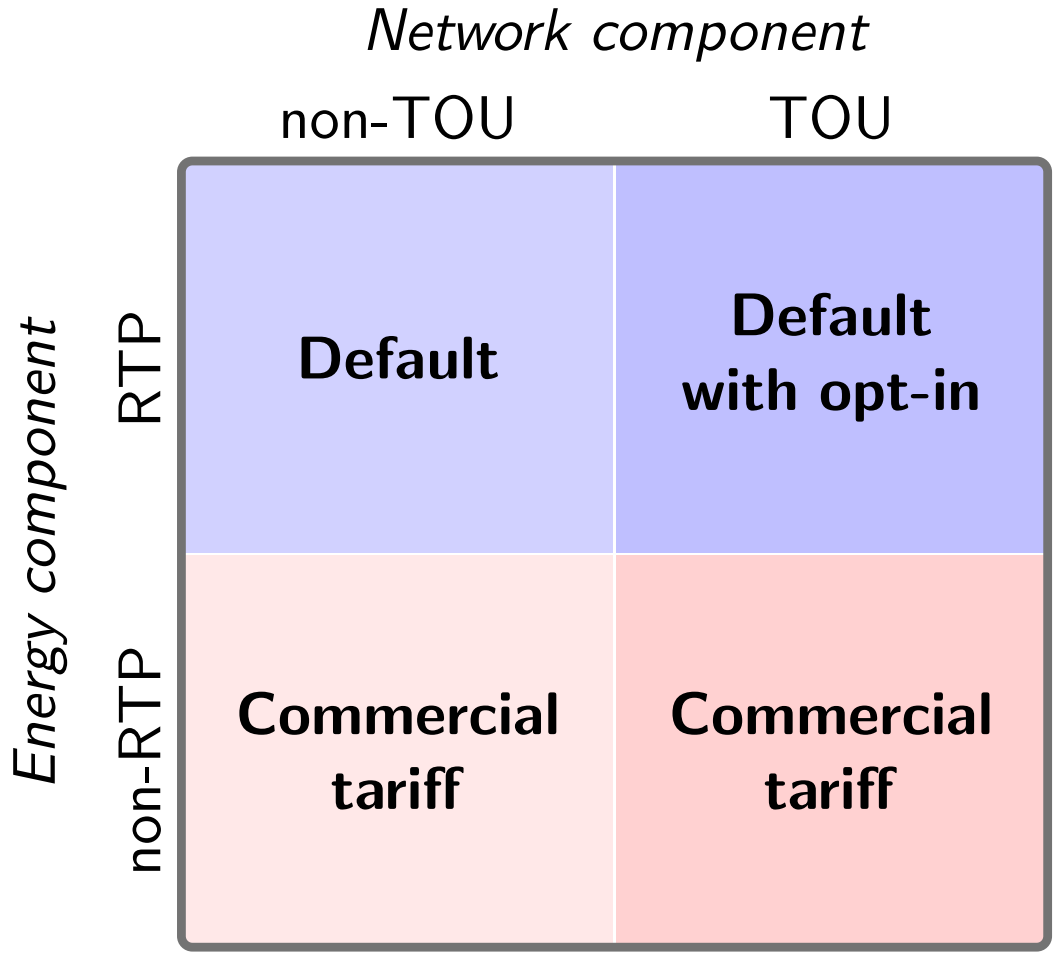
This project: Real-Time Pricing in Spain

- April 2014: In Spain, RTP becomes the **default option for all households** (below 10 kW).
  - "The case of Spain with a regulated default dynamic price contract is unique" (EC 2019)

- Electricity **marginal price** composed of two parts:
  - **Energy component**: passthrough of hourly wholesale electricity market price (**RTP**), or time-invariant (non-RTP).
  - **Network component**: regulated costs charged at the margin; peak/off-peak prices (**TOU**) or time-invariant (non-TOU).

Unique opportunity to **measure demand response** to hourly price changes of the general population

Tariff taxonomy



Tariff taxonomy: prices over the day

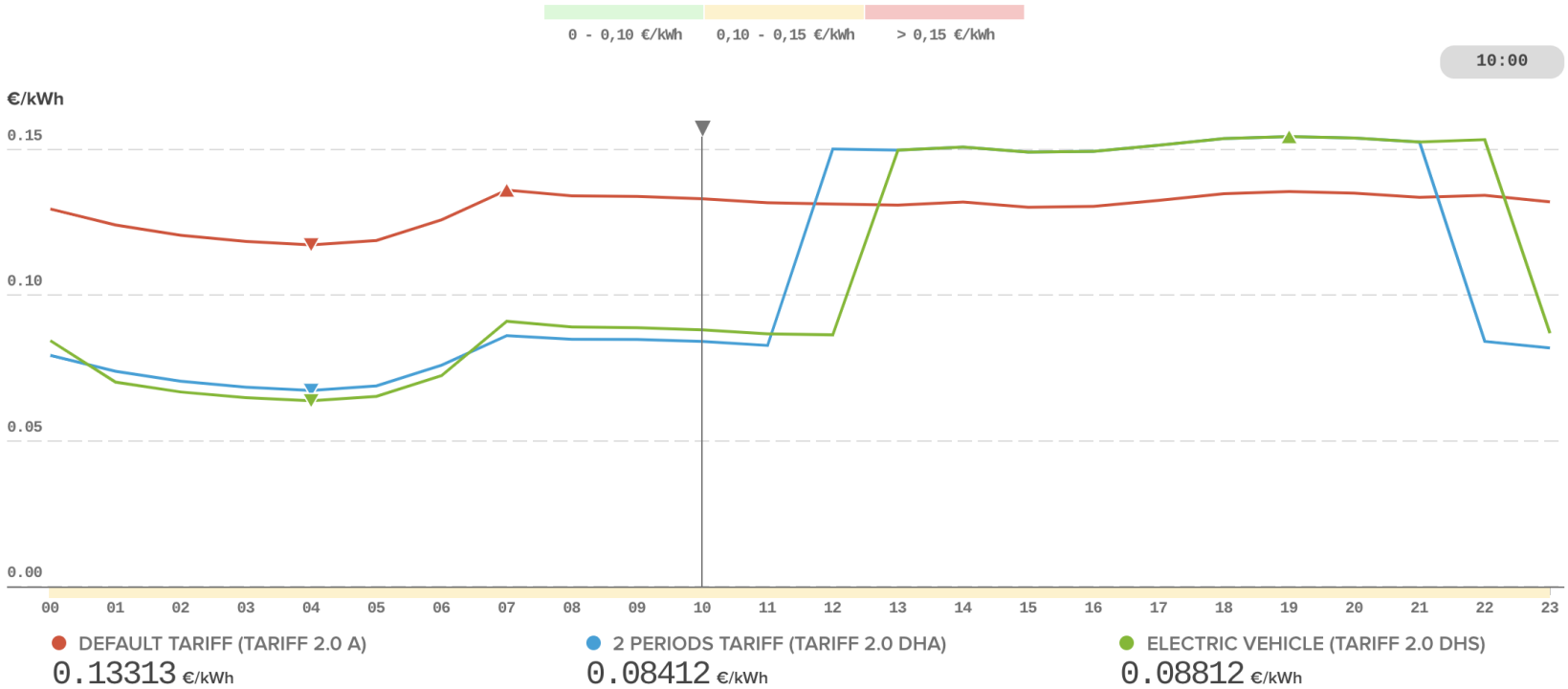


Figure: Prices over day: RTP+Non-TOU (red) and RTP+TOU (blue)

Tariff taxonomy: prices over the day

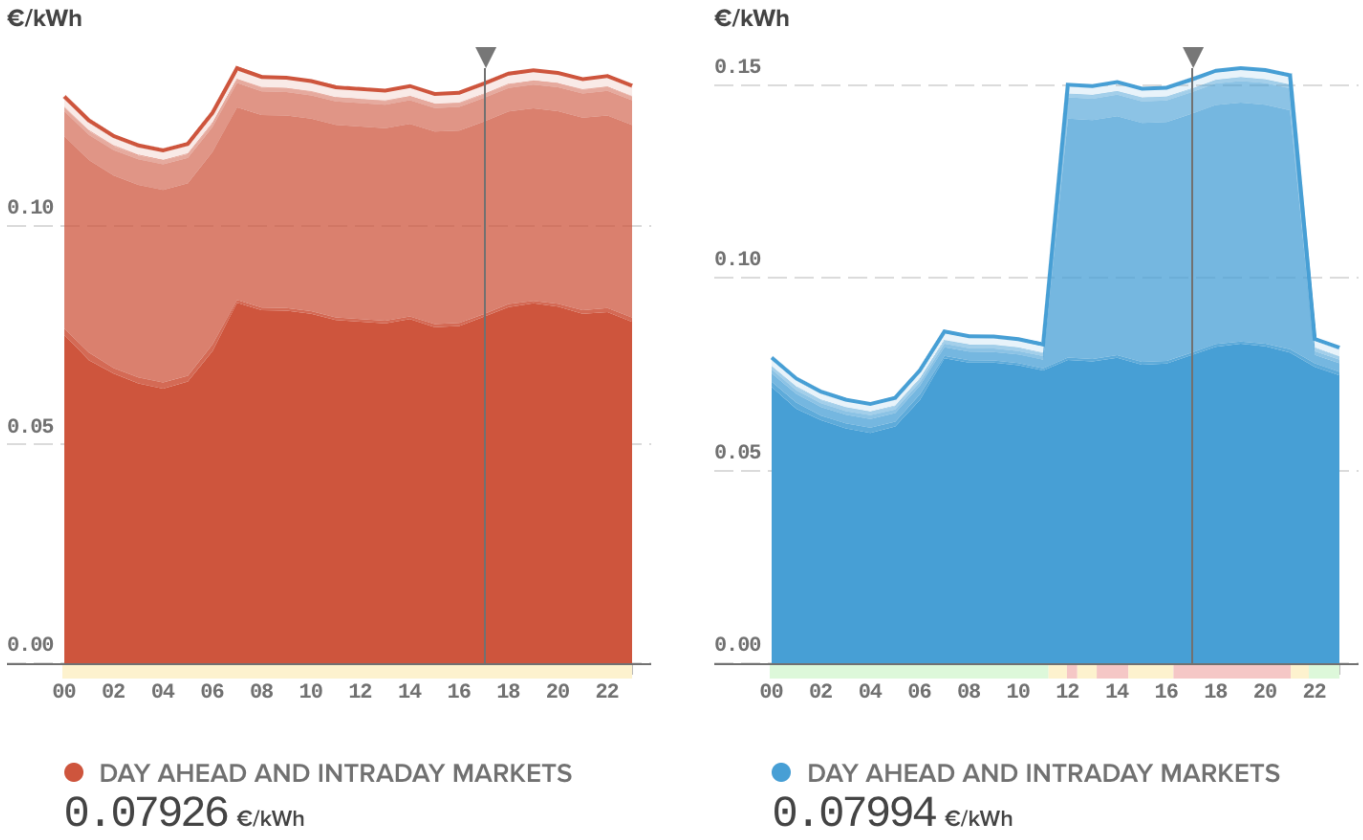


Figure: Energy and Network components in RTP+Non-TOU (left) and RTP+TOU (right) tariffs [note the two figures have different scale]

Data

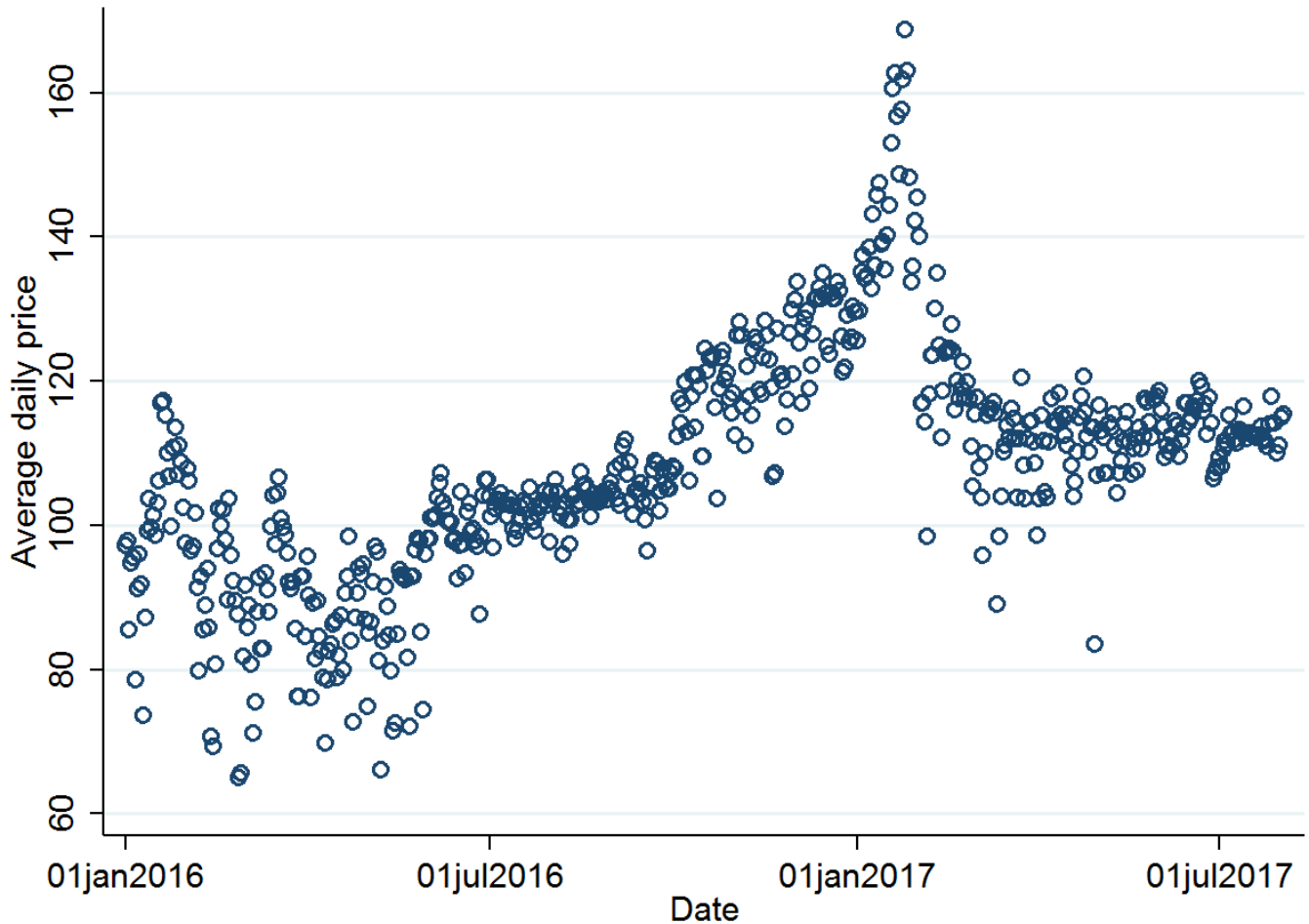
- We have obtained from two large utilities smart-meter data for 4M Spanish households (January 2016- July 2017).
  - Over 4 Million households
  - For each household: hourly electricity consumption during 2016; plan characteristics and zip code.
  - Households on RTP are spread over approx 1.500 zip codes; those on non-RTP in approx 5000 zip codes.
  - We link the zipcode with detailed Census demographic data.

Many terabytes of data! Still learning how to analyze it all.

Today focus on zip code level data and a random sample for the individual-level analysis.

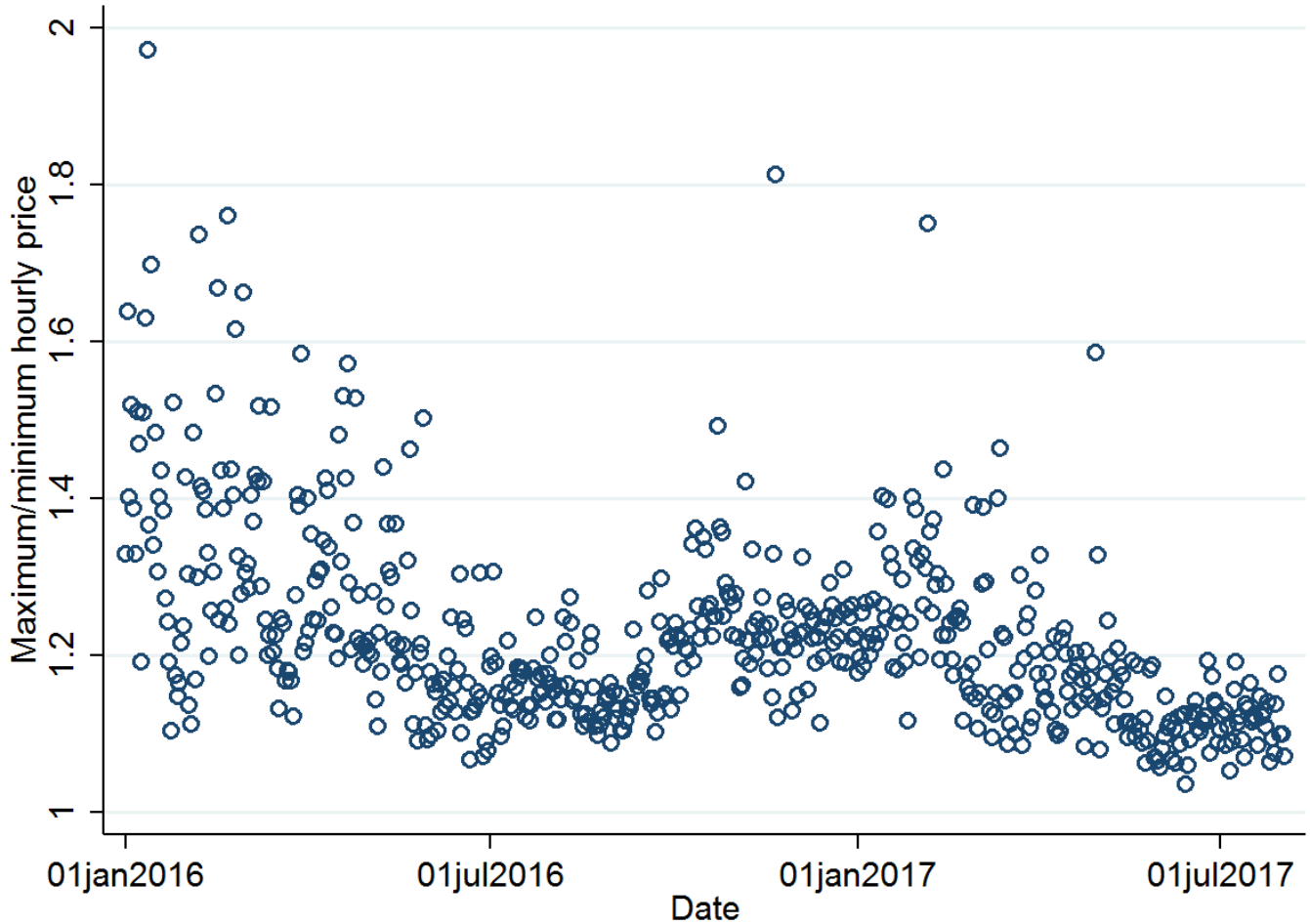
A first look at the data: prices

Figure: Average daily prices over the sample period (Euro/MWh)



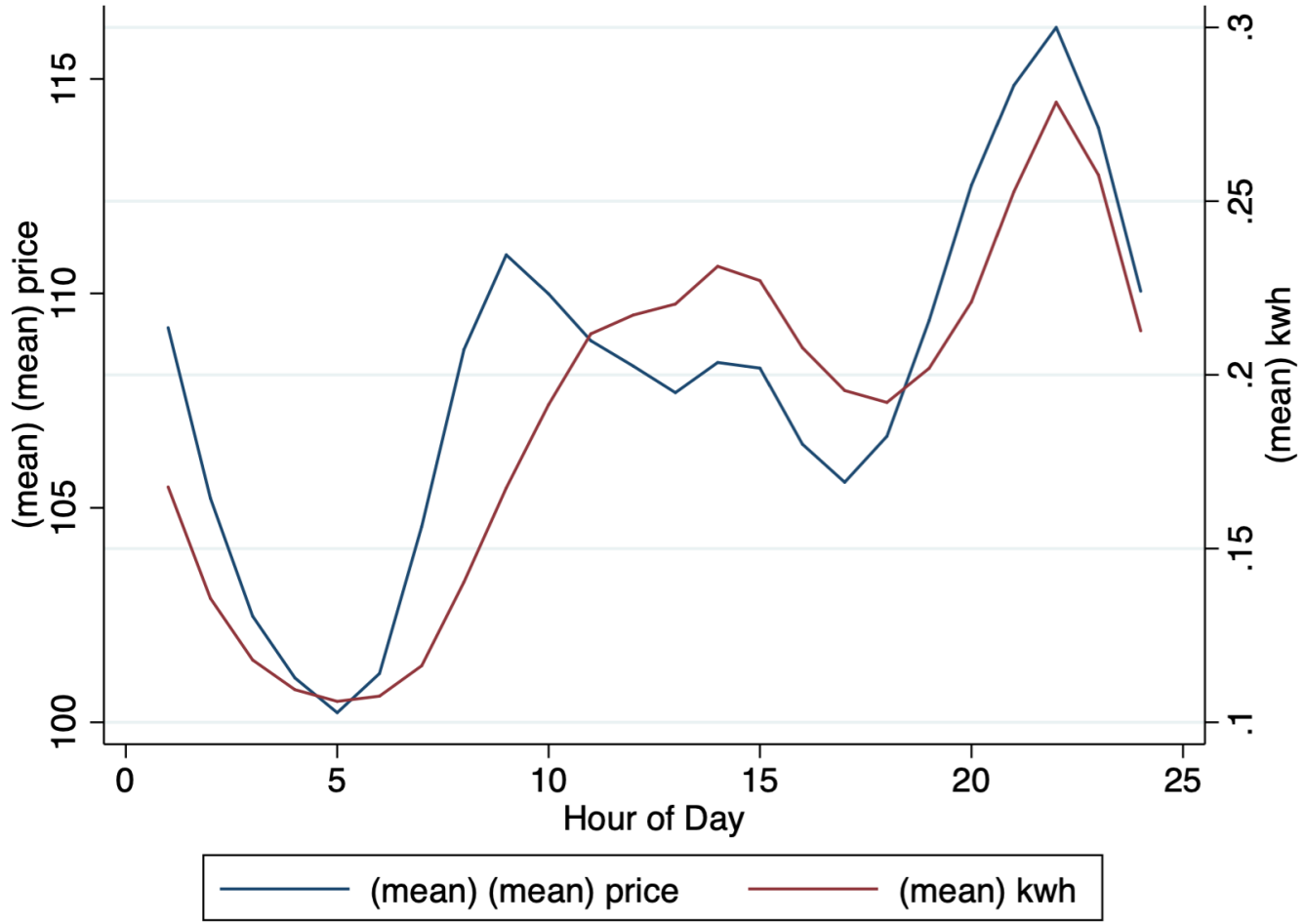
A first look at the data: price variation over the day

Figure: Ratio between the highest and lowest price each day



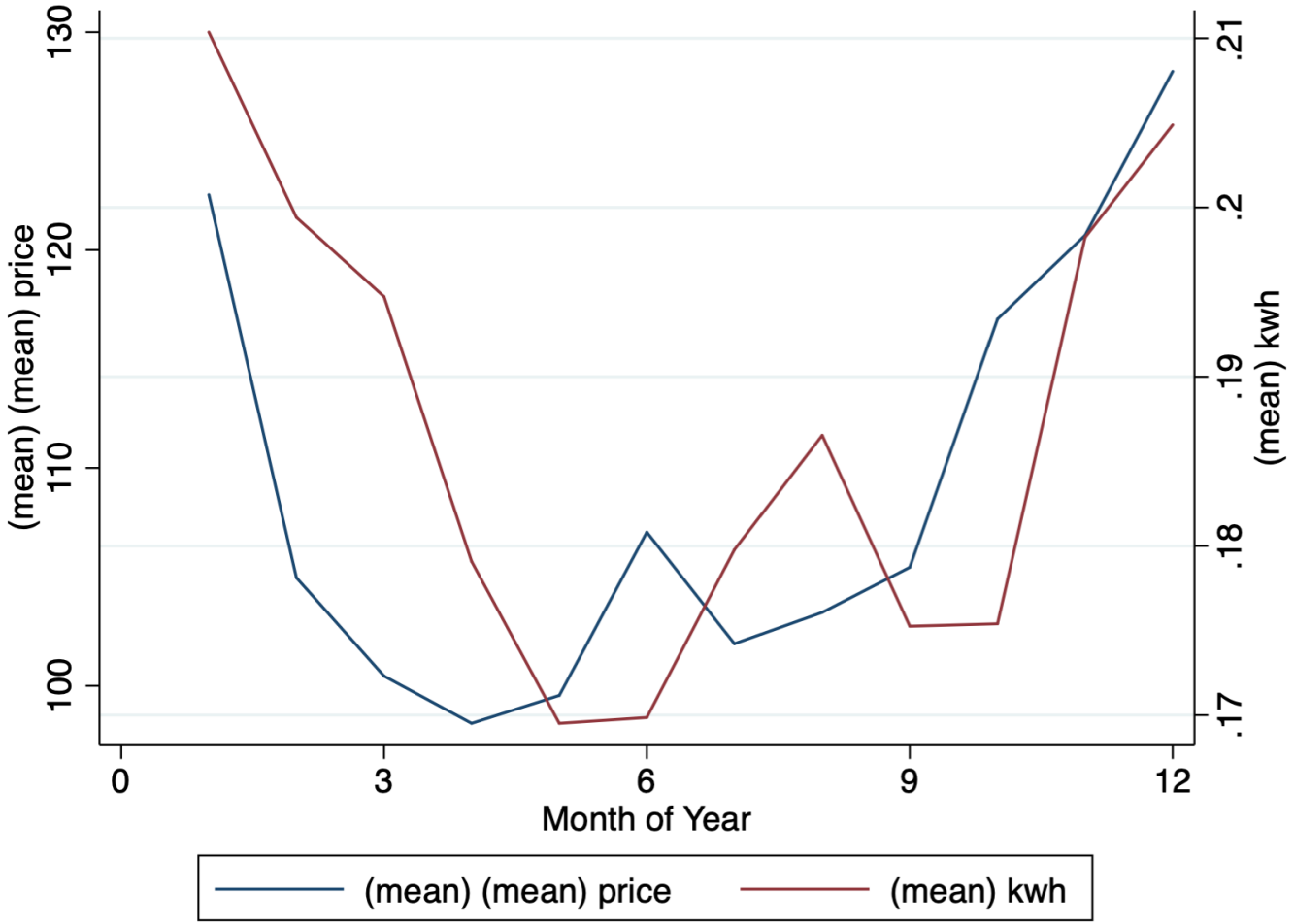
A first look at the data: consumption and prices

Figure: Consumption and price by hour-of-day



A first look at the data: consumption and prices

Figure: Consumption and price by month



Findings

- **RTP vs non-RTP** consumers appear to behave in a similar manner *at the margin*.

  $\rightarrow$ Limited impact of short run variation of real-time prices.

  $\rightarrow$ Information provision does not seem to make a difference

Findings

- **RTP vs non-RTP** consumers appear to behave in a similar manner *at the margin*.

  $\rightarrow$ Limited impact of short run variation of real-time prices.

  $\rightarrow$ Information provision does not seem to make a difference

- **TOU vs non-TOU** consumers appear to behave differently.

  $\rightarrow$ Selection or actual response?

  $\rightarrow$ Important to disentangle for policy implications.

  $\rightarrow$ In new work exploiting recent change, we find that there seems to be a response, not only selection.

Empirical strategy for RTP response

- We estimate the **short-run price elasticity** of consumers.
- Main regression (individual by individual or zip-code level):

$$\ln q_{ith} = \beta_i \ln p_{ith} + \phi X_{ith} + \gamma_{th} + \epsilon_{ith}.$$

- In baseline specifications, we control for:
  - Temperature bins by hour.
  - Fixed effects: hour x month, year x month, day of week.

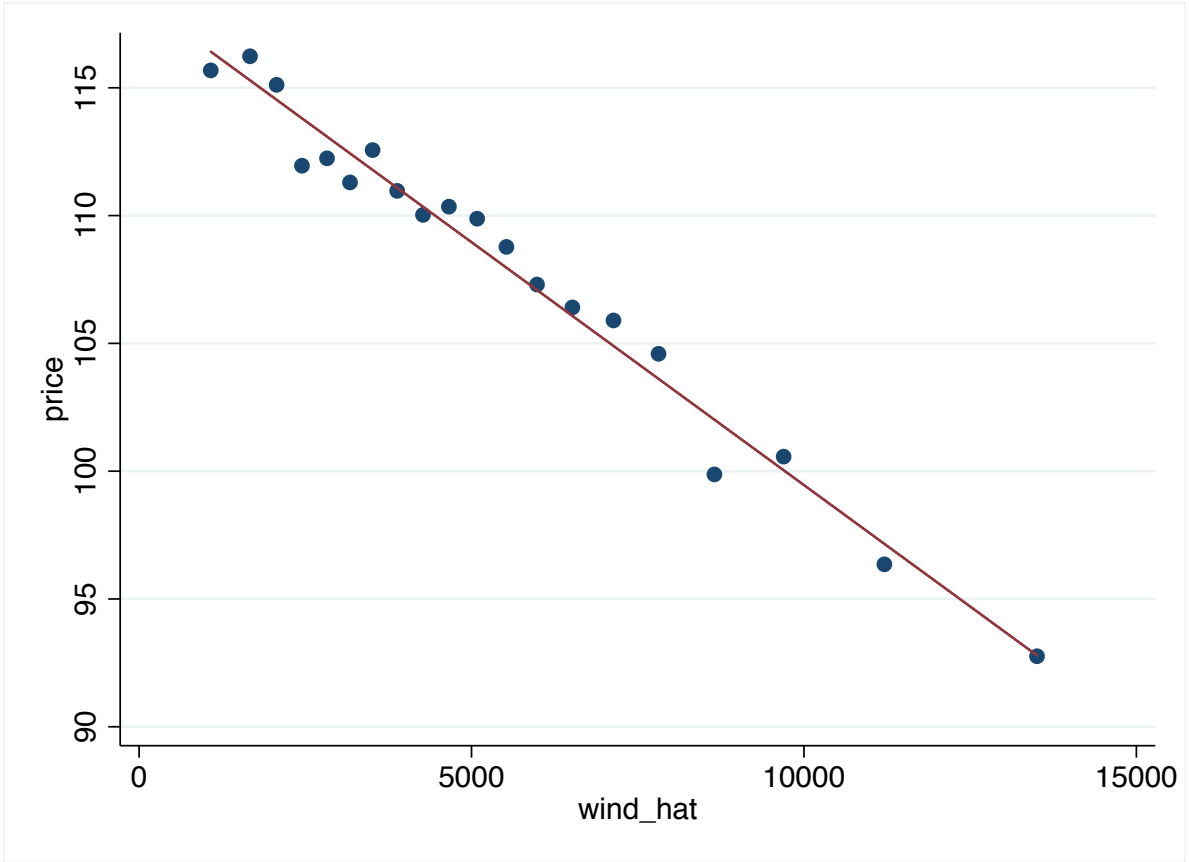
Empirical strategy for RTP response

- We estimate the **short-run price elasticity** of consumers.
- Main regression (individual by individual or zip-code level):

$$\ln q_{ith} = \beta_i \ln p_{ith} + \phi X_{ith} + \gamma_{th} + \epsilon_{ith}.$$

- In baseline specifications, we control for:
  - Temperature bins by hour.
  - Fixed effects: hour x month, year x month, day of week.
- Prices high when demand is high $\rightarrow$ Need to find an IV
  - Day-ahead wind forecast: reduces RTP prices

IV strategy



- Instrument shows strong first stage, also after conditioning.
- Plausibly exogenous after controlling for local weather conditions.

Instrumental Variable challenges

- Most consumers do not consume electricity explicitly based on wind patterns, so exclusion restriction plausibly valid.
- Yet, wind patterns are intertwined with weather.
- Weather can affect electricity consumption in many ways: temperature control, sunset/sunrise, type of activities, time at home, etc.
- Difficult to control for potentially all confounders.
- High-frequency data can easily lead to significant spurious patterns due to omitted variable bias.

We consider an array of fixed-effect individual specifications together with a lasso estimator.

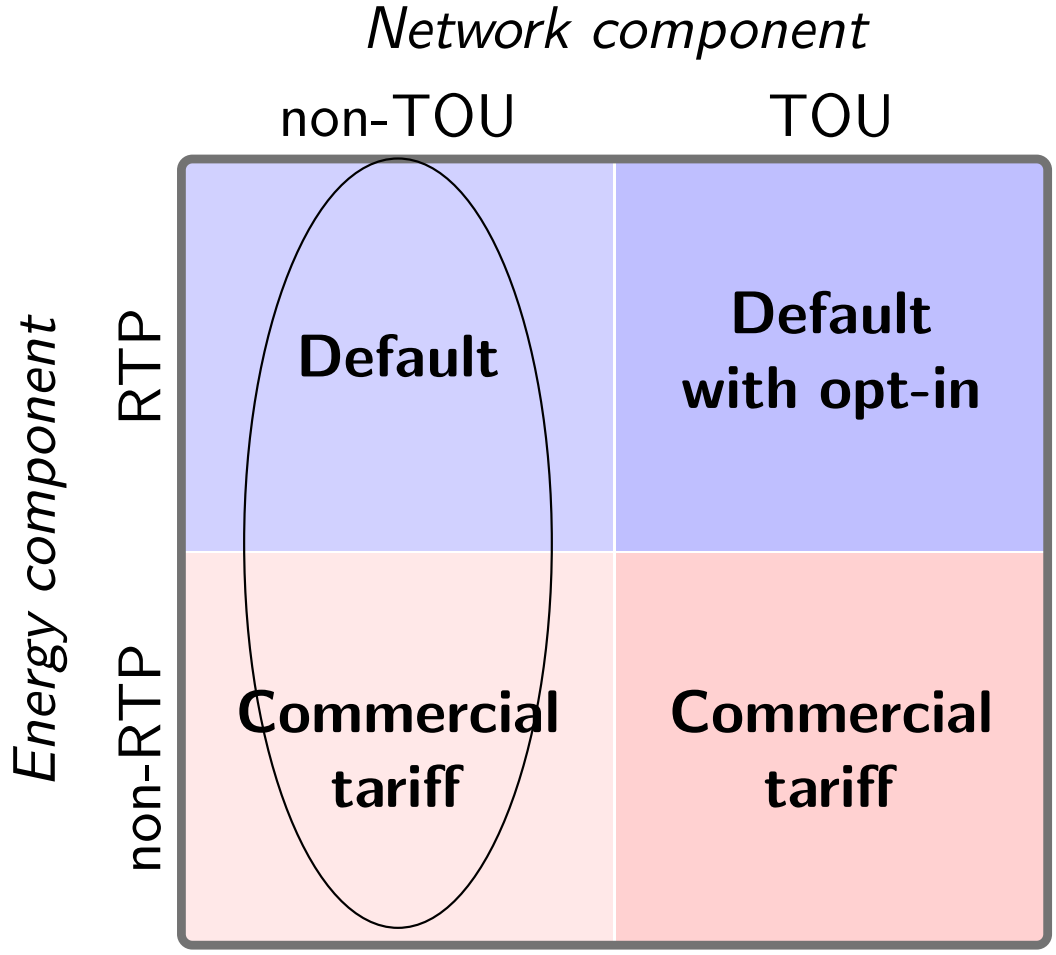
Comparison of behavior by RTP vs non-RTP

- Compare **RTP vs non-RTP customers**.
- Non-RTP should be seen as a "placebo".
  - Caveats: customers might not be aware of the plan they are in; some heterogeneity across the two groups.
- Focus on those who were on RTP or non-RTP from the start, i.e., defaulted into these choices.

Comparison of behavior by RTP vs non-RTP

- Compare **RTP vs non-RTP customers**.
- Non-RTP should be seen as a "placebo".
  - Caveats: customers might not be aware of the plan they are in; some heterogeneity across the two groups.
- Focus on those who were on RTP or non-RTP from the start, i.e., defaulted into these choices.
- Focus on those who do not select into TOU to minimize selection issues.

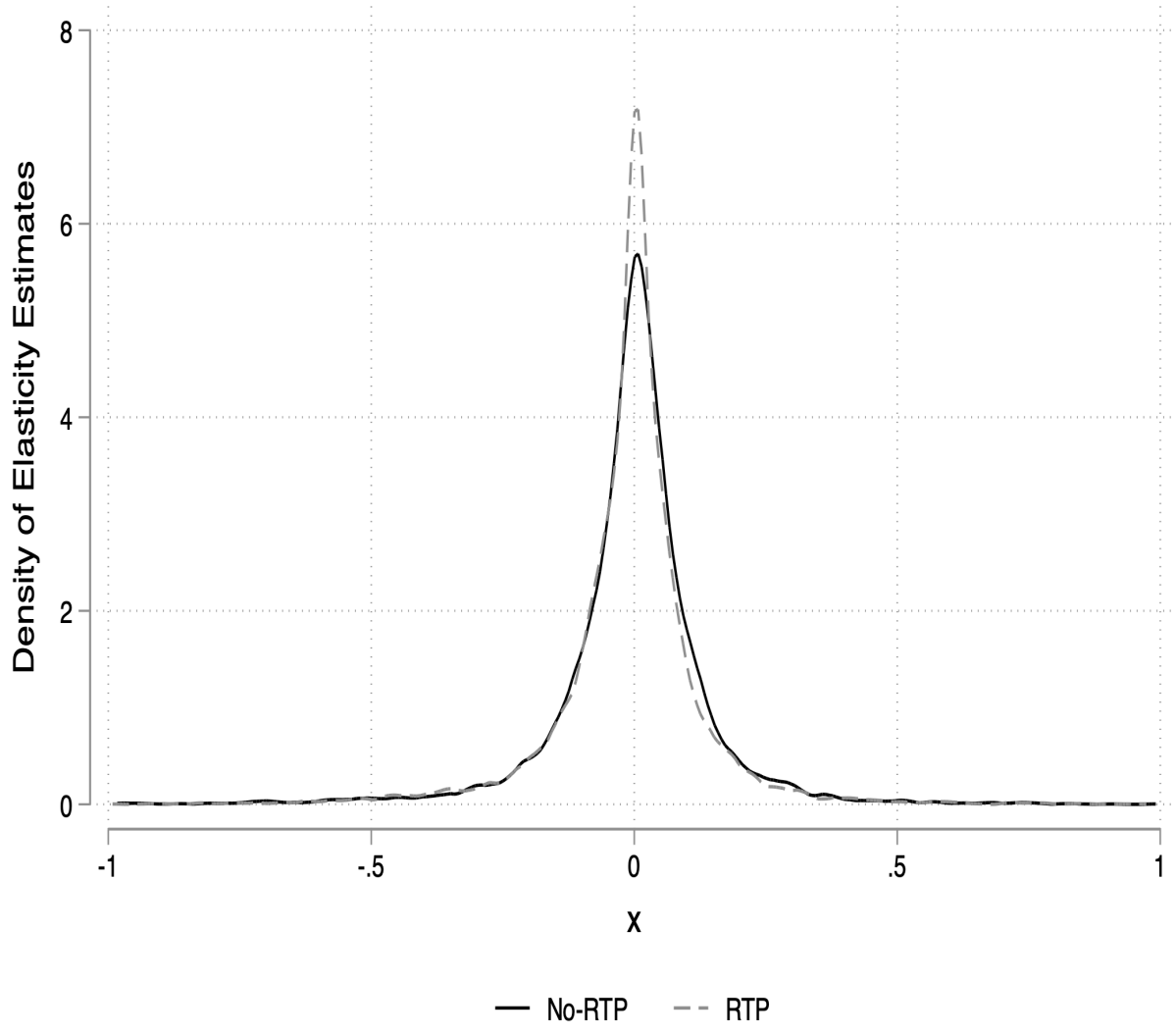
Comparison: RTP vs. non-RTP



Individual-level comparison

- Perform estimation individual by individual (random sample).
- We compare RTP vs. non-RTP customers to analyze potential additional response by RTP customers.
- Opens the door to look at **heterogeneity** in responses (for now, limited evidence given the small sample).

We find similar distributions of price elasticities



- Distribution centered around zero, median of no response.

Average elasticities by group are close to zero

	(1) p_iv11	(2) p_iv21	(3) p_iv31	(4) p_lasso
rtp	-0.00513	-0.00430	-0.00374	-0.00468
	(0.00238)	(0.00237)	(0.00220)	(0.00217)
Constant	-0.00473	-0.00883	-0.0117	-0.0237
	(0.00244)	(0.00252)	(0.00182)	(0.00274)
Observations	14598	14598	14598	14598

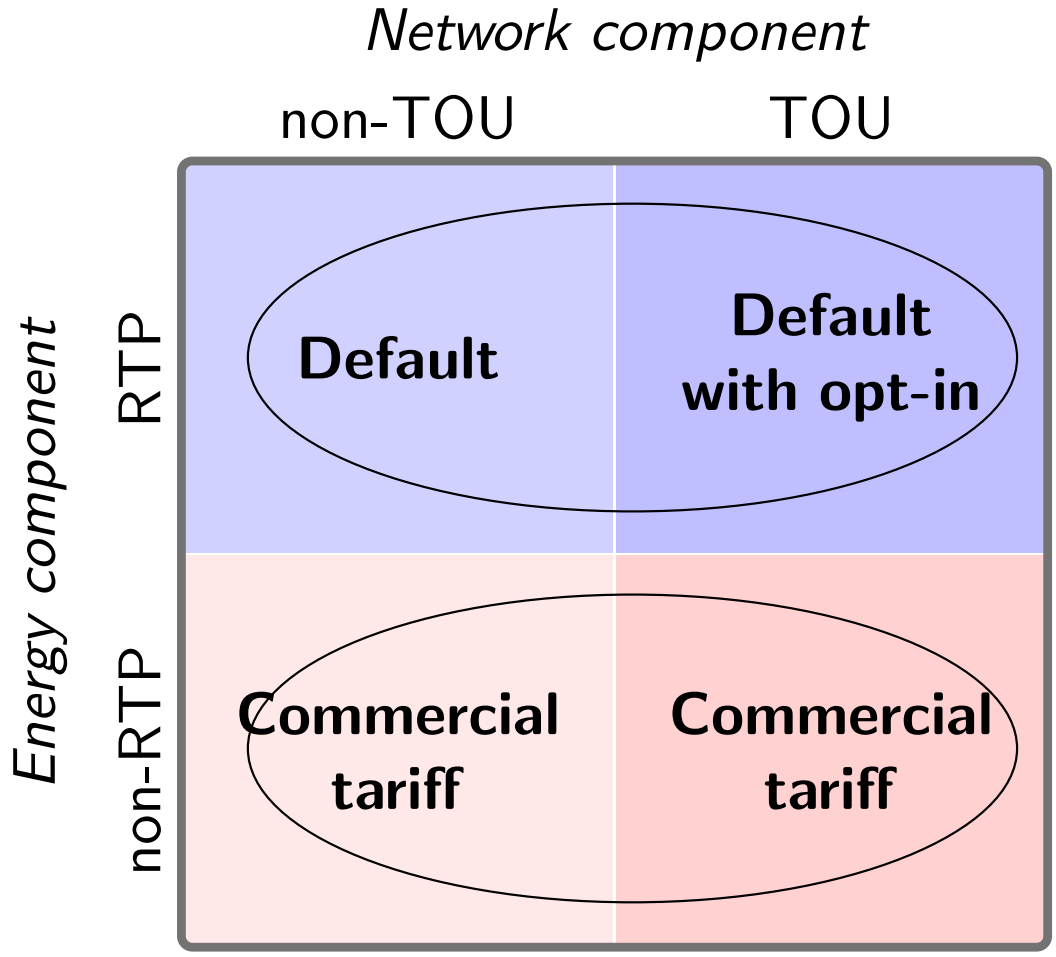
Standard errors in parentheses

- Not much of an effect from RTP.

Customer behavior by TOU vs non-TOU

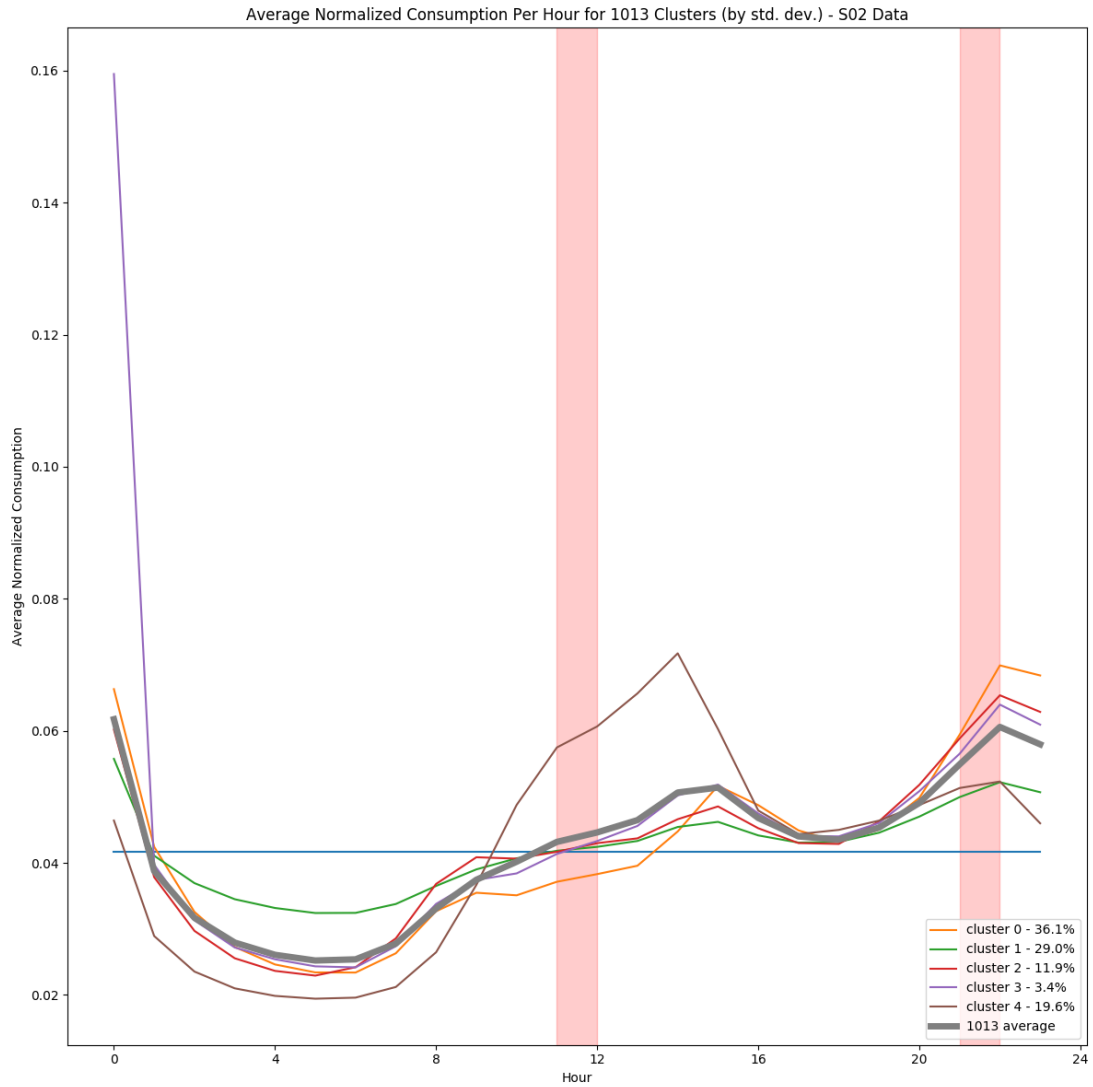
- Compare **TOU vs non-TOU customers**.
- Clustering algorithm to classify customers into customer profiles.
- Each profile represents the percentage of electricity consumption consumed at different hours of the days (shares).
- Represents preliminary reduced-form evidence on their differential behavior.
- To do: selection or price response?

Comparison: TOU vs. non-TOU



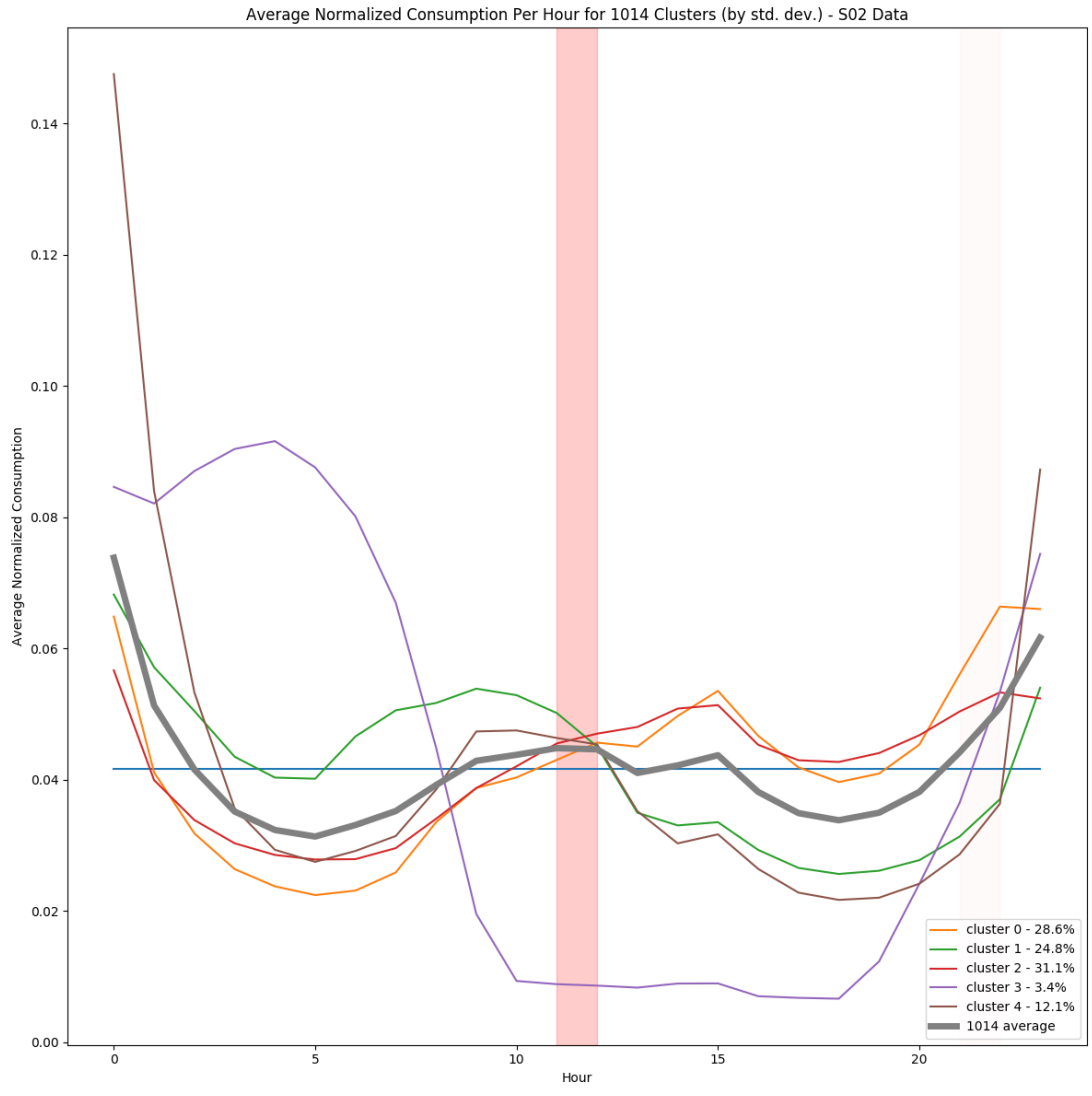
We find potentially distinct behavior

Figure: Consumption percentages for non-TOU customers



We find potentially distinct behavior

Figure: Consumption percentages for TOU customers



Policy implications: RTP vs TOU

- RTP does not appear to engage customers in an effective manner, at least in the short-run.
  - Efficient pricing is necessary, but not sufficient.
  - Information provision and cost/benefits of responding.

Policy implications: RTP vs TOU

- RTP does not appear to engage customers in an effective manner, at least in the short-run.
  - Efficient pricing is necessary, but not sufficient.
  - Information provision and cost/benefits of responding.
- TOU potentially **more effective** (habituation, salience?), but theoretical literature emphasizes the **limits of TOU** to delivering all benefits from demand response.

Policy implications: RTP vs TOU

- **Key challenge**: intermittency really not addressed with TOU; at the very least it requires general patterns with seasonal adjustments (e.g., solar); it doesn't work for wind.
- Combine RTP+TOU+information provision at critical peaks?

Policy implications: RTP vs TOU

- **Key challenge**: intermittency really not addressed with TOU; at the very least it requires general patterns with seasonal adjustments (e.g., solar); it doesn't work for wind.
- Combine RTP+TOU+information provision at critical peaks?
- Need to analyze from a customer behavior point of view what the **"sweet spot"** could be.

Wrap up: Many unexplored questions

- We have just started to scratch the surface of the data.
- Many potential comparisons given tariff design and richness of household data (combined with Census data).

- **Caveats**:
  - Challenges with selection+identification not present in RCTs.
- **Upsides**:
  - Data representative of a large market with a very high penetration of intermittent generation.
  - Fewer concerns regarding selection as in natural experiments.